

**A computational and empirical perspective on gendered correlates
of heterogeneous childlessness: Micro-level inequalities, meso-level
networks and macro-level developments**

by

Florianne Celeste Johanna Verkroost

Student Number: 1138483

Department Supervisor: Prof. Dr. C.W.S. Monden

College Supervisor: Prof. Dr. J.O. Jonsson

A thesis submitted in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN SOCIOLOGY

at the

Department of Sociology and Nuffield College

UNIVERSITY OF OXFORD

January, 2023

Word count: 67,000

A computational and empirical perspective on gendered correlates of heterogeneous childlessness: Micro-level inequalities, meso-level networks and macro-level developments

by

Florianne Celeste Johanna Verkroost

A thesis submitted in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN SOCIOLOGY

at the Department of Sociology and Nuffield College, University of Oxford

January, 2023

Abstract

This thesis investigates childlessness across time and levels of socio-economic development as well as its pathways and consequences in individual life courses, and the role social network influences play in connecting the two. Throughout three standalone but related papers, this thesis first examines the gendered relationship between childlessness types and development components in sub-Saharan African subnational regions using hierarchical modelling and Demographic and Health Surveys data. Second, it proposes a Bayesian hierarchical growth curve modelling approach, using 1970 British Cohort Study data, to assess the accumulation of socio-economic (dis)advantage throughout the life courses of parents and permanently childless men and women. Third, it investigates the role of structural and compositional characteristics of social networks in the interaction between individual-level childbearing behaviour and aggregate childlessness patterns using agent-based simulation models calibrated to Dutch data and emulated by statistical and machine learning models. This thesis contributes to the literature by examining childlessness from the interconnected micro-, meso-, and macro-level perspectives; acknowledging the heterogeneity regarding gender and reasons for childlessness; and applying advanced methodologies to overcome current modelling limitations. The findings suggest that in developing regions, macro-level decreases in involuntary childlessness and increases in voluntary and circumstantial childlessness may be explained by educational, income and health advancements. In developed regions, remaining childless may contribute to the accumulation of socio-economic (dis)advantage throughout individuals' life courses. Decreasing abidance to social norms through increasingly individualistic meso-level social networks may connect macro-level childlessness norms and patterns which emerge from and sequentially influence micro-level childbearing values and behaviours. Contextual factors on the micro-, meso- and macro-levels, such as marriage and employment, influence the direction and magnitude of the observed associations. The findings have societal and policy implications regarding the viability of populations and welfare states; equality by both parental status and gender; and public perceptions of childlessness.

For my grandmother Cornelia Verkroost – de Ruiter (1940 – 2021)

Committee

Supervisor: Prof. Dr. C. W. S. Monden, *University of Oxford*

Examination committee: Prof. Dr. F. C. Billari, *Bocconi University*
Prof. Dr. R. Kashyap, *University of Oxford*

Funding

This research has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 681546 (FAM-SIZEMATTERS).



European Research Council
Established by the European Commission

The author is also grateful for financial support from Nuffield College and the Department of Sociology, both at the University of Oxford.

Acknowledgements

I would like to pay my utmost gratitude to a number of exceptionally talented people who have supported me throughout the process of writing this thesis. First and foremost, I am grateful to my supervisor Christiaan Monden for his guidance and mentorship. His research expertise, skills and experience have helped me develop myself into the interdisciplinary scientist I am today, and to navigate the field of social science with little knowledge or experience prior to starting my D.Phil. I would also like to thank colleagues and members from the academic community at the University of Oxford and beyond, including John Ermisch, Janne Johnsson and Ridhi Kashyap; various members of the Global Family Change team; and a number of anonymous reviewers from a variety of scientific journals, for their feedback in developing this work. My gratitude also goes out to my colleagues from our ‘Monday meeting group’, particularly Lewis Anderson, Liliana Andriano, Mariana de Araujo Cunha, Nicole Kapelle, Joan Madia, Deni Mazrekaj, Antonino Polizzi, Patrick Präg, Tobias Rüttenauer, Paula Sheppard and Zachary Van Winkle, for their helpful feedback on my chapters.

I owe much to a number of institutions and opportunities that have supported and inspired me in executing the research presented in this thesis. I would like to thank the European Research Council as well as Nuffield College and the Department of Sociology, both at the University of Oxford, for their funding and financial support. My gratitude also goes out to the wonderful people and staff at these latter two institutions for their academic support and for the inspiring conversations I have been lucky enough to enjoy. I would also like to acknowledge the use of the University of Oxford Advanced Research Computing (ARC) facility in carrying out parts of this work.¹ During my D.Phil, I had the privilege to attend two prestigious summer schools, namely the 2019 Princeton Summer Institute in Computational Social Science at the University of Princeton and the 2020 Summer School in Bayesian Agent-Based Modelling organized by the University of Southampton, which have inspired some of the methodological work in this thesis and have broadened my professional and social networks with some of the smartest people I have met.

My route to sociology has perhaps been a bit unconventional, coming from a background in mathematics, statistics and econometrics. I have had a passion for numbers, formulas and digits ever since I can remember, but it was sparked by some of my high school teachers and mentors whom, at the time, I promised to mention should I ever complete a doctorate. So, here goes: Jerry Boulogne, Mischa Kuster and Herman Zechiel: thank you for seeing my potential and challenging me to go beyond limits I could never have imagined I was capable of crossing. I also believe I would never have arrived at this point without the inspiration and passion I gained during my undergrad degree at University College Twente. This interdisciplinary degree, focused on developing one’s own learning and research agenda while growing not only intellectually but also personally, taught me the skill of self-directed learning, i.e. of identifying knowledge gaps and independently overcoming these. I will be forever grateful to all the wonderful people involved in this program, both staff and students, for helping me develop the resilience as well as research and interpersonal skills needed to overcome some of the challenges faced during the course of writing this thesis. Enschede is also where my passion for solving societal problems using computational methods started, upon writing my bachelor’s thesis on the Dutch gender wage gap. I would like to thank Ariana Need and Bernard Veldkamp for introducing me to the wonderful field of quantitative/computational social science back in those days.

Most of my free time in Oxford I was lucky enough to spend with friends and ‘family’ from Nuffield College and Linacre Boat Club. Bethany Bloomer, Roberto Cerina, Sarah Clifford, Artur Doshchyn, Marta Golin, Domanté Gerčienė, Matthias Haslberger, Fijnanda van Klingeren, Sarah Schneider-Alia, Laurin Weissinger, and many others I got to spend time with along the way: rowing and having lunch, dinners and pints with you made my Oxford experience even more enjoyable. I am grateful for the memories we have made so far, and I am certain our friendship will continue to cross country borders wherever we may go next.

¹Richards, A. (2015). Technical Note on ARC facility and service deployment for publication reference. University of Oxford Advanced Research Computing Facility. DOI = [10.5281/zenodo.22558](https://doi.org/10.5281/zenodo.22558)

I would also like to thank Tom Ingelse for his support, patience and confidence during the largest part of writing this thesis. Being a sounding board to my thoughts and ideas, you have helped me develop some of the work in this thesis and, more importantly, gain confidence in my ability to bring this thesis to successful completion. Thank you for having reminded me of my achievements and for having celebrated the successes with me, even when I tended to surpass them on my way to achieving the next goal I had already lined up for myself.

I also want to acknowledge my dearest friends from the Netherlands – Bart Bussmann, Bas Coenen, Yentl Lassche, Julia Nauta and Finn de Ridder: your friendship and visits to Oxford have given me an immense amount of joy and support during the process of writing this thesis. Thank you for your ‘gezelligheid’, openness, confidence, willingness to proofread, and for all the great memories we have made and will continue to make together. Your enduring friendship, patience, sobriety and sincerity help remind me what’s really important in life, and to pursue it fearlessly and confidently. Thank you for breaking down my walls and for seeing me as the person I truly am – you guys are the best.

Last but not least, I would like to thank my family, including my grandparents, aunts, uncles and cousins who all came to visit me during my time in Oxford. Family really is a gift that lasts forever. In particular, I am grateful to my parents, Ronald Verkroost and Johanna Verkroost-de Paauw, and my sister Vivienne Verkroost and her partner Paul van Alphen for their support throughout my D.Phil. These past few years have posed their challenges for each one of us, and I am proud of and grateful for the way we support each other to get through difficult times and come out stronger. While you never hesitated to tease me saying you did not understand much of the work I was doing, you were always eager to read my papers and tell me how proud you were of the path I have taken and the challenges I have overcome. I am especially grateful for your never-ending confidence and faith in me, particularly during the countless times I lost it myself. You taught, stimulated, facilitated and helped me to be independent and to follow my own path in life, and break any existing barriers to pursue my own goals and happiness without limits. Your support has helped me become the woman I am today, and develop and maintain my own unique identity in a world where doing so remains challenging to many. I am sure plenty of personal and professional challenges will follow in life, but I am even more certain that you have taught me the mindset and resilience to face these independently, and with passion, hope, strength and courage. May we forever have each other’s backs – I love you.

Contents

Committee	vii
Funding	ix
Acknowledgements	xi
List of Figures	xvii
List of Tables	xix
1 Introduction	1
1.1 Societal Relevance of Researching Childlessness	3
1.2 Childlessness: Trends, Drivers and Outcomes	4
1.2.1 Levels and Trends of Childlessness	4
1.2.2 Drivers of Childlessness	6
1.2.3 Outcomes of Childlessness	13
1.3 Scientific Relevance of Researching Childlessness	22
1.4 Thesis Objective and Research Questions	24
1.4.1 Childlessness and Development	25
1.4.2 Childlessness and Socio-economic (Dis)advantage	25
1.4.3 Childlessness and Social Networks	26
1.5 Contributions	26
1.6 Outline	29
References	30
2 Childlessness and Development in sub-Saharan Africa	41
2.1 Introduction	42
2.2 U-shape of Childlessness and Development	45
2.3 Data	48
2.3.1 Aggregation	49
2.3.2 Childlessness	49
2.3.3 Development	51
2.3.4 Other Factors	53
2.3.5 Missing Data	55
2.4 Methods	55
2.5 Results	57
2.6 Conclusion and Discussion	63
References	68
Appendices	73
Appendix 2.A Authorship Statement	74
Appendix 2.B Countries and Original and Selected Sample Sizes	75
Appendix 2.C Overview of DHS Surveys	76

Appendix 2.D	Age Distributions per Country	77
Appendix 2.E	Distribution of Childlessness and Age at First Birth	78
Appendix 2.F	Childlessness and Sample Size	79
Appendix 2.G	Trends of SHIHD	80
Appendix 2.H	Trends of HIHD and Components for sub-Saharan Africa	87
Appendix 2.I	Missingness in the Data	88
Appendix 2.J	Pooling Strategy for Hierarchical Regression Results after Multiple Imputation	89
Appendix 2.K	Computation of Orthogonal Polynomials	90
Appendix 2.L	Correlation Between Independent Variables	91
Appendix 2.M	Childlessness Trends by Country, Gender and Type	92
Appendix 2.N	Goodness-of-Fit Measures for Sub-National-Level Models	93
Appendix 2.O	Model Comparison for Basic Models	95
Appendix 2.P	Random Effects for Hierarchical Models	96
Appendix 2.Q	Marginal Effects of Independent Variables on Childlessness	97
Appendix 2.R	Bivariate Regression Results for Types of Childlessness and development Components	98
3	Childlessness and Cumulative Socio-economic (Dis)advantage in the UK	99
3.1	Introduction	100
3.2	Childlessness as a Life Course Process	106
3.2.1	Childlessness and Subjective Well-being	107
3.2.2	Childlessness and Economic Well-being	108
3.2.3	Childlessness and the Interaction Between Subjective and Economic Well-being	109
3.3	Data	110
3.3.1	Operationalisation	111
3.4	Methodology	114
3.4.1	Bayesian Multivariate Multiple Hierarchical Growth Curve Model	116
3.4.2	Analytical Strategy	118
3.4.3	Missing Data, Priors and Model Implementation	119
3.5	Results	120
3.5.1	Socio-economic Differentials between Parents and Childless Adults throughout the Life Course	121
3.5.2	Explanations for Socio-economic (Dis)advantage and its Accumulation throughout Life	122
3.5.3	Influence of Socio-economic Domains on one another and their Relationships with Eventual Parental Status	127
3.6	Conclusion and Discussion	128
	References	136
	Appendices	143
Appendix 3.A	Distinction of Childlessness Types	144
Appendix 3.B	Missingness Plots	145
Appendix 3.C	Bayesian Hierarchical Regression Results for Models 1 to 6	146
Appendix 3.D	Convergence Diagnostics	150
Appendix 3.E	Sensitivity Analyses	153
3.E.1	Sensitivity Analysis – Uninformative Priors	153
3.E.2	Sensitivity Analysis – Highly Informative Priors	154
Appendix 3.F	Bayesian Multinomial Regression Results	155
4	Childlessness and Social Networks in the Netherlands	157
4.1	Introduction	158
4.2	Childlessness and Social Networks	163
4.2.1	Mechanisms of Social Influence	164

4.2.2	Structural and Compositional Characteristics of Social Networks	165
4.2.3	Context and Objective	166
4.3	Agent-based Simulation Model	167
4.3.1	Agent-based Simulation Modelling	167
4.3.2	Purpose	168
4.3.3	Entities, State Variables and Scales	168
4.3.4	Initialisation	170
4.3.5	Process Overview and Scheduling	172
4.3.6	Input Parameters	181
4.3.7	Design Concepts	181
4.3.8	Implementation	182
4.4	Data	186
4.5	Results	187
4.5.1	Model Calibration	188
4.5.2	Experimental Scenarios	193
4.5.3	Sensitivity Analysis	195
4.6	Conclusion and Discussion	199
	References	208
Appendices		215
Appendix 4.A	Pseudo-code for ABSM	216
Appendix 4.B	Rates of Social Network Turnover as Input for Logistic Regression Model Predicting Agents' Probability of Removing a Friend from their Full Network	218
Appendix 4.C	Descriptive Results	219
4.C.1	Outcome Distributions	219
4.C.2	Input-Output Correlations	220
Appendix 4.D	GBM Emulator Hyperparameters	222
Appendix 4.E	Emulator Prediction Performance	223
Appendix 4.F	Sobol Sensitivity Indices	224
5 Conclusion		227
5.1	Summary	227
5.2	Contributions	230
5.3	Societal and Policy Implications	233
5.4	Limitations	238
5.5	Avenues for Future Research	242
5.6	Finishing Thoughts	245
	References	247

List of Figures

2	Childlessness and Development in sub-Saharan Africa	41
2.1	Overview of hypotheses regarding the relationship between childlessness types and components of development	47
2.2	Decision tree for the classification of types of childlessness	51
2.3	National childlessness levels for men and women in 1997-2001, 2005-2009 and 2011-2015	58
2.4	Male and female childlessness levels across 372 respectively 384 subnational regions in sub-Saharan Africa	59
2.5	Relationship between male and female childlessness and development on the (a) national and (b) subnational level	60
2.6	Fitted values for the multivariate regressions estimating male and female childlessness from development on the subnational level	61
2.7	Fitted values for the bivariate regressions estimating male and female childlessness types from development components on the subnational level	64
2.C.1	Overview of male and female DHS surveys	76
2.D.1	Distribution of male and female ages per country	77
2.E.1	Distribution of male and female childlessness and age at first birth across age	78
2.F.1	Scatter plot of sample sizes and childlessness levels	79
2.G.1	SHDI trends per component by country and subnational region	80
2.H.1	Trend of the HIHD and its components by country	87
2.I.1	Aggregation plot for missingness in male data	88
2.I.2	Aggregation plot for missingness in female data	88
2.L.1	Correlation between independent variables in male data	91
2.L.2	Correlation between independent variables in female data	91
2.M.1	National trends in overall, involuntary, voluntary and circumstantial childlessness by country and gender	92
2.Q.1	Marginal effect on childlessness of each independent variable	97
3	Childlessness and Cumulative Socio-economic (Dis)advantage in the UK	99
3.1	Expectations of SWB and EWB life course trajectories and interactions	110
3.2	Predicted SWB trajectories for women and men by eventual parental status	122
3.3	Predicted EWB trajectories for women and men by eventual parental status	123
3.4	Marginal effect of eventual childlessness on SWB for women and men	124
3.5	Marginal effect of eventual childlessness on EWB for women and men	124
3.6	Predicted probabilities from Bayesian (multinomial) logistic regression models	125
3.7	Marginal effect of EWB on SWB by eventual parental status for women and men	127
3.8	Marginal effect of SWB on EWB by eventual parental status for women and men	128
3.B.1	Aggregation plots for missingness proportions and patterns in (a) female and (b) male data	145
3.D.1	Average scale reduction factor on split chains ($\hat{R}$) per parameter (x-axis) per model (facets)	150
3.E.1	Predicted SWB trajectories for women and men by eventual parental status with uninformative priors	153

3.E.2 Predicted EWB trajectories for women and men by eventual parental status with uninformative priors	153
3.E.3 Predicted SWB trajectories for women and men by eventual parental status with highly informative priors	154
3.E.4 Predicted EWB trajectories for women and men by eventual parental status with highly informative priors	154
4 Childlessness and Social Networks in the Netherlands	157
4.1 Coleman's diagram for macro-meso-micro interaction in the context of childlessness . .	164
4.2 Actual and simulated trends in (a) permanent childlessness and (b) total fertility rate (simulation without social influence)	171
4.3 Visual representation of the ABSM process overview	173
4.4 Probability distribution functions for befriending and unfriending	177
4.5 Illustration of the social influence function	180
4.6 Contour plots of ABSM fit (RMSE)	190
4.7 Contour plots of change in childlessness between the 1935 and 1965 birth cohorts	192
4.8 Actual and simulated trends in permanent childlessness amongst women born between 1935 and 1965 inclusive (simulation with social influence from 1935 onwards)	193
4.9 Simulated experimental trends in permanent childlessness amongst women born between 1935 and 1965 inclusive (simulation with social influence from 1935 onwards)	194
4.10 Sobol sensitivity indices for (a) the ABSM fit (RMSE) and (b) the change in childlessness (1935 - 1965 birth cohorts)	198
4.11 Impurity and permutation feature importance for the ABSM fit (RMSE) and the change in childlessness (1935 - 1965 birth cohorts)	199
4.B.1 Probability of voluntarily removing a peer from one's peer network by age	218
4.C.1 Histogram of ABSM outcome across simulation runs	219
4.C.2 Input-output correlations per model parameter for the outcome of ABSM fit (RMSE) . .	220
4.C.3 Input-output correlations per model parameter for the outcome of childlessness change between the 1935 and 1965 birth cohort	221

List of Tables

2	Childlessness and Development in sub-Saharan Africa	41
2.1	Overview of hypotheses regarding the relationship between childlessness types and indicators of development	47
2.2	Descriptive statistics for subnational regional-level data	50
2.3	Regression coefficients of the subnational regional-level multivariate hierarchical models estimating childlessness from development for men and women	63
2.B.1	Countries under analysis and original and selected sample sizes	75
2.N.1	Goodness-of-fit measures and ANOVA p-values for national-level bivariate models for childlessness and SHIHD	93
2.N.2	Goodness-of-fit measures and ANOVA p-values for subnational-level bivariate models for childlessness and SHIHD	93
2.N.3	Goodness-of-fit measures for subnational-level multivariate models for childlessness	94
2.O.1	Goodness-of-fit measures and χ^2 p-values for basic univariate models	95
2.P.1	Random effects for subnational-level multivariate total models for childlessness	96
2.R.1	Regression coefficients of the subnational regional-level bivariate models estimating childlessness types from development components for men and women	98
3	Childlessness and Cumulative Socio-economic (Dis)advantage in the UK	99
3.1	Descriptive statistics	115
3.2	Pooled coefficients for the female and male Bayesian HGCMs estimating EWB and SWB	135
3.A.1	Childlessness types based on respondents' answer to the question 'What is the most important reason that you have not had any children?'	144
3.C.1	Pooled coefficients for the female Bayesian HGCMs estimating EWB and SWB	146
3.C.2	Pooled coefficients for the male Bayesian HGCMs estimating EWB and SWB	148
3.F.1	Pooled coefficients from Bayesian (multinomial) logistic regression models	155
4	Childlessness and Social Networks in the Netherlands	157
4.1	Model entity state variables, names, values and dynamicity	169
4.2	Agent entity state variables, names, values and dynamicity	170
4.3	Model input parameters, notation and range	181
4.4	Regression coefficients and ANOVA estimates for the RMM estimating the ABSM fit (RMSE)	206
4.5	Regression coefficients and ANOVA estimates for the RMM estimating the change in childlessness between the 1935 and 1965 birth cohorts	207
4.B.1	Empirical findings of social network turnover rates by age as used to compute probabilities of removing a peer from agents' peer networks	218
4.D.1	Optimal hyperparameters for the GBM emulator	222
4.E.1	Cross-validated emulator performance measures	223
4.F.1	Sobol sensitivity indices for the ABSM fit (RMSE)	225
4.F.2	Sobol sensitivity indices for the change in childlessness between the 1935 and 1965 birth cohorts	226

Chapter 1

Introduction

Over the past decades, the majority of countries worldwide have experienced a decline in fertility rates. In a study of 195 countries, [GBD 2017 Population and Fertility Collaborators \(2018\)](#) found that the total fertility rate (TFR) nearly halved from 4.7 births per woman in 1950 to 2.4 births per woman in 2017 globally. In addition, all 195 countries experienced a fertility decline between 1950 and 2017, and nearly half of these countries reported a TFR below replacement level, i.e. the TFR necessary to sustain population levels, in 2017. More socio-economically developed regions, including Europe, the United States and Oceania, generally have some of the lowest levels of fertility. On the other hand, in less developed regions, mainly sub-Saharan Africa, fertility rates are still relatively high (*ibid.*).

Most demographic and sociological studies of fertility have initially focused on changes in the timing at which women have children (tempo) or changes in the number of children they have (quantum), and which of these changes has most strongly influenced the observed fertility decline ([Billari and Kohler, 2004](#); [Sobotka, 2004](#)). Childlessness has been largely overlooked in these studies, however. The main reason for this is the assumption that high fertility rates correspond to low childlessness rates, and low fertility rates equate with high levels of childlessness ([Keizer, 2010](#)). However, this is often not the case in reality ([Sobotka, 2017](#)). For example, while women in sub-Saharan Africa on average have many children, there is also a substantial number of women who never have any children, sometimes referred to as the ‘barrenness amid plenty’ paradox ([Inhorn and Patrizio, 2015](#)). Similar discrepancies between TFRs and childlessness rates have been documented across United Nations Economic Commission for Europe (UNECE) countries ([Billari, 2005](#)). Indeed, the negative correlation between childlessness rates and completed cohort fertility has weakened across birth cohorts, and these patterns suggest that childlessness should be given more attention as a demographic phenomenon on its own ([Tanturri and Mencarini, 2008](#); [Tanturri et al., 2015](#)).

In response to this suggestion, more recent analyses of childlessness have shown that the share of women remaining permanently childless has increased over the past decades, particularly in more developed regions like Europe and the United States (Sobotka, 2017). In Europe, for instance, childlessness has grown from about 10% amongst women born in 1945 to almost 15% amongst women born in 1970 (Sobotka, 2017). While childlessness in Latin America and Eastern, Southern and Central Europe has remained relatively low at less than 10% amongst the female 1970 birth cohort, rapid increases to over 20% have been observed in parts of Western and Southern Europe (Sobotka, 2017) as well as the United States, Australia and Japan (Organisation for Economic Co-operation and Development [OECD], 2015; Rowland, 2007). Nevertheless, recently observed childlessness levels are not unprecedentedly high: historical data have shown that amongst cohorts born in the early 20th century, childlessness levels reached 25%, in some cases like Australia and Germany even exceeding that number (Rowland, 2007; Sobotka, 2017). Potential explanations for these high levels of childlessness at the time include marital fertility restrictions up to the 1930s (van Bavel and Reher, 2013), a lack of fertility partners after World War I and economic insecurity due to the Great Depression of the 1930s (Sobotka, 2017). Although childlessness levels amongst women born in the 1930s and 1940s fell substantially due to the economic prosperity and wide adoption of the ‘traditional family’ model, they have substantially increased since then (Sobotka, 2017).

As will become clear from the upcoming literature review, different definitions of childlessness are used throughout studies, and sometimes different substantive connotations are linked to these. Throughout this thesis, childlessness is defined in its demographic terms, namely as the absence of ever having had at least one biological live-born child. Stillbirths, miscarriages and other forms of terminated pregnancies are not included as live births. Adopted and stepchildren are excluded as not to downwardly bias the observed levels of childlessness, nor their association with socio-economic factors given that residential parents are often more socio-economically advantaged relative to non-residential parents, particularly when it comes to men (Poole et al., 2016). In line with other relevant studies of childlessness (see for example (references in) Buhr and Huinink, 2017), I distinguish between those who actively chose childlessness *voluntarily*; those who *involuntarily* remained childless because of health problems or infertility (i.e. “the inability to bear any children, either due to the inability to conceive or the inability to carry a pregnancy to a live birth” (Rutstein and Shah, 2004, p. 3)); those who remained childless because of their *circumstances* (e.g. not having a mating partner or the financial means to raise children); and those who were *indecisive* about their reason for childlessness. This distinction will be discussed in more detail in the upcoming sections.

1.1 Societal Relevance of Researching Childlessness

The globally observed increases in childlessness are concerning for the viability of populations and welfare systems (Keizer, 2010). That is, increased levels of childlessness, and declining fertility more generally, contribute to the ageing of the population (Coleman, 2001). This may pose a threat to welfare systems, given that older populations are generally less healthy and require more spendings on welfare payment while having a smaller work force to produce revenue (Coleman, 2001; Parliament of the United Kingdom, 2015). As a result, 28% of governments globally, and 66% of European governments, have taken measures to increase childbearing by for example introducing support for family planning and balancing work and family (United Nations Population Division, 2017). Although these policies have shown to be effective regarding the timing and spacing of childbearing, they have not necessarily led to a decrease in childlessness (yet) (Frejka et al., 2008; Sobotka et al., 2020). Therefore, it seems that those who postpone childbearing and those who forego childbearing are differently influenced by such policies. Understanding whether and how these groups differ in characteristics would help policy makers in developing more effective measures to reduce childlessness (Keizer, 2010).

Moreover, childlessness remains an “ideologically charged” topic in the public debate (Kreyenfeld and Konietzka, 2017b, p. 3). By some, childlessness has been characterised as a result of an individualistic and egoistic society (*ibid.*), and they have characterised childless individuals as somehow impaired, lacking, or deviating (Berrington, 2017). Contrary to the deprivation that is implied from the term ‘childless’, from a more feminist perspective the so-called ‘childfree’ lifestyle resulting from foregoing parenthood is seen as an expression of self-determination (Letherby, 2002). While in previous generations women’s primary roles were those of wife and mother (Gillespie, 2003), women now have more autonomy and opportunity to prioritise roles besides the traditional familial ones (Beaujouan et al., 2016). Researching the drivers and consequences of childlessness could provide a more neutral and fact-based argument in the public debate.

Related, another important reason to study childlessness is to obtain a better idea of the potentially blurred boundary between intended and unintended childlessness, and what governments and welfare states could contribute to reduce unwanted outcomes for their people. As aforementioned, for some childlessness is a personal choice in line with expressions of freedom and self-determination (Letherby, 2002). However, research has also shown that in advanced societies childlessness is more often even the result of individual experiences and conditions (e.g. Berrington, 2017; Rotkirch and Miettinen, 2017), blurring the boundary between personal choice and circumstances (Kelly, 2009). With infertility becoming more common in advanced societies (Levine et al., 2017) and with women’s continued empowerment

(Beaujouan et al., 2016), it is crucial that governments take measures to protect their people from undesired outcomes when it comes to childbearing, especially because these can be related to the accumulation of (dis)advantage in other domains of life as well (see Chapter 3). This could be done, for example, by increased efforts to promote healthy lifestyles, egalitarian division of housework and women's ability and incentive to return to the labour market after having children.

1.2 Childlessness: Trends, Drivers and Outcomes

This section provides a concise review of the literature on childlessness levels, trends, drivers and outcomes.

1.2.1 Levels and Trends of Childlessness

Current levels of female childlessness vary substantially across the world. Some of the highest levels of childlessness amongst women aged 40-44 (15+%) occur in highly developed areas, including North America, Europe and Oceania, while less than five percent of women remain childless in less developed areas like sub-Saharan Africa and Central Asia (United Nations, 2012). Intermediate levels of childlessness (5-15%) are found in Latin America and North Africa (*ibid.*). In an analysis of 131 countries during the period between 2000 and 2011, the lowest levels of childlessness amongst women aged 40 to 44 were found in Sao Tome and Principe (0.3%), and the highest levels occurred in Singapore (23.1%) (*ibid.*). However, as it is unlikely that countries achieve childlessness levels below 3%, which is approximately the rate of primary infertility in high-fertility societies (Bongaarts and Potter, 1983), these levels might be subject to misreporting issues (United Nations, 2012).

Not only between, but also within regions, there is substantial variation in female childlessness. For example, the European average share of childlessness amongst women born in 1968 is 14.5%, with variations from almost 8% in Portugal and former state socialist countries in Central and Eastern Europe (e.g. Bulgaria, Czech Republic, Russia), to a moderate $\pm 15\%$ in for example France, Belgium, Sweden and Norway, to close to 20% in Switzerland, Finland, Ireland, Austria, Germany and the United Kingdom, for instance (Sobotka, 2017; Tanturri et al., 2015). More generally, France and most Scandinavian countries have relatively high levels of fertility and low levels of childlessness, and they are often referred to as 'egalitarian' (Basten et al., 2014; Rendall et al., 2010; Tanturri et al., 2015). However, high fertility rates need not necessarily equate to low levels of childlessness and vice versa. For instance, in Finland and the United Kingdom, the so-called 'polarised societies', high levels of childlessness co-occur with high-parity birth rates (Shkolnikov et al., 2007). Central, Eastern and Southern European countries have both

low fertility and low childlessness rates (Mencarini and Tanturri, 2006; Seiz, 2013). On the contrary, high levels of childlessness tend to be the main cause of low fertility in German-speaking European countries (Basten et al., 2014; Sobotka, 2009).

Historical data on female childlessness are generally limited to more developed countries (Tanturri et al., 2015). Extensive overviews of long-term childlessness trends in Europe, the United States, Australia and New Zealand show that childlessness levels generally developed over time according to a U-shaped pattern (Rowland, 2007; Sobotka, 2017; Tanturri et al., 2015). These levels were generally high (20+%) amongst women born in the early 20th century, mainly due to a large proportion of individuals marrying late, or not at all. This phenomenon characterised the so-called West European Marriage Pattern (Hajnal, 1965), which resulted from the Great Depression in the 1930s and the sex imbalance following excess male mortality and emigration during World War I (Dykstra, 2009; Rowland, 2007). The lowest levels of childlessness (below 10%) occurred amongst women born around 1940, who were in their childbearing ages during the prosperous 1960s, which were marked by traditional values regarding family formation and gender¹ roles, and a steep increase in birth rates ('Baby Boom') (Miettinen and Szalma, 2014; Sobotka, 2017). After this period, childlessness levels started to increase again, at first mostly for Western European countries as well as the United States, Australia and New Zealand, but later also for Nordic, Southern and Central-Eastern European countries (Miettinen et al., 2015; Rowland, 2007; Sobotka, 2017; Tanturri et al., 2015). Contrary to the high levels of childlessness observed amongst women born in the early 20th century, these increases were not necessarily the result of non-marriage but rather of the postponement of parenthood until later ages (Berrington, 2017; Holden, 2005). Such postponement was likely due to enhanced female educational and occupational attainment, in combination with relatively unchanged gender roles, resulting in longer time spent in education as well as family-work dilemmas and increasing opportunity costs of children for women in particular. Other reasons for postponing parenthood may have been unfortunate and uncertain economic conditions, resulting in financial and occupational insecurity and limitations regarding childbearing (Sobotka, 2017). Amongst the most recent birth cohorts for which we can currently conclude permanent childlessness, i.e. cohorts born in the late 1960s and early 1970s, childlessness levels have been levelling off in Western and Nordic Europe (Miettinen et al., 2015; Sobotka, 2017; Tanturri et al., 2015). On the contrary, they have been increasing in countries in Southern and Central-Eastern Europe which reported low levels of childlessness amongst older birth cohorts (*ibid.*). In some exceptional cases, childlessness levels have decreased

¹I use the terms 'women' and 'females' interchangeably to refer to cisgender women, and 'men' and 'males' to refer to cisgender men. While the experiences of people of other genders and gender identities might be different, and are at least as important and interesting as those of cisgender people, there is currently still too little research and data on these people to make any inferences for them. The binary terminology of 'gender differences' used in this work therefore refers to differences between cisgender women and cisgender men.

amongst the most recently observed cohorts, for example in Switzerland, England, Wales, Portugal and Sweden (Sobotka, 2017).

In a more recent analysis of 53 (also non-European) countries for three periods (1970-1979, 1990-1999 and 2000-2011), United Nations (2012) found that the distribution of female childlessness for all countries shifted downward, although the countries showed substantial variation. Generally, childlessness remained stable or declined in African countries, whereas countries in Southern and Central America and the Caribbean showed a decline until the second period followed by a stable pattern thereafter. Countries in Oceania reported stable levels of childlessness during the first two periods considered, and an incline during the late 1990s and early 2000s. Asian countries reported mixed patterns in childlessness, with increases observed particularly in Western Asia, and more stable or even declining trends in South-(eastern) Asia.

While the levels and trends in female childlessness have been documented quite extensively, much less is known about levels and trends of male childlessness, mainly because of limited reliable and large-scale data (Miettinen et al., 2015). The current proportion of childlessness amongst men in their late forties is highest (about 25%) in most Western and Nordic European countries, whereas some of the lowest levels of male childlessness (about 10%) occur in mostly Central and Eastern European countries such as Estonia, Russia and Georgia (Jalovaara et al., 2019; Miettinen et al., 2015). Out of 20 European countries considered, Georgia is the only country in which female childlessness exceeded male childlessness; the average ratio of male to female childlessness equals 1.56 (*ibid.*). Documented trends in male childlessness are even scarcer, mainly because childbearing and childlessness were long viewed as predominantly female matters (Dyer et al., 2004), a view that has only quite recently started to change (Schoumaker, 2019). A study on Sweden reported constant trends of male childlessness at levels of approximately 25% amongst highly educated men born between 1956 and 1972 (Chudnovskaya, 2019). Additionally, a recent study on sub-Saharan Africa (see Chapter 2) showed that national levels of childlessness varied between almost one percent and 12%, with some of these highest levels of childlessness—as well as variation across time and place—occurring amongst men rather than women. Male childlessness exceeded female childlessness in 60 to 65% of the countries throughout the period between 1997 and 2015, with observed increases in male childlessness in 14 countries, and stable or declining patterns in 11 countries (*ibid.*).

1.2.2 Drivers of Childlessness

Theories and findings on drivers of childlessness can be divided into macro-level explanations for high childlessness rates, and micro-level examinations for whom remains childless and for which reasons.

Both are discussed in the upcoming sections.

1.2.2.1 Macro level: Societal changes in relation to childlessness

In the literature, a number of reasons for and drivers of childlessness have been identified, which can be divided into three interrelated topics: structural, ideological and technological drivers (e.g. [Keizer, 2010](#)). Structural drivers of childlessness are largely related to economic circumstances. On the one hand, we might expect that economic prosperity is related to higher levels of childlessness, particularly voluntary and partnership-related circumstantial childlessness, through two mechanisms. First, according to the ideas of rational choice theory ([Becker, 1981a](#)), the amount of resources spent on each child (i.e. the quality and cost of children) is larger at higher levels of economic well-being, which results in lower child mortality and therefore a lower demand for children ([Tanturri et al., 2015](#)). This view is in line with that of evolutionary life history theory, which asserts that high-mortality environments encourage resource usage for reproduction even if that means sacrificing growth and large investments in offspring ([Gadgil and Bossert, 1970](#); [Tanturri et al., 2015](#); [Vitzthum, 2008](#)). Additionally, in societies that offer a social safety net, there is less of a demand for children as care providers for parents when they reach old age ([Becker et al., 2016](#); [Tanturri et al., 2015](#)). Such lower fertility intentions may result in childbirth postponement, which may in turn lead to age-related infertility or the choice to forego having children ([Burkimsher and Zeman, 2017](#); [Madsen et al., 2017](#)).

Second, higher levels of development are generally accompanied by higher levels of (female) educational attainment and labour force participation. These phenomena drive voluntary and circumstantial childlessness particularly amongst women ([Miettinen et al., 2015](#); [Tanturri et al., 2015](#)) through a variety of mechanisms. These mechanisms include increased opportunity cost of having children (e.g. [Neyer et al., 2017](#); [Oppenheimer, 1994](#)); longer time spent in education ([Gustafsson, 2001](#); [Kravdal, 2001](#); [Rindfuss and Bumpass, 1976](#)); higher levels of autonomy and self-sustenance ([Oppenheimer, 1994](#)); more diverse life opportunities ([Rindfuss and Bumpass, 1976](#); [Surkyn and Lesthaeghe, 2004](#); [van de Kaa, 1996](#)); and a declined evolutionary need to invest in parental care ([Aarssen and Altman, 2006](#); [Tanturri et al., 2015](#)). According to gender equity theory, female educational and occupational attainment may drive childlessness especially in societies where it is difficult for women to reconcile work and family, and where traditional gender roles in housework have remained in place ([McDonald, 2000a,b, 2008](#); [Tanturri et al., 2015](#)). Alternatively, this process may increasingly leave men childless by circumstance, as they are left behind on the mating market ([Kreyenfeld and Konietzka, 2017b](#)). That is, women tend to marry men with similar (homogamy) or higher (hypergamy) levels of education while men tend to marry women who are at most as highly educated as themselves (hypogamy), which may lead to an imbalance in the marriage market when women become increasingly higher educated ([Chudnovskaya, 2019](#); [van](#)

Bavel, 2012). According to evolutionary theory, a relatively large number of ‘available’ men may lead to increases in male childlessness, whereas a relatively large number of ‘available’ women may rather increase female childlessness (Székely and Székely, 2012; Tanturri et al., 2015).

On the other hand, adverse economic circumstances might be related to high levels of childlessness, and more specifically financial-related circumstantial childlessness. A number of studies have shown that during times of economic recession, first births are postponed (Caltabiano et al., 2017) and childlessness increases (Comolli and Bernardi, 2015). The reason for this is because economic hardship, and the labour market deregulation that often accompanies it, brings insecurities, for example in the form of flexible short-term contracts (Sobotka, 2017). Additionally, income tends to stagnate (Fry and Kochhar, 2014); wealth and income distributions tend to change (Saez and Zucman, 2016); and the work force tends to hollow out (Cherlin, 2014). As a result, according to uncertainty or risk aversion theory, individuals tend to avert any risks when the anticipated rewards and costs are unsure (Simpson, 2007). To hedge against these insecurities, individuals invest in human capital, and postpone childbearing (perpetually) until they feel like they can afford having children, sometimes to such an extent that they can no longer have them or decide they no longer want to (Keizer, 2010).

Generally, childlessness levels may alter as a consequence of ideological changes as well. In regions where fertility is high, there usually is a strong desire for children and childbearing is often nearly universal (Bongaarts and Casterline, 2013). Simultaneously, there is a strong stigma associated with remaining childless, often resulting in social exclusion, divorce and abuse (Inhorn and Patrizio, 2015). With educational expansion, individuals are increasingly exposed to global culture. With a more pronounced focus on values such as self-actualisation, freedom and autonomy, existing norms and values on family formation and childbearing may change, as argued by the post-material values theory (Inglehart, 1971; Tanturri et al., 2015). As a result, women are encouraged to go after their true predispositions (Hakim, 2000, 2003), leading to the emergence of the concept of ‘childfree’ lives (Beaujouan et al., 2016; Letherby, 2002). Hereby, personal desires and preferences for recreational and luxurious opportunities can be met without the burden of children nor stigma (Hakim, 2000, 2003; Tanturri et al., 2015; van Bavel and Kok, 2010). This may also lead to postponement in marriage and childbearing (Kohler et al., 2002; Miettinen et al., 2015), increasing the share of people foregoing having children (Burkimsher and Zeman, 2017; Hayford, 2013; Madsen et al., 2017; Miettinen et al., 2015). As a result, the so-called monopolistic civic family model is gradually exchanged for a model of private life focused on the individual or the couple, rather than the child(ren) (Eckhard, 2014). With such shifts in cultural values, voluntary and circumstantial childlessness may become not only more prevalent but also more socially accepted (Burkimsher, 2014; Tanturri et al., 2015; van Balen, 2008; van Balen and Bos, 2009). These ideational changes are generally accompanied by rising cohabitation and divorce rates, decreasing marriage rates, growing ages

at parenthood and decreasing fertility (Cherlin, 2010). Such a complex course of social change has taken place in the West since the 1970s, and has been referred to as the Second Demographic Transition (SDT) (Lesthaeghe, 2007, 2010; Lesthaeghe and van de Kaa, 1986; van de Kaa, 1997, 2001).

Related to these aforementioned economic and idealistic circumstances, technological and medical expertise may also influence childlessness rates. On the one hand, at the lowest levels of development, childlessness is mainly caused by poverty-driven infertility (Baudin et al., 2020; Poston and Trent, 1982). Infertility or involuntary childlessness may derive from for example malnutrition, famine, disease (mainly sexually transmitted or pelvic inflammatory), female circumcision, exposure to chemicals and radiation or a lack of good pre-, ante-, and post-natal care (in the case of secondary infertility) (Larsen, 1994; Poston et al., 1983). Improved nutrition as well as medical expertise and expenditure may reduce the prevalence of poverty-driven infertility through better prevention and treatment of diseases and other health problems (Inhorn and Patrizio, 2015). With growing medical expertise and expenditure we might also expect to see increasing usage of medically assisted reproductive (MAR) technologies, which will reduce infertility rates directly, and also indirectly by assuring positive birth outcomes despite postponement of childbearing (Casterline and Han, 2017; Marmot, 2005). On the other hand, technological advancements may be related to higher levels of especially voluntary but also circumstantial childlessness, as the ability of contraceptive technology allows people, and particularly females, to control their childbearing outcomes (van de Kaa, 1997). Hence, contraceptive technology allows and facilitates them to invest in their human capital or to pursue priorities other than family formation (Keizer, 2010).

1.2.2.2 Micro level: Who remains childless and why so?

The aforementioned explanations for changes in aggregate levels of childlessness are related to theories and findings on whom remains childless at the individual level and why. Childbearing intentions are strong predictors of childbearing outcomes, particularly when these intentions are negative, i.e. when the aim is not to have children (Kuhnt and Trappe, 2016; Rybińska and Morgan, 2019).

While relatively rare and less stable than intentions to have children, the intention to remain childless does prevail (Albertini and Brini, 2021; Rybińska and Morgan, 2019). In an analysis of several European countries, Miettinen et al. (2015) showed that voluntary childlessness is relatively rare in Europe, although substantial variations exist between less than one percent (e.g. Latvia, Bulgaria) and approximately ten percent (e.g. Netherlands, Austria). Voluntary childlessness is generally more common amongst men than women (*ibid.*). In less developed areas, such as sub-Saharan Africa, levels of voluntary childlessness are amongst some of the lowest globally at around one percent (see Chapter 2). Generally, women who remain voluntarily childless lack motherly instinct or interest in children (Park, 2005); have

concerns about societal issues such as politics and climate change (Stegen et al., 2020); reject the perceived advantages of parenthood (Kelly, 2009); have higher expectations of and desires for freedom, independence and self-actualisation (Callan and Hennessey, 1989; Park, 2005); report lower agreeableness and extraversion (Avison and Furnham, 2015); are non-religious and politically liberal (e.g. Burkimsher and Zeman, 2017);² or reject traditional gender roles and prefer to follow their own autonomous life paths (Stegen et al., 2020). The latter is also the case for voluntarily childless men, especially because they feel that having children will negatively affect their financial situation (Park, 2005).

Many childless women who consider their choice to have been voluntary report higher levels of education and income than other women (Abma and Martinez, 2006), and highly educated women also tend to be the ones who are most approving of childlessness (Koropeckyj-Cox and Pendell, 2007; Merz and Liefbroer, 2012). While some of these women perceive their choice as an act of empowered feminism, others report that their choice has been influenced by their individual experiences and circumstances (Kelly, 2009). This notion highlights how the boundary between personal choice and circumstances can sometimes be blurred, and how ex-post rationalisation is often (unintentionally) used to justify and gain control over outcomes resulting from one's circumstances (Jeffries and Konnert, 2002; Kelly, 2009). If a woman chooses not to have children because that would interfere with her career, is that a voluntary choice or a judgement based on current circumstances that might be different if circumstances were 'ideal'? The answers to such questions remain complex and subjective (Kelly, 2009).

In line with this notion, a large number of studies have shown, indeed, that the group of individuals who desire not to have children is small (Berrington, 2017; Köppen et al., 2017; Rotkirch and Miettinen, 2017). While there are some people who have other priorities in life than having children (Stegen et al., 2020; Tanturri and Mencarini, 2008), the majority of individuals who remain permanently childless had initially wanted children, or were unsure about their desires (Berrington, 2017; Rotkirch and Miettinen, 2017). Generally, folk theory asserts that most people still have the perception that a life with children is more meaningful and fulfilled (Blake, 1979; Hansen, 2012), and have a preference for two children (Testa, 2012). Some of these individuals remain childless unintendedly because of biological reasons that hamper their ability to conceive or carry a pregnancy to live birth, such as infertility or other health problems (e.g. Berrington, 2017). Generally, these individuals have characteristics and values similar to parents, which are more traditional than those of voluntarily childless adults (Callan and Hennessey, 1989). Research has shown that the rate of primary infertility in high-fertility societies is approximately three percent (Bongaarts and Potter, 1983), whereas in advanced societies around four percent of all couples remain infertile, even despite developments in the treatment of infertility (Karmaus et al., 1999).

²Also see Abma and Martinez (2006); Avison and Furnham (2015); Miettinen (2010); Miettinen et al. (2015); Tanturri and Mencarini (2008). To help keep the text readable and reduce citations, some citations are given in footnotes additionally to examples given in the main text.

Given that generally a small minority of childless individuals actively chose their childless lifestyle or turned out to be infertile, the majority of permanently childless individuals have remained without children despite having non-negative intentions nor infertility issues (e.g. Buhr and Huinink, 2017).³ Rather, the reason these individuals end up childless despite of having no negative intentions, is because their childbearing intentions and outcomes are strongly dependent on their short-term and long-term circumstances and resources (e.g. Stegen et al., 2020).⁴ Indeed, rather than being an active choice, childlessness often is the outcome of a complex and heterogeneous life course process (Allen and Wiles, 2013; Mynarska et al., 2015; Raab and Struffolino, 2020), whereby intentions change depending on other life transitions (Berrington, 2017; Kuhnt et al., 2017; Wagner et al., 2019). In other words, these ‘circumstantially’ childless adults often feel like “the necessary prerequisites for parenthood are not met at a given point in time” (Buhr and Huinink, 2017, p. 586), for example when it comes to occupational and partnership status (*ibid.*). As such, childbearing is often postponed perpetually to a time when these circumstances will be more fortunate and resources will be more readily available, until a person has reached the end of their fecund period or decides to no longer want children (Huber et al., 2010; Mynarska et al., 2015).

While the extent to which some circumstances influence childbearing intentions and outcomes is more or less independent of macro-level contexts, the influence of other circumstances is strongly dependent on contextual factors. Examples of factors that have been identified to affect childbearing intentions and outcomes are job security, living conditions and partnership status and quality. Although these factors often depend on the national context, their influence on childbearing intentions and outcomes is similar across contexts. Job security generally improves females’ intentions to have children (e.g. Miettinen and Szalma, 2014),⁵ although unfortunate prospects of one’s career development might also lead some women to ‘give up’ on their career and become full-time mothers instead (Keizer et al., 2008). Particularly those who leave the parental home and/or get married at a relatively old age, not necessarily because of having been in higher education but rather because of socio-economic selection or having been caregiver to a parent in need, struggle to secure an economic basis for becoming a parent (Hagestad and Call, 2007; Huber et al., 2010). Related to this, challenging living conditions tend to increase one’s chances of childlessness as well, given that individuals in these conditions often postpone parenthood until they feel their situation (e.g. financial, housing) is better suited for raising children (Frejka, 2017; Miettinen and Szalma, 2014). Moreover, while most childless women are highly educated (e.g. Berrington, 2017),⁶ the

³Other relevant citations include Berrington (2017); Köppen et al. (2017); Rotkirch and Miettinen (2017).

⁴Also see Huber et al. (2010); Kuhnt et al. (2017); Miettinen and Paajanen (2005); Tanturri et al. (2015).

⁵Also see Abma and Martinez (2006); Bernardi and Keim (2017); Buhr and Huinink (2017); Fieder and Huber (2007); Geist and Brauner-Otto (2017); Huber et al. (2010); Kreyenfeld and Konietzka (2017a); Kuhnt et al. (2017); Kuhnt and Trappe (2016); Miettinen and Paajanen (2005); Schaeper et al. (2017); Szalma and Takács (2015).

⁶Other relevant citations include Barthold et al. (2012); Burkimsher and Zeman (2017); Fieder and Huber (2007); Keizer et al. (2008); Köppen et al. (2017); Kreyenfeld and Konietzka (2017a); Schaeper et al. (2017); Tanturri and Mencarini (2008).

majority of childless men are single and of low socio-economic status (SES) (e.g. Köppen et al., 2017).⁷ Oftentimes, these men struggle to find a partner as a consequence of their diminished prospects to care and provide for their family (*ibid.*). The lack of a stable relationship is one of the strongest predictors of male and female childlessness, albeit more strongly so for men (e.g. Jalovaara and Fasang, 2017).⁸ Finally, living in a pronatalist country with strong family values may reduce one's risk of remaining childless, because in these societies childlessness is generally not approved of and childbearing is pressured (Merz and Liefbroer, 2012; Miettinen and Szalma, 2014).

Some of the most commonly studied factors that influence childbearing intentions and outcomes, strongly moderated by contextual factors, are education and, related to it, income. The majority of studies focusing on reasons for childlessness have found that highly educated and/or earning women are more likely to remain childless than their lower educated, lower earning counterparts. This is the case for childless women in for example the United Kingdom (Berrington, 2017), France (Köppen et al., 2017), (West) Germany (Kreyenfeld and Konietzka, 2017a; Raab and Struffolino, 2020; Schaeper et al., 2017), Switzerland and Austria (Burkimsher and Zeman, 2017), the Netherlands (Keizer et al., 2008), Italy (Tanturri and Mencarini, 2008), a variety of (other) European countries (Barthold et al., 2012; Miettinen et al., 2015; Tanturri et al., 2015) and the United States (Abma and Martinez, 2006; Hayford, 2013; Huber et al., 2010). The main reason for this differential is that these women postpone childbearing because they face constraints that diminish their intention to have children, such as dilemmas in combining work and family, struggling to find a partner in largely hypergamous marriage markets, and wanting to wait until job tenure has been achieved (e.g. Bianchi, 2011; Burkimsher and Zeman, 2017; Keizer et al., 2008).

In some countries, such as the United Kingdom, this educational gradient has increased over time (Berrington, 2017), while in other countries such as the Netherlands, Norway, Sweden and West Germany, this gradient has decreased (Andersson et al., 2009; Berrington, 2017; Kreyenfeld and Konietzka, 2017a; van Agtmaal-Wobma and van Huis, 2008). The main reasons given for this decline in the educational gradient in childlessness prevalence is that lower educated women remain childless relatively more often now than in the past because they struggle to find a partner (e.g. Kreyenfeld and Konietzka, 2017a; Rotkirch and Miettinen, 2017), which used to be the case for highly educated women (Fieder and Huber, 2007), and/or because policy reforms have mainly been beneficial for highly educated women (e.g. Kreyenfeld and Konietzka, 2017a). Additionally, highly educated postponers with higher levels of emotional autonomy are generally better able to achieve their childbearing intentions than lower-educated postponers (Berrington, 2017; Buhr and Huinink, 2017). Similar kinds of explanations are also offered

⁷See also Barthold et al. (2012); Berrington (2017); Fieder and Huber (2007); Fiori et al. (2017); Huber et al. (2010); Keizer et al. (2008); Koropecj-Cox and Call (2007); Kuhnt et al. (2017); Raab and Struffolino (2020); Rotkirch and Miettinen (2017).

⁸See also Berrington (2017); Keizer et al. (2008); Köppen et al. (2017); Kuhnt and Trappe (2016); Miettinen and Paajanen (2005); Raab and Struffolino (2020); Szalma and Takács (2015); Tanturri and Mencarini (2008); Wagner et al. (2019).

for the reverse phenomenon in Finland, where lower-educated men and women more often remain childless than their highly educated counterparts, a difference that has become more pronounced over time (Rotkirch and Miettinen, 2017). In other countries even, such as some Nordic and Eastern European countries, education does not seem to be a determinant of childlessness (Neyer et al., 2017).

The reason for these cross-country differences in educational gradients, and more generally in levels of childlessness, is that structural factors to a large extent influence the ability of women to have financial security and pursue a career while being mothers (Ferragina, 2019). For example, government benefits and policies are a crucial factor in determining whether women will be able to combine work and family (Tanturri and Mencarini, 2008), as are flexible educational systems that allow women to have children during their education rather than postpone it until they finish (Neyer et al., 2017). In addition, the childcare infrastructure of one's physical environment may facilitate women's participation in the labour force, especially when other forms of social support are limited (Keim, 2011; Laughlin, 2010). The importance of such interventions and benefits is also highlighted by the observation that childlessness is considerably lower amongst women working in female-dominated (public) sectors, often with standard work hours, a low employee turnover and a low degree of specialisation, given that these sectors generally provide women with more opportunities to have children and continue work thereafter (Neyer et al., 2017).

1.2.3 Outcomes of Childlessness

Childlessness can have a number of consequences, both on the aggregate level of society, as well as for individuals and their life courses. The upcoming sections will elaborate on these consequences and outcomes of childlessness.

1.2.3.1 Macro level: Societal consequences of childlessness

High levels of childlessness, and more generally low levels of fertility, have a number of societal consequences. First and foremost, childlessness leads to decreasing population growth and increasing population ageing (Coleman, 2001). The size and age structure may additionally be affected by mortality and immigration (Bloom et al., 2010), but the focus here is on fertility. While there may be some advantages to these changes, such as environmental benefits and short-term increases in per capita income (Lee and Mason, 2014), the economic burden on the long term is substantial (Bloom et al., 2010). That is, as the size of the labour force relative to the whole population decreases, the output per capita will be smaller in equilibrium (*ibid.*). At the same time, given that older populations are generally less healthy and require more spendings on welfare payment while having a smaller work force to produce revenue, welfare

systems may be threatened (Coleman, 2001; Parliament of the United Kingdom, 2015) and the costs of social services will have to be borne by a narrowing labour force (Bachi, 1990).

To prevent and/or counteract these implications, governments are increasingly adopting pronatalist policies meant to increase childbearing, for example by providing tax benefits for parents or lengthy parental leaves (United Nations Population Division, 2017). These policies have been shown to be mainly effective in influencing the timing, spacing and quantum of childbirths on the short term. However, their impact on childlessness as well as fertility timing, spacing and quantum on the long term has been limited (Brainerd, 2014; Sobotka et al., 2020). As a consequence, scholars have called for an approach that does not only incentivise childbearing monetarily, but also takes into account the needs and challenges of contemporary families, including more diverse family compositions, rising economic inequalities and reconciliation between career and family (Sobotka et al., 2020). As a result, we might expect high childlessness and low fertility to indirectly lead to continued increases in gender equality, more diverse life courses and inclines in female labour force participation on the longer term (Karra et al., 2017).

Second, higher levels of childlessness are expected to increase tolerance towards and acceptance of the childless lifestyle. Generally, more developed societies are more approving of childlessness (Merz and Liefbroer, 2012), although endorsement of childlessness is still rare (Koropecj-Cox and Pendell, 2007). As societies continue to develop, and as particularly religiosity –one of the most important factors rejecters of childlessness have in common– may be expected to decrease, the acceptance of childlessness will likely incline as well (Noordhuizen et al., 2010). As a consequence, social norms of and pressure for family formation may diminish, and relatively more individuals may remain childless in turn (Bernardi and Klärner, 2014). Nevertheless, whether we will actually observe increases in childlessness will depend on many more factors besides childlessness acceptance, including for example the aforementioned provision of pronatalist policies (Sobotka, 2017; Sobotka et al., 2020).

1.2.3.2 Micro level: Are parents better off than childless individuals?

Scholars have paid substantial attention to researching the consequences of parenthood versus childlessness over the past decades throughout a variety of life domains, including psychological, economic, social and physical well-being. The upcoming sections describe the current state of the literature for each of these domains.

1.2.3.2.1 Psychological Well-being

The most commonly studied outcome of childlessness versus parenthood is psychological well-being (PWB), here defined broadly to include emotional health, mental health and subjective well-being (for

reviews, see [Nomaguchi and Milkie, 2020](#); [Umberson et al., 2010](#)).⁹ However, reported results have been rather mixed and inconsistent, mainly because of differences in research designs as well as (the extent to which researchers account for) circumstances and contextual factors ([Kohler and Mencarini, 2016](#); [Nomaguchi and Milkie, 2020](#); [Umberson et al., 2010](#)). Indeed, childlessness and parenthood both come with a ‘mixed bag’ of emotions and feelings as well as demands and rewards ([Musick et al., 2016](#)), and the ‘balance sheet’ of this mixed bag depends on an individual’s social status and resources, the stage of their life course and the national context in which they are embedded ([Musick et al., 2016](#); [Nomaguchi and Milkie, 2017](#); [Simon and Caputo, 2019](#)).

Some of the differences in research designs that have led to a lack of consensus include the definition and operationalisation of PWB and childlessness as well as the life stage(s) at which respondents are interviewed and the duration of the period during which they are followed. According to the demands-rewards perspective, childlessness and parenthood each come with their own rewards and demands ([Nomaguchi and Milkie, 2020](#)), which can in turn influence various aspects of PWB differently. For example, while parenthood comes with a variety of challenges throughout life, such as financial burden, anxiety and stress ([Neppl et al., 2016](#); [Twenge et al., 2003](#)), children may also bring a sense of life meaning and purpose ([Musick et al., 2016](#); [Nomaguchi and Milkie, 2017, 2020](#)). In line with this idea, childlessness has been found to be associated with higher anxiety and loneliness as well as lower life satisfaction but not necessarily less usefulness amongst Chinese elderly ([Zhang and Liu, 2007](#)). Similarly, [Connidis and McMullin \(1992\)](#) found that amongst adults aged 55 and over, childless women were more depressed than close mothers while childless men were unhappier than close fathers, a finding that projects how different definitions of PWB may prevail to a different extent across individuals. Another dimension of PWB often researched in relation with parenthood and childlessness is that of relationship or family satisfaction: while childlessness negatively influences family satisfaction, especially so amongst women ([Singh and Williams, 1981](#)), parenthood often decreases partnership satisfaction after the transition to parenthood ([Keizer et al., 2010](#)) although it returns to pre-parenthood levels around seven years after childbirth ([Keizer and Schenk, 2012](#)).

Similarly, the definition and type of childlessness or non-parenthood may also affect the conclusions drawn by different studies ([Nomaguchi and Milkie, 2020](#)). That is, some studies define childless individuals as those who never had any biological children (e.g. [Margolis and Myrskylä, 2011](#); [Nelson et al., 2013](#)). Other studies, however, define childlessness in social terms, i.e. excluding adoptive or step-parents from the childless (e.g. [Bures et al., 2009](#)). Yet other researchers adopt a perspective of residency, i.e. assuming that childless individuals may have children but none living with them (e.g. [Aassve et al., 2012](#);

⁹In this introductory chapter, psychological or subjective well-being is abbreviated as PWB and social well-being as SWB; this is not to be confused with the abbreviation ‘SWB’ used to denote subjective well-being in Chapter 3.

Glass et al., 2016; Herbst and Ifcher, 2016; Kendig et al., 2007). For example, using different definitions of childlessness and parenthood, Keizer et al. (2009) found that differences between childless men and fathers were conditioned by the residency status of fathers' children: childless men's community involvement, life satisfaction and income differed mainly compared to resident fathers, while their work hours and income mostly differed compared to non-resident fathers, who are more often socio-economically disadvantaged in the first place (Poole et al., 2016). Similarly, in an analysis distinguishing four categories of parenthood (i.e. no biological nor non-biological children, only non-biological children, only biological children, only deceased biological children), Bures et al. (2009) found that depressive symptoms were highest amongst biological mothers who were never married and/or had outlived their children.

Related, the type of childlessness (i.e. involuntary, voluntary or circumstantial) studied makes a large difference when it comes to the observed relationship with PWB. While voluntarily childless adults have similar PWB experiences to parents (Connidis and McMullin, 1992; Schoon et al., 2012) and report some of the highest levels of well-being and autonomy (Jeffries and Konnert, 2002), those with relinquished parenthood intentions face higher levels of distress (White and McQuillan, 2006). Particularly involuntarily childless adults face substantial deficits in their PWB due to intense emotions and feelings of distress, grief, depression, exclusion, isolation and disrupted identities (e.g. Koert and Daniluk, 2017),¹⁰ although coping and adaptation may have a positive effect on PWB for these individuals throughout their life course (Hadley and Hanley, 2011). On the contrary, voluntarily childless women more often report feelings of relief and acceptance, and hardly tend to regret their choice (Stegen et al., 2020).

The life stage at which respondents are interviewed is of importance for the conclusions drawn as well. Not only does this make a difference in terms of the ages of parents' children (Kohler and Mencarini, 2016), but also in terms of coping with or accepting one's childlessness (Wenger, 2009). For example, while the transition into parenthood often increases PWB temporarily, it decreases PWB shortly thereafter (Keizer and Schenk, 2012). This decrease is often followed by particular trade-offs between demands and rewards at each stage of parents' child(ren)'s life (Barr et al., 2018; Kalmijn and De Graaf, 2012; Luthar and Ciciolla, 2016; Meier et al., 2016), depending on childbirth timing and intentions, work-family policies and how well the children function in daily life (Nomaguchi and Milkie, 2020). Additionally, a study of Australian women showed that childless women have poorer mental health than mothers during the peak reproductive years, but that childless women are mentally better off than mothers after age 65 (Graham, 2015). Similarly, it turns out that childless individuals tend to adapt their expectations of life to their childless lifestyle (Wenger, 2009) and that, in the case of unintended childlessness, they tend to cope better with time (Hadley and Hanley, 2011).

¹⁰Other relevant citations include Dyer et al. (2002); Hadley and Hanley (2011); McQuillan et al. (2003); Payne et al. (2019); Tanturri et al. (2015).

In relation to the life stage at measurement, the duration of the period during which respondents are examined matters for the outcomes of the study (Keizer et al., 2010). Generally, longitudinal designs are strongly preferred for these types of analyses (Nomaguchi and Milkie, 2020; Umberson et al., 2010), mainly because they allow for examining both short-term as well as long-term demands and rewards of childlessness versus parenthood; for taking into account pre-transition levels of PWB; and for ruling out potential reverse causation and self-selection effects (Kohler and Mencarini, 2016). To illustrate, previous research has shown that negative consequences of parenthood compared to remaining childless are experienced shortly after the transition into parenthood, especially so for women, due to role adaptations and time pressure (Keizer et al., 2010; Ruppanner et al., 2019; Twenge et al., 2003). On the other hand, some of the more rewarding parts of parenting become manifest before the child is born (Myrskylä and Margolis, 2014); when parents' children are toddlers (Meier et al., 2016; Nomaguchi, 2012), or when they are adults who make socially desirable life transitions (Kalmijn and De Graaf, 2012). Furthermore, a longitudinal perspective may be helpful to avoid claims of reverse causation, given that a number of studies have shown that some individuals, such as unhappier people (Cetre et al., 2016; Mastekaasa, 1992; Rooney and Domar, 2018), highly educated women (e.g. Becker, 1981b) or men of lower SES (e.g. Dykstra and Hagestad, 2007a; Fieder and Huber, 2007; Mari, 2019), tend to be selected into childlessness.

Besides differences in research designs, individual characteristics and social status strongly condition the relationship between childlessness and PWB (e.g. Nomaguchi and Milkie, 2020). Therefore, the extent to which these characteristics are controlled for matters in terms of the conclusions inferred from relevant studies. One of the most studied moderating factors for the relationship between childlessness and PWB is marital status: partnership differences to a large extent influence, or even make up, the PWB differences between childless adults and parents (e.g. Dykstra and Wagner, 2007).¹¹ To illustrate, childlessness increases depression amongst widowed adults and elderly (Gibney, 2012; Zhang and Hayward, 2001), and involuntarily childless adults have particularly low levels of PWB when their relationship is strained (Payne et al., 2019). Additionally, never married childless women have more favourable outcomes than married, divorced or widowed childless women and mothers (Dykstra and Hagestad, 2007a; Graham, 2015; Keizer and Ivanova, 2017). On the other hand, never married or divorced mothers were most disadvantaged in terms of PWB than other women (Bures et al., 2009; Koropecj-Cox et al., 2007). Children seem to be particularly important for the PWB of widowed individuals (Cheng et al., 2014): widowed childless elderly women report lower PWB than widowed elderly mothers (Beckman and Houser, 1982), and widowed men are generally more depressed than other men regardless of parental status (Bures et al., 2009). The conditioning effect of marital status has been found to be particularly strong amongst men, who tend to suffer more from being single or divorced than their female counterparts (Connidis and

¹¹Also see Chou and Chi (2004); Kendig et al. (2007); Kohler et al. (2005); Koropecj-Cox and Call (2007); Wenger et al. (2007).

McMullin, 1992; Keizer and Ivanova, 2017; Kohler et al., 2005). Additionally, a number of studies even report a main effect for childlessness, which no longer remains when controlling for marital status (e.g. Gibney et al., 2017). More generally, celibacy contributes to lower PWB (Chang et al., 2010; Dykstra and Keizer, 2009), while a successful marriage protects against depression (Hank and Wagner, 2013; Kohler et al., 2005).

As becomes clear from previous studies, the moderating effect of marital status on the relationship between childlessness and PWB is particularly strong amongst men. More generally, it has commonly been concluded that the association between childlessness and PWB differs for women and men. On the one hand, involuntarily childless women tend to suffer more in terms of PWB than their male counterparts (Lechner et al., 2007), which may well be because childbearing is still considered a mainly female experience that is central to women's lives (Blair-Loy, 2009). On the other hand, women who do have children tend to suffer more in terms of PWB than men because of a larger mismatch between expectations and reality (Kohler and Mencarini, 2016). That is, women are more often the primary caregivers, suffering more from sleep deprivation and isolation (Myrskylä and Margolis, 2014), time pressure (Ruppanner et al., 2019), physical and cognitive household tasks (Daming, 2019; Offer and Schneider, 2011), and work-family conflicts (Orgad, 2019)¹² than their male partners. Women who remain childless for reasons other than infertility, and whom are often highly educated and non-partnered (Berrington, 2017),¹³ tend to have the highest levels of PWB (Dykstra and Hagestad, 2007a; Graham, 2015; Keizer and Ivanova, 2017). This is most likely because these women have more freedom and independence (Agrillo and Nelini, 2008) and need not face the burdens of traditional gender roles in housework and childcare (Myrskylä and Margolis, 2014). On the contrary, circumstantially childless men most often remain childless because of low SES and celibacy (Köppen et al., 2017),¹⁴ which particularly negatively affects their PWB (Connidis and McMullin, 1992; Keizer and Ivanova, 2017).

Social status and employment additionally condition the relationship between childlessness and PWB. Generally, those with low SES and worse employment conditions experience higher rewards from having children (Edin and Nelson, 2013), but also more strains due to lower economic security (Cooper, 2014). On the other hand, high-SES individuals might have a harder time separating their work and private lives (Bianchi, 2011), but may also face lower strains because they have more resources (Meier et al., 2016). Most studies that find a negative association between childlessness and PWB also report a moderating effect of SES in this relationship: that is, the negative consequences of childlessness are generally worse for those of low SES than those of high SES (e.g. Zhang and Liu, 2007). On the contrary, scholars who

¹²Other relevant citations include Connelly and Kimmel (2015); Craig and Brown (2017); Keizer et al. (2010); Musick et al. (2016); Orgad (2019).

¹³See also Burkimsher and Zeman (2017); Keizer et al. (2008); Köppen et al. (2017); Kreyenfeld and Konietzka (2017a); Raab and Struffolino (2020); Schaeper et al. (2017); Tanturri and Mencarini (2008).

¹⁴Also see Berrington (2017); Fiori et al. (2017); Keizer et al. (2008); Kuhnt et al. (2017); Raab and Struffolino (2020); Rotkirch and Miettinen (2017).

have focused on early childbearing generally find that women who had children early in life face PWB disadvantages in later life, particularly due to their low SES (Koropeckyj-Cox et al., 2007; Spence, 2008).

Other, less commonly incorporated characteristics that influence the extent to which childlessness affects PWB include ethnicity, sexuality, the quality of parent-child relationships, the timing of child-birth and physical health. Generally, those from migrant backgrounds and/or ethnic minorities often face larger parenting strains due to worries about their offspring's experiences with racial discrimination (Elliott and Aseltine, 2013), lower SES (Nomaguchi and House, 2013; Yu and Singh, 2012), language deficiencies and more demanding parenting styles (Nomaguchi and Milkie, 2020). More recently, research has started to focus on how the sexuality of parents affects their PWB in relation to parenthood. The few studies conducted so far have generally concluded that gay or lesbian couples face additional struggles of parenthood in terms of discrimination and/or institutional systems that are not yet adapted to same-sex parental couples (e.g. Frost et al., 2017), although these strains largely depend on social status (Carroll, 2018). Another factor important to consider when comparing studies is whether the closeness or quality of the relationships of parents with their children was considered. That is, some studies concluded that parents have similar or even higher PWB than childless adults, but only when these parents were in close and frequent contact with their offspring (Albertini and Arpino, 2018; Connidis and McMullin, 1992). Moreover, as indicated earlier, the timing of childbearing also influences the observed relationship between childlessness and PWB. Generally, early mothers have lower PWB (Koropeckyj-Cox et al., 2007; Spence, 2008), whereas those who have children later in life more positively respond to the transition into parenthood (Myrskylä and Margolis, 2014). Finally, physical health may moderate the association between PWB and childlessness (Koropeckyj-Cox et al., 2007). To give an example, one study found that the distress of relinquished positive childbearing intentions was larger amongst women with ill health (White and McQuillan, 2006).

In addition to differences in research designs and individual characteristics, the broader national context in which individuals are embedded also moderates the association between childlessness and psychological well-being (e.g. Nomaguchi and Milkie, 2020). The main channels through which this happens is through cultural norms (i.e. the acceptance of childlessness and non-marital childbearing); by supporting working parents, and mothers in particular, to combine work and family; and by providing institutional care for childless elderly who cannot rely on familial support to the same extent as do parents (e.g. Dykstra and Hagestad, 2007a; Glass et al., 2016; Tanaka and Johnson, 2016). For example, a number of cross-country studies of over 20 European and other highly developed countries (e.g. United States, Australia and New Zealand) found that work-family policies, such as childcare provision for infants, were associated with greater happiness amongst parents, particularly mothers, relative to their childless counterparts (Aassve et al., 2012; Glass et al., 2016; Margolis and Myrskylä, 2011; Ugur, 2020). The same

conclusion was drawn from a qualitative cross-country study of Sweden, Germany, Italy and the United States, although the importance of cultural norms regarding childbearing and gender equality should not be overlooked (Collins, 2019). To illustrate, in a study of 24 European countries, Huijts et al. (2013) found a PWB disadvantage for childless individuals, which was smaller in countries with tolerant norms and high levels of social contacts than in countries with less socialisation and more traditional norms. Similarly, childless adults tend to be happier and more satisfied with life if they live in a region with individualised rather than pronatalist values (Tanaka and Johnson, 2016). This is often the case for more advanced societies, where childlessness is more accepted and approved (Merz and Liefbroer, 2012). Not only childless adults are happier in more advanced societies, but so are parents, and almost always more so than non-parents (Aassve et al., 2012; Kohler and Mencarini, 2016). Finally, as a number of studies have shown that childless adults more often than parents rely on institutional care in old age (Dykstra, 2015; Koropeckyj-Cox and Call, 2007; Rowland, 1998; Wenger, 2009), national provision of such care may help childless elderly in facing the support deficits that might negatively affect their PWB (Dykstra and Hagestad, 2007a).

1.2.3.2.2 Economic Well-being

Another dimension of well-being often studied in relation to childlessness is economic well-being (EWB). In contrast to the findings for PWB, conclusions regarding EWB have been more consistent, although equally contingent on individual characteristics, particularly gender, and national contexts. The relationship between childlessness and EWB is strongly conditioned by gender, with the current consensus being that childless women fare economically better than mothers, whereas childless men are economically disadvantaged compared to fathers (e.g. Keizer and Ivanova, 2017). While this phenomenon may, to some extent, be due to self-selection effects into childlessness, as discussed in section 1.2.2.2, research has provided sufficient evidence to believe that childlessness actually has consequences in economic terms. That is, having remained without children is thought to positively affect female EWB for two reasons (e.g. Cwikel et al., 2006; Fieder and Huber, 2007; Koropeckyj-Cox and Call, 2007; Mika and Czaplicki, 2017). First, from the supply side of labour, childless women may more likely remain on the labour market because their work is not interrupted by childbearing (Gangl and Ziefle, 2009). This allows them to accumulate EWB over time in higher-status jobs compared to mothers who leave the labour market to bear and raise children, and possibly return to mobilise into mother-friendly jobs (Gangl and Ziefle, 2009). Second, from the demand side of labour, working mothers may be discriminated against as being less committed and capable than working non-mothers (Correll et al., 2007), although not all researchers find evidence for such discrimination (Gangl and Ziefle, 2009). Contrastingly, the effect of childlessness on EWB is thought to be negative for men for two reasons (e.g. Dykstra and Keizer, 2009). First,

childless men may be less likely to succeed in their career because of lacking the ‘male breadwinner motivation’, which inclines fathers to increase their EWB to care for their family (Dykstra and Keizer, 2009; Kaufman and Uhlenberg, 2000; Keizer et al., 2009). Second, from the demand side of labour, employers tend to discriminate against childless men because they perceive fathers as being more capable and committed than equally qualified childless men with the same marital status (Killewald, 2013). All in all, these mechanisms point to positive economic outcomes for childless women compared to mothers, and negative economic outcomes for childless men compared to fathers.

1.2.3.2.3 Social Well-being

Social well-being (SWB) is a dimension of well-being less often investigated by scholars in relation to childlessness, although the few scholars who have looked into this association, particularly during old age, have generally reported consistent findings. While parenthood has generally been shown to have a ‘social integration effect’, as asserted by Durkheimian theory (Dykstra and Keizer, 2009), childless adults do not necessarily fare worse socially than parents (Hank and Wagner, 2013). Childless individuals generally have fewer relatives living close by, and consequentially have smaller social networks than parents (Dykstra and Wagner, 2007), which is especially the case for men (Keizer and Ivanova, 2017). Nevertheless, childless individuals adapt to the absence of children by having similar or even closer contacts with neighbours and friends compared to parents (Vikström et al., 2011; Wenger, 2009), and tend to both give and receive similar or even higher levels of social support as/than do parents (Albertini and Kohli, 2017; Cwikel et al., 2006). This seems to be the case particularly for childless women however, while resident fathers are generally more involved in their community than non-resident fathers or childless men (Keizer et al., 2009).

Generally, elderly childless parents may face support deficits (Dykstra and Hagestad, 2007a), mainly when it comes to support needed for ill health (Albertini and Mencarini, 2014). Being unmarried particularly reduces the likelihood of personal care (Chang et al., 2010). As a result, childless adults have a similar or even higher risk of institutionalisation than parents: almost all childless people enter institutional care in old age (Dykstra, 2015).¹⁵ This is however contingent on individual characteristics, such as partnership, gender and social and financial capital (Wenger, 2009). For example, childless elderly women generally have no expectations of family care and, particularly in the case of never married women, prefer to remain independent for as long as possible (Wenger, 2009). On the other hand, childless elderly men expect support from their spouses, or, in the case of never married or widowed men, from their mothers and/or sisters (*ibid.*). Also, given the aforementioned potential support deficits in later life,

¹⁵See also Koropecj-Cox and Call (2007); Rowland (1998); Vikström et al. (2011); Wenger (2009).

the national context and the extent to which welfare systems provide such support, is of importance when assessing the relationship between childlessness and SWB (Albertini and Mencarini, 2014).

1.2.3.2.4 Physical Well-being

While lower physical or corporeal well-being (CWB) may lead some individuals to be selected into involuntary childless via infertility (Gibney et al., 2017; Rooney and Domar, 2018), it seems that differences in CWB between childless adults and parents can also be the consequence of their parental status differences. Generally, childless individuals are found to have similar (Cwikel et al., 2006) or worse CWB and lower life expectancy than parents (Albertini and Kohli, 2017; Dykstra and Hagestad, 2007b; Keizer et al., 2009; Kendig et al., 2007). While parenthood is demanding (Nomaguchi and Milkie, 2020), it also provides a form of social control for healthy behaviours (Dykstra and Hagestad, 2007b; Kendig et al., 2007). Furthermore, childless individuals are more often non-married than parents, a characteristic which negatively affects CWB, at least amongst men (Keizer et al., 2009). Amongst women, the childless also seem to report lower CWB than their parental counterparts, although merely during the peak reproductive years, after which the effect reverses in direction (Graham, 2015). This association is conditioned by marital status, however, given that never married childless women are physically better off than not only mothers, but also divorced, widowed or married childless women (*ibid.*). Another important moderator of the relationship between CWB and childlessness is the timing at which parents have their children, given that early childbearing is associated with physical health issues (Spence, 2008).

1.3 Scientific Relevance of Researching Childlessness

From the literature review in the preceding section, a number of gaps in the literature on childlessness can be identified. Each of these gaps can be linked to broader sociological topics, such as modernisation, social inequality and social cohesion (Keizer, 2010).

First, the majority of the studies conducted on childlessness focus on developed regions in the world where fertility rates have declined substantially, such as Europe and the United States (see for instance Frejka, 2017; Kreyenfeld and Konietzka, 2017b). However, childlessness in less developed regions, such as Africa and Latin America, has hardly been investigated, because of the assumption that childlessness is not significant in these regions. One reason for this assumption is that fertility rates have historically been high in developing regions (The World Bank, 2018), and although they have been decreasing over the past decades (GBD 2017 Population and Fertility Collaborators, 2018), they are often still larger than the replacement level. Nevertheless, while women in these regions may still have relatively many children on

average, there is also a substantial number of women who will never have children (Bongaarts and Castlerline, 2013; Inhorn and Patrizio, 2015; Larsen, 1994). This is particularly problematic as poverty may be the strongest driver of childlessness in less developed areas (Baudin et al., 2020), and childlessness is severely stigmatised and punished in these regions (Inhorn and Patrizio, 2015). This reflects also how particularly in less developed areas, childlessness is less often the result of personal choice, but rather of constraints in terms of personal circumstances like infertility and non-marriage as well as contextual factors such as welfare states and cultural norms (e.g. Berrington, 2017).¹⁶ To examine childlessness in the broader sociological context of modernisation, this thesis assesses the relationship between childlessness and socio-economic development for sub-Saharan Africa, a region that has recently seen substantial improvements in development.

A second gap that can be identified from the literature review is the lack of connection between socio-economic causes (or self-selection) and consequences of childlessness. As addressed earlier, there are two major strands in the literature, one focusing on examining the pathways into childlessness (e.g. Gemmill, 2019; Hagestad and Call, 2007; Keizer et al., 2008; Raab and Struffolino, 2020), and the other one focusing on the (old-age) socio-economic consequences of having remained childless (e.g. Hansen et al., 2009; McQuillan et al., 2003; Zhang and Hayward, 2001). However, these studies have not been able to examine socio-economic factors before, during and after the process of remaining childless in the same individuals. The main reason for this is because commonly used methods struggle to simultaneously incorporate and model a number of substantive complexities of the question at hand. These complexities mainly stem from childlessness often being a product of a complex life course process which is not clearly marked; might not be definitive at the time of measurement; may have different reasons; and may associate with multiple life domains simultaneously and contemporaneously (e.g. Abbott, 2005; Berrington, 2017; Keizer et al., 2009; Nomaguchi and Milkie, 2020). Assessing socio-economic well-being across the life course is important, nonetheless, because the association between (foregoing) childbearing and socio-economic factors may be bidirectional (Bijlsma and Wilson, 2020; Plotnick, 2009; Umberson et al., 2010), and its direction might depend on the life course stage (i.e. socio-economic circumstances influence childbearing outcomes earlier in life, and childbearing outcomes in turn influence socio-economic well-being in later life). As a result, socio-economic (dis)advantage, and thus inequality, may accumulate throughout life via childbearing outcomes (Elder Jr et al., 2003). To illustrate with an example that was discussed in the literature review: lower-earning women might accumulate earnings disadvantage over the life course compared to highly earning women, because they may be selected into motherhood via lower opportunity cost of having children (Becker, 1981b), and then face a further earnings disadvantage by interrupting their career to bear children (Gangl and Ziefle, 2009). To assess the

¹⁶Also see Mayer (2004, 2009); Mayer and Müller (1986); Mayer and Schoepflin (1989).

growth of socio-economic inequalities across the life courses of those who eventually become parents and those who remain permanently childless and for different reasons so, this thesis proposes applying a Bayesian modelling approach from statistics to sociology.

As discussed earlier, the literature has identified three major drivers of childlessness at the macro level: structural advancements, ideological changes and technological innovations. These aggregate phenomena emerge from individual-level behaviour (Ciganda and Villavicencio, 2017), and in turn shape individual fertility intentions by means of societal norms and values (e.g. Buyukkececi et al., 2020).¹⁷ Social networks on the meso level connect individual family norms and outcomes at the micro level to cultural and institutional systems and fertility levels at the macro level, and serve as a (reinforcing) feedback channel between the two (Balbo et al., 2013; Billari, 2015; Ciganda and Villavicencio, 2017). This social interaction creates, diffuses and transforms intentions, values, norms and support regarding family formation (e.g. Bernardi and Klärner, 2014).¹⁸ As becomes clear from the literature review, academics have increasingly investigated how childless individuals cohere in society compared to parents (e.g. Dykstra and Keizer, 2009; Dykstra and Wagner, 2007). However, currently little quantitative evidence exists for the role social networks play in linking macro-level childlessness patterns to micro-level childbearing intentions and outcomes, and more specifically how the structural and compositional characteristics of these networks affect how childlessness spreads across populations (Coleman et al., 1966; Keim, 2011; Kohler et al., 2001). This thesis fills the gap in the literature by quantitatively assessing how macro-level trends in childlessness emerge from micro-level childbearing behaviour, and what role social network influences play in this process. Hereby examining the impact of structural and compositional social network characteristics, the results can be used to formulate hypotheses regarding potential trends in social network structures and how these might have influenced the empirically observed growth in childlessness.

1.4 Thesis Objective and Research Questions

This thesis investigates childlessness at the macro level across time and levels of socio-economic development as well as its pathways and consequences in micro-level individual life courses, and the role meso-level social network influences play in connecting the two. Hence, the overarching objective of this thesis is to provide a better understanding of how childlessness may come about in and affect people's lives, and how these pathways and consequences interact with individuals' social environment and the

¹⁷Other relevant citations include Balbo and Barban (2014); Kotte and Ludwig (2011); Lois and Becker (2014); Lyngstad and Prskawetz (2010); Pink et al. (2014); Richter et al. (2012).

¹⁸See also Bongaarts and Watkins (1996); Kohler (2001); Kohler et al. (2002, 2006); Mönkediek and Bras (2016); Montgomery and Casterline (1996); Myrskylä and Goldstein (2013).

societal context they are embedded in more broadly. More specifically, throughout a series of three standalone but related chapters, this thesis i) examines the relationship between childlessness and development on the (sub-)national level for sub-Saharan Africa; ii) assesses the accumulation of socio-economic (dis)advantage throughout the life courses of those who have eventually remained childless; and iii) investigates the role of structural and compositional characteristics of social networks in the interaction between individual-level childbearing outcomes and aggregate trends in childlessness. The next sections elaborate on the research questions addressed in each of these chapters.

1.4.1 Childlessness and Development

As aforementioned, the first chapter of this thesis assesses the relationship between childlessness and development for sub-Saharan Africa to examine childlessness in the broader sociological context of modernisation. That is, to better understand the extent to which childlessness can be viewed as a response to structural socio-economic conditions, the variation of childlessness across levels of socio-economic development is examined. More specifically, the following three questions are answered for sub-Saharan Africa. First, how are permanent childlessness and indicators of development at the subnational level related? Second, how does this association differ across types of childlessness (i.e. involuntary, voluntary and circumstantial childlessness)? Third, are there gender differences with respect to the first two questions? These questions will be answered by using hierarchical models in conjunction with data from 291 Demographic and Health Surveys collected between 1986 and 2018 throughout 38 sub-Saharan African countries and 384 subnational regions. Hereby, the three types of childlessness (i.e. involuntary, voluntary and circumstantial) are distinguished, and various other data sets are exploited to construct innovative historical subnational-level development indicators and take into account other factors that may be related to childlessness.

1.4.2 Childlessness and Socio-economic (Dis)advantage

Section 1.3 mentioned that this thesis proposes applying a modelling approach that takes into account several substantive and conceptual complexities of cumulative socio-economic (dis)advantage and its relationship to childlessness. The use of this approach is demonstrated by estimating a Bayesian multivariate multiple hierarchical growth model on data from the 1970 British Cohort Study to estimate prospective SWB and EWB trajectories simultaneously for those who have ever had a child before age 46 and those who have eventually remained voluntarily, involuntarily, circumstantially and indecisively (i.e. for no clear reason) childless up to age 46. As such, this thesis will provide answers to the questions of whether socio-economic (dis)advantage accumulates throughout the life course via permanent childlessness; how

the social and economic domains moderate each others' association with permanent childlessness; what factors besides permanent childlessness influence (the development of) socio-economic differentials between childless adults and parents; and what gender differences exist with respect to these questions. Hereby, childlessness and socio-economic well-being (SEWB) are considered continually both outcome and determinant in a dynamic interplay over longer periods of the life course. Additionally, the potential roles partnerships, education, employment and health may play in influencing both permanent childlessness and SEWB are taken into account.

1.4.3 Childlessness and Social Networks

As addressed earlier, quantitative evidence for the role (changes in) structural and compositional characteristics of social networks have played in the observed increase of childlessness has been lacking. This is mainly because of the assumption that social network influences on childbearing are of less relevance in secular and individualistic post-industrial societies (Bernardi and Klärner, 2014); the limited availability of large-scale longitudinal data including information on social networks and childbearing (Balbo et al., 2013); and methodological limitations in accurately replicating real-life and complex human behaviour in formal models (Gilbert, 2008; Wilensky and Rand, 2015). Therefore, this thesis quantitatively assesses to what extent and how structural and compositional characteristics of social networks influence the increasing prevalence of female childlessness. To this end, it develops a single-sex agent-based simulation model (ABSM) that is able to both model and assess emerging macro-level patterns in female childlessness as a result of meso-level interactions amongst individuals at the micro level that stem from endogenous social network formation. The ABSM is calibrated to data about Dutch women born between 1935 and 1965, which makes for a particularly interesting case because permanent childlessness in the Netherlands increased from 11.7% amongst women born in 1935 to 18.1% amongst women born in 1965, and followed a sigmoidal curve with particularly large growth amongst women born between the mid 1940s and 1950s. Consequentially, this thesis helps enhance our understanding of how structural characteristics influence the increasing prevalence of female childlessness, and what these influences might imply for trends of social network structures during the same period of time.

1.5 Contributions

This thesis as a whole, besides the specific contributions of the three standalone studies that the thesis consists of, makes several empirical and methodological contributions to the scientific literature concerning childlessness.

First, as shows from the literature review, most studies on childlessness have been conducted on the individual micro level or the aggregated macro level. However, hardly any studies have connected the micro and macro levels, and examined the importance of meso-level social networks in the spread of aggregate childlessness levels. In explanations of fertility decline, the importance and inclusion of social network effects have become increasingly recognised (e.g. Bernardi and Klärner, 2014).¹⁹ However, as argued earlier, high levels of childlessness do not simply equate to low levels of fertility (Keizer, 2010; Tanturri et al., 2015), and the experiences of individuals embedded in social networks should therefore be examined not only regarding questions of childbearing timing and quantum, but also regarding questions of whether or not to bear children at all (*ibid.*). In fact, while studying childlessness at the macro level remains crucial to understand past and predict future trends in population characteristics (Sobotka, 2020), merely examining macro-level trends without considering how they might emerge from micro-level behaviour might not be sufficient to enhance our understanding of the growth in childlessness observed over the past decades (Billari, 2015). Therefore, this thesis examines childlessness from the micro-, meso-, and macro-perspectives to provide a holistic overview of the phenomenon, and better understand how experiences at these three different levels are linked.

Second, the majority of studies conducted on childlessness view the phenomenon as a dichotomous factor (Allen and Wiles, 2013). However, more recent studies on intentions and experiences of childlessness have revealed that the process of remaining childless is often varied and complex in nature (e.g. Berrington, 2017; Raab and Struffolino, 2020). That is, permanent childlessness is most often a process outcome of “a sequence of socially defined events and roles that the individual enacts over time” (Abbott, 2005; Giele and Elder Jr, 1998, p. 22). As such, some individuals may choose early on not to have children, while others anticipate becoming parents but turn out to be infertile, never meet someone to have children with, or ‘perpetually’ postpone childbearing until they can no longer have children (e.g. Berrington, 2017). Therefore, a complete and consistent picture of (correlates of) childlessness would need to acknowledge the heterogeneity in the group of childless individuals (e.g. Raab and Struffolino, 2020). Nonetheless, the majority of studies examining childlessness consider a variety of family trajectories and pathways into childlessness, but do not necessarily distinguish between different reasons for childlessness explicitly (e.g. Comolli et al., 2021; Jalovaara and Fasang, 2020; Kahn et al., 2014; Mynarska et al., 2015; Van Winkle and Fasang, 2020), albeit with some exceptions (e.g. Buhr and Huinink, 2017; Tanturri and Mencarini, 2008). This thesis acknowledges the heterogeneity in reasons for childlessness by making use of rich data to both directly and indirectly distinguish between reasons for and types of childlessness (i.e. involuntary, voluntary and circumstantial), and as such examine how the assessed relationships differ across these various experiences of childlessness.

¹⁹See also Bongaarts and Watkins (1996); Kohler (2001); Kohler et al. (2002, 2006); Mönkediek and Bras (2016); Montgomery and Casterline (1996); Myrskylä and Goldstein (2013).

Third, studies on fertility and childlessness have generally focused on women, most often because of the assumption that childbearing mainly is a female experience, and/or a lack of relevant data on males (Keizer, 2010). However, the few studies that have included men in their analyses have shown that female and male experiences of childlessness are different, and have acknowledged the importance of including men in analyses of childlessness (e.g. Keizer et al., 2008). For example, it turns out that childless women are often highly educated and have remained childless because of the high opportunity cost of children they face (e.g. Kreyenfeld and Konietzka, 2017a).²⁰ On the contrary, childless men are usually of lower SES than fathers and have often remained childless as a consequence of being left behind on largely hypergamous mating markets (Kreyenfeld and Konietzka, 2017b). In addition, childlessness may be less socially acceptable for women than men, which might affect their experiences differently (Rijken and Merz, 2014). To better understand how these experiences of childlessness differ for women and men, this thesis takes a gendered perspective and examines trends, drivers and outcomes of childlessness for both women and men.

Fourth, some of the aforementioned gaps in the literature are the consequence of limited data availability, given that the collection of traditional survey and/or census data is costly in terms of finances and time. For instance, acknowledging the heterogeneity in childlessness experiences requires detailed and preferably longitudinal data on individuals' intentions and life course transitions, such as partnership histories (Mynarska et al., 2015). Beyond data limitations, though, social scientists' methodological training to develop models that as accurately as possible 'imitate' the real world and as such incorporate the relevant conceptual features of the substantive problems at hand is often limited (Lynch and Bartlett, 2019). For example, assessing the role of social influences through social networks in shaping childbearing intentions and outcomes requires the explicit modelling of interactions amongst humans, and taking into consideration that humans are heterogeneous and tend to form their social networks endogenously (e.g. Aparicio Diaz et al., 2011; Gilbert, 2008; Wilensky and Rand, 2015). As these examples illustrate, answering novel and more complex questions sometimes requires the use of more advanced and sophisticated methods, including Bayesian inference and simulation techniques (e.g. Bruch and Atwell, 2015; Lynch and Bartlett, 2019). Therefore, this thesis makes use of such rich longitudinal data and advanced methodologies. Not only does this allow for overcoming current limitations in our analyses and understanding of childlessness, but 'repurposing' such more advanced methodologies from other disciplines also helps demonstrate the use and advantages of these methods to a wider sociological and demographic audience.

²⁰See also Berrington (2017); Burkimsher and Zeman (2017); Keizer et al. (2008); Köppen et al. (2017); Schaeper et al. (2017); Tanturri and Mencarini (2008).

1.6 Outline

The remainder of this document is structured as follows. Chapter 2 examines the macro-level relationship between childlessness and socio-economic development in sub-Saharan Africa, and whether this can be described by a U-shaped pattern. Chapter 3 assesses whether remaining childless may contribute to the accumulation of socio-economic (dis)advantage throughout the life courses of British individuals, which it does by proposing and applying a Bayesian modelling approach. Chapter 4 contains a meso-level analysis of the role structural and compositional characteristics of social networks have played in the increasing prevalence of childlessness observed amongst Dutch women. The main findings and implications of this thesis are summarised and concluding remarks are provided in Chapter 5.

References

- Aarssen, L. W. and Altman, S. T. (2006). Explaining below-replacement fertility and increasing childlessness in wealthy countries: Legacy drive and the “transmission competition” hypothesis. *Evolutionary Psychology*, 4(1):290–302.
- Aassve, A., Goisis, A., and Sironi, M. (2012). Happiness and childbearing across Europe. *Social Indicators Research*, 108(1):65–86.
- Abbott, A. (2005). Process and Temporality in Sociology: The Idea of Outcome in U.S. Sociology. In Steinmetz, G., editor, *The Politics of Method in the Human Sciences: Positivism and Its Epistemological Others*, pages 393–426. Durham, NC: Duke University Press.
- Abma, J. C. and Martinez, G. M. (2006). Childlessness among older women in the United States: Trends and profiles. *Journal of Marriage and Family*, 68(4):1045–1056.
- Agrillo, C. and Nelini, C. (2008). Childfree by choice: A review. *Journal of Cultural Geography*, 25(3):347–363.
- Albertini, M. and Arpino, B. (2018). Childlessness, parenthood and subjective wellbeing: The relevance of conceptualizing parenthood and childlessness as a continuum. SocArXiv: [10.31235/osf.io/xtfq6](https://doi.org/10.31235/osf.io/xtfq6).
- Albertini, M. and Brini, E. (2021). I’ve changed my mind. The intentions to be childless, their stability and realisation. *European Societies*, 23(1):119–160.
- Albertini, M. and Kohli, M. (2017). Childlessness and intergenerational transfers in later life. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 351–368. Springer.
- Albertini, M. and Mencarini, L. (2014). Childlessness and support networks in later life: New pressures on familistic welfare states? *Journal of Family Issues*, 35(3):331–357.
- Allen, R. E. and Wiles, J. L. (2013). The utility of positioning theory to the study of ageing: Examples from research with childless older people. *Journal of Aging Studies*, 27(2):175–187.
- Andersson, G., Rønsen, M., Knudsen, L. B., Lappegård, T., Neyer, G., Skrede, K., Teschner, K., and Vikat, A. (2009). Cohort fertility patterns in the Nordic countries. *Demographic Research*, 20:313–352.
- Aparicio Diaz, B., Fent, T., Prskawetz, A., and Bernardi, L. (2011). Transition to parenthood: The role of social interaction and endogenous networks. *Demography*, 48(2):559–579.
- Avison, M. and Furnham, A. (2015). Personality and voluntary childlessness. *Journal of Population Research*, 32(1):45–67.
- Bachi, R. (1990). Low Fertility in Industrial Countries: Causes, Consequences, Policies. *Annals of the New York Academy of Sciences*, 610:83–96.
- Balbo, N. and Barban, N. (2014). Does fertility behavior spread among friends? *American Sociological Review*, 79(3):412–431.
- Balbo, N., Billari, F. C., and Mills, M. (2013). Fertility in advanced societies: A review of research. *European Journal of Population*, 29(1):1–38.
- Barr, A. B., Simons, L. G., Simons, R. L., Beach, S. R., and Philibert, R. A. (2018). Sharing the burden of the transition to adulthood: African American young adults’ transition challenges and their mothers’ health risk. *American Sociological Review*, 83(1):143–172.
- Barthold, J. A., Myrskylä, M., and Jones, O. R. (2012). Childlessness drives the sex difference in the association between income and reproductive success of modern Europeans. *Evolution and Human Behavior*, 33(6):628–638.
- Basten, S., Sobotka, T., and Zeman, K. (2014). *Future fertility in low fertility countries*. Oxford, United Kingdom: Oxford University Press.
- Baudin, T., De la Croix, D., and Gobbi, P. (2020). Endogenous childlessness and stages of development. *Journal of the European Economic Association*, 18(1):83–133.
- Beaujouan, E., Brzozowska, Z., and Zeman, K. (2016). The limited effect of increasing educational attainment on childlessness trends in twentieth-century Europe, women born 1916–65. *Population Studies*, 70(3):275–291.
- Becker, G. (1981a). *A treatise on the family*. Cambridge, MA: Harvard University Press.
- Becker, G. S. (1981b). *A treatise on the family*. Cambridge, MA: Harvard University Press.
- Becker, G. S., Murphy, K. M., and Spenkuch, J. L. (2016). The manipulation of children’s preferences,

- old-age support, and investment in children's human capital. *Journal of Labor Economics*, 34(S2):S3–S30.
- Beckman, L. J. and Houser, B. B. (1982). The consequences of childlessness on the social-psychological well-being of older women. *Journal of Gerontology*, 37(2):243–250.
- Bernardi, L. and Keim, S. (2017). Childless at Age 30: A Qualitative Study of the Life Course Plans of Working Women in East and West Germany. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 253–267. Springer.
- Bernardi, L. and Klärner, A. (2014). Social networks and fertility. *Demographic Research*, 30:641–670.
- Berrington, A. (2017). Childlessness in the UK. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 57–76. Springer.
- Bianchi, S. M. (2011). Changing families, changing workplaces. *The Future of Children*, 21(2):15–36.
- Bijlsma, M. J. and Wilson, B. (2020). Modelling the socio-economic determinants of fertility: a mediation analysis using the parametric g-formula. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 183(2):493–513.
- Billari, F. (2005). Partnership, childbearing and parenting: Trends of the 1990s. In Macura, M., MacDonald, A., and Haug, W., editors, *The new demographic regime: Population challenges and policy responses*, pages 63–94. New York/Geneva: United Nations, Sales No. E.
- Billari, F. and Kohler, H.-P. (2004). Patterns of low and lowest-low fertility in Europe. *Population Studies*, 58(2):161–176.
- Billari, F. C. (2015). Integrating macro-and micro-level approaches in the explanation of population change. *Population Studies*, 69(sup1):S11–S20.
- Blair-Loy, M. (2009). *Competing devotions: Career and family among women executives*. Cambridge, MA: Harvard University Press.
- Blake, J. (1979). Is zero preferred? American attitudes toward childlessness in the 1970s. *Journal of Marriage and Family*, 41(2):245–257.
- Bloom, D. E., Canning, D., Fink, G., and Finlay, J. E. (2010). The cost of low fertility in Europe. *European Journal of Population/Revue Européenne de Démographie*, 26(2):141–158.
- Bongaarts, J. and Casterline, J. (2013). Fertility transition: is sub-Saharan Africa different? *Population and Development Review*, 38:153–168.
- Bongaarts, J. and Potter, R. E. (1983). *Fertility, biology, and behavior: An analysis of the proximate determinants*. New York, NY: Academic Press.
- Bongaarts, J. and Watkins, S. C. (1996). Social interactions and contemporary fertility transitions. *Population and Development Review*, 22(4):639–682.
- Brainerd, E. (2014). Can government policies reverse undesirable declines in fertility? IZA World of Labor. Retrieved from: <https://wol.iza.org/uploads/articles/23/pdfs/can-government-policies-reverse-undesirable-declines-in-fertility.one-pager.pdf>.
- Bruch, E. and Atwell, J. (2015). Agent-based models in empirical social research. *Sociological Methods & Research*, 44(2):186–221.
- Buhr, P. and Huinink, J. (2017). Why childless men and women give up on having children. *European Journal of Population*, 33(4):585–606.
- Bures, R. M., Koropecj-Cox, T., and Loree, M. (2009). Childlessness, parenthood, and depressive symptoms among middle-aged and older adults. *Journal of Family Issues*, 30(5):670–687.
- Burkimsher, M. (2014). Is religious attendance bottoming out? An examination of current trends across Europe. *Journal for the Scientific Study of Religion*, 53(2):432–445.
- Burkimsher, M. and Zeman, K. (2017). Childlessness in Switzerland and Austria. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 115–137. Springer.
- Buyukkececi, Z., Leopold, T., van Gaalen, R., and Engelhardt, H. (2020). Family, Firms, and Fertility: A Study of Social Interaction Effects. *Demography*, 57:243–266.
- Callan, V. J. and Hennessey, J. F. (1989). Psychological adjustment to infertility: A unique comparison of two groups of infertile women, mothers and women childless by choice. *Journal of Reproductive and Infant Psychology*, 7(2):105–112.
- Caltabiano, M., Comolli, C. L., and Rosina, A. (2017). The effect of the Great Recession on permanent childlessness in Italy. *Demographic Research*, 37:635–668.
- Carroll, M. (2018). Managing without moms: Gay fathers, incidental activism, and the politics of parental gender. *Journal of Family Issues*, 39(13):3410–3435.

- Casterline, J. and Han, S. (2017). Unrealized fertility: Fertility desires at the end of the reproductive career. *Demographic Research*, 36:427–454.
- Cetre, S., Clark, A. E., and Senik, C. (2016). Happy people have children: Choice and self-selection into parenthood. *European Journal of Population*, 32(3):445–473.
- Chang, E., Wilber, K. H., and Silverstein, M. (2010). The effects of childlessness on the care and psychological well-being of older adults with disabilities. *Aging & Mental Health*, 14(6):712–719.
- Cheng, S.-T., Chan, T. W. S., Li, G. H., and Leung, E. M. (2014). Childlessness and subjective well-being in Chinese widowed persons. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 69(1):48–52.
- Cherlin, A. J. (2010). *The marriage-go-round: The state of marriage and the family in America today*. Vintage.
- Cherlin, A. J. (2014). *Labor's love lost: The rise and fall of the working-class family in America*. New York, NY: Russell Sage Foundation.
- Chou, K.-L. and Chi, I. (2004). Childlessness and psychological well-being in Chinese older adults. *International Journal of Geriatric Psychiatry*, 19(5):449–457.
- Chudnovskaya, M. (2019). Trends in childlessness among highly educated men in Sweden. *European Journal of Population*, 35:939–958.
- Ciganda, D. and Villavicencio, F. (2017). Feedback mechanisms in the postponement of fertility in Spain. In Grow, A. and Van Bavel, J., editors, *Agent-Based Modelling in Population Studies*, pages 405–435. Springer.
- Coleman, D. A. (2001). Population ageing: An unavoidable future. *Social Biology and Human Affairs*, 66:1–11.
- Coleman, S., Katz, E., and Menzel, H. (1966). *Medical innovation: A diffusion study*. Indianapolis, IN: The Bobbs-Merrill Company.
- Collins, C. (2019). *Making motherhood work: How women manage careers and caregiving*. Princeton, NJ: Princeton University Press.
- Comolli, C., Bernardi, L., and Voorpostel, M. (2021). Joint family and work trajectories and multidimensional wellbeing. *European Journal of Population*, 37:643–696.
- Comolli, C. L. and Bernardi, F. (2015). The causal effect of the great recession on childlessness of white American women. *IZA Journal of Labor Economics*, 4(1):1–24.
- Connelly, R. and Kimmel, J. (2015). If you're happy and you know it: How do mothers and fathers in the US really feel about caring for their children? *Feminist Economics*, 21(1):1–34.
- Connidis, I. A. and McMullin, J. A. (1992). Getting out of the house: The effect of childlessness on social participation and companionship in later life. *Canadian Journal on Ageing*, 11(4):370–386.
- Cooper, M. (2014). *Cut adrift: Families in insecure times*. Berkeley, CA: University of California Press.
- Correll, S. J., Benard, S., and Paik, I. (2007). Getting a job: Is there a motherhood penalty? *American Journal of Sociology*, 112(5):1297–1338.
- Craig, L. and Brown, J. E. (2017). Feeling rushed: Gendered time quality, work hours, nonstandard work schedules, and spousal crossover. *Journal of Marriage and Family*, 79(1):225–242.
- Cwikel, J., Gramotnev, H., and Lee, C. (2006). Never-married childless women in Australia: Health and social circumstances in older age. *Social Science & Medicine*, 62(8):1991–2001.
- Daminger, A. (2019). The cognitive dimension of household labor. *American Sociological Review*, 84(4):609–633.
- Dyer, S. J., Abrahams, N., Hoffman, M., and van der Spuy, Z. M. (2002). 'Men leave me as I cannot have children': women's experiences with involuntary childlessness. *Human Reproduction*, 17(6):1663–1668.
- Dyer, S. J., Abrahams, N., Mokoena, N., and van der Spuy, Z. M. (2004). 'You are a man because you have children': Experiences, reproductive health knowledge and treatment-seeking behaviour among men suffering from couple infertility in South Africa. *Human Reproduction*, 19(4):960–967.
- Dykstra, P. A. (2009). Childless old age. In Uhlenberg, P., editor, *International Handbook of Population Aging*, pages 671–690. Springer.
- Dykstra, P. A. (2015). Childless older adults. In Krauss Whitbourne, S., editor, *The Encyclopedia of Adulthood and Aging*, pages 1–5. Chichester, United Kingdom; Hoboken, NJ: John Wiley & Sons.
- Dykstra, P. A. and Hagestad, G. O. (2007a). Childlessness and parenthood in two centuries: Different roads, different maps? *Journal of Family Issues*, 28(11):1518–1532.
- Dykstra, P. A. and Hagestad, G. O. (2007b). Roads less taken: Developing a nuanced view of older adults without children. *Journal of Family Issues*, 28(10):1275–1310.

- Dykstra, P. A. and Keizer, R. (2009). The wellbeing of childless men and fathers in mid-life. *Ageing & Society*, 29(8):1227–1242.
- Dykstra, P. A. and Wagner, M. (2007). Pathways to childlessness and late-life outcomes. *Journal of Family Issues*, 28(11):1487–1517.
- Eckhard, J. (2014). Theoretical Explanations of Increasing Childlessness–Divergent Approaches and the Integrating Potential of the Frame Selection Theory. *Comparative Population Studies*, 39(1).
- Edin, K. and Nelson, T. J. (2013). *Doing the best I can: Fatherhood in the inner city*. Berkeley, CA: University of California Press.
- Elder Jr, G. H., Johnson, M. K., and Crosnoe, R. (2003). The emergence and development of life course theory. In Mortimer, J. and Shanahan, M., editors, *Handbook of the Life Course*, pages 3–19. Springer.
- Elliott, S. and Aseltine, E. (2013). Raising teenagers in hostile environments: How race, class, and gender matter for mothers’ protective carework. *Journal of Family Issues*, 34(6):719–744.
- Ferragina, E. (2019). Does family policy influence women’s employment? Reviewing the evidence in the field. *Political Studies Review*, 17(1):65–80.
- Fieder, M. and Huber, S. (2007). The effects of sex and childlessness on the association between status and reproductive output in modern society. *Evolution and Human Behavior*, 28(6):392–398.
- Fiori, F., Rinesi, F., and Graham, E. (2017). Choosing to Remain Childless? A Comparative Study of Fertility Intentions Among Women and Men in Italy and Britain. *European Journal of Population*, 33(3):319–350.
- Frejka, T. (2017). Childlessness in the United States. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 159–179. Springer.
- Frejka, T., Sobotka, T., Hoem, J., and Toulemon, L. (2008). Childbearing trends and policies in Europe: Summary and general conclusions. *Demographic Research*, 19:5–13.
- Frost, D. M., LeBlanc, A. J., de Vries, B., Alston-Stepnitz, E., Stephenson, R., and Woodyatt, C. (2017). Couple-level minority stress: An examination of same-sex couples’ unique experiences. *Journal of Health and Social Behavior*, 58(4):455–472.
- Fry, R. and Kochhar, R. (2014). America’s wealth gap between middle-income and upper-income families is widest on record. Pew Research Center. Retrieved from <https://www.pewresearch.org/fact-tank/2014/12/17/wealth-gap-upper-middle-income/>.
- Gadgil, M. and Bossert, W. H. (1970). Life historical consequences of natural selection. *The American Naturalist*, 104(935):1–24.
- Gangl, M. and Ziefle, A. (2009). Motherhood, labor force behavior, and women’s careers: An empirical assessment of the wage penalty for motherhood in Britain, Germany, and the United States. *Demography*, 46(2):341–369.
- GBD 2017 Population and Fertility Collaborators (2018). Population and fertility by age and sex for 195 countries and territories, 1950–2017: a systematic analysis for the global burden of disease study 2017. *The Lancet*, 392(10159):1995–2051.
- Geist, C. and Brauner-Otto, S. (2017). Constrained intentions: Individual economic resources, regional context, and fertility expectations in Germany. *Socius: Sociological Research for a Dynamic World*, 3:1–17.
- Gemmill, A. (2019). From some to none? Fertility expectation dynamics of permanently childless women. *Demography*, 56(1):129–149.
- Gibney, S. (2012). OP18 Childlessness in Europe: Implications for Wellbeing in Later Life. *Journal of Epidemiology and Community Health*, 66(Suppl 1):A7–A8.
- Gibney, S., Delaney, L., Codd, M., and Fahey, T. (2017). Lifetime childlessness, depressive mood and quality of life among older Europeans. *Social Indicators Research*, 130(1):305–323.
- Giele, J. and Elder Jr, G. (1998). *Methods of life course research: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications.
- Gilbert, N. (2008). *Agent-Based Models*. Sage Publications.
- Gillespie, R. (2003). Childfree and feminine: Understanding the gender identity of voluntarily childless women. *Gender & Society*, 17(1):122–136.
- Glass, J., Simon, R. W., and Andersson, M. A. (2016). Parenthood and happiness: Effects of work-family reconciliation policies in 22 OECD countries. *American Journal of Sociology*, 122(3):886–929.
- Graham, M. (2015). Is being childless detrimental to a woman’s health and well-being across her life course? *Women’s Health Issues*, 25(2):176–184.
- Gustafsson, S. (2001). Optimal age at motherhood: Theoretical and empirical considerations on postponement of maternity in Europe. *Journal of Population Economics*, 14(2):225–247.

- Hadley, R. and Hanley, T. (2011). Involuntarily childless men and the desire for fatherhood. *Journal of Reproductive and Infant Psychology*, 29(1):56–68.
- Hagestad, G. O. and Call, V. R. (2007). Pathways to childlessness: A life course perspective. *Journal of Family Issues*, 28(10):1338–1361.
- Hajnal, J. (1965). European marriage patterns in perspective. In Glass, D. and Eversley, D., editors, *Population in history*. London, United Kingdom: Arnold.
- Hakim, C. (2000). *Work-lifestyle choices in the 21st century: Preference theory*. Oxford, United Kingdom: Oxford University Press.
- Hakim, C. (2003). A new approach to explaining fertility patterns: Preference theory. *Population and Development Review*, 29(3):349–374.
- Hank, K. and Wagner, M. (2013). Parenthood, marital status, and well-being in later life: Evidence from SHARE. *Social Indicators Research*, 114(2):639–653.
- Hansen, T. (2012). Parenthood and happiness: A review of folk theories versus empirical evidence. *Social Indicators Research*, 108(1):29–64.
- Hansen, T., Slagsvold, B., and Moum, T. (2009). Childlessness and psychological well-being in midlife and old age: An examination of parental status effects across a range of outcomes. *Social Indicators Research*, 94(2):343–362.
- Hayford, S. R. (2013). Marriage (still) matters: The contribution of demographic change to trends in childlessness in the United States. *Demography*, 50(5):1641–1661.
- Herbst, C. M. and Ifcher, J. (2016). The increasing happiness of US parents. *Review of Economics of the Household*, 14(3):529–551.
- Holden, K. (2005). Imaginary widows: Spinsters, marriage, and the “lost generation” in Britain after the Great War. *Journal of Family History*, 30(4):388–409.
- Huber, S., Bookstein, F. L., and Fieder, M. (2010). Socioeconomic status, education, and reproduction in modern women: An evolutionary perspective. *American Journal of Human Biology*, 22(5):578–587.
- Huijts, T., Kraaykamp, G., and Subramanian, S. V. (2013). Childlessness and psychological well-being in context: A multilevel study on 24 European countries. *European Sociological Review*, 29(1):32–47.
- Inglehart, R. (1971). The silent revolution in Europe: Intergenerational change in post-industrial societies. *The American Political Science Review*, 65(4):991–1017.
- Inhorn, M. C. and Patrizio, P. (2015). Infertility around the globe: New thinking on gender, reproductive technologies and global movements in the 21st century. *Human Reproduction Update*, 21(4):411–426.
- Jalovaara, M. and Fasang, A. E. (2017). From never partnered to serial cohabitators: Union trajectories to childlessness. *Demographic Research*, 36:1703–1720.
- Jalovaara, M. and Fasang, A. E. (2020). Family life courses, gender, and mid-life earnings. *European Sociological Review*, 36(2):159–178.
- Jalovaara, M., Neyer, G., Andersson, G., Dahlberg, J., Dommermuth, L., Fallesen, P., and Lappegård, T. (2019). Education, gender, and cohort fertility in the Nordic countries. *European Journal of Population*, 35(3):563–586.
- Jeffries, S. and Konnert, C. (2002). Regret and psychological well-being among voluntarily and involuntarily childless women and mothers. *The International Journal of Ageing and Human Development*, 54(2):89–106.
- Kahn, J. R., García-Manglano, J., and Bianchi, S. M. (2014). The motherhood penalty at midlife: Long-term effects of children on women’s careers. *Journal of Marriage and Family*, 76(1):56–72.
- Kalmijn, M. and De Graaf, P. M. (2012). Life course changes of children and well-being of parents. *Journal of Marriage and Family*, 74(2):269–280.
- Karmaus, W., Juul, S., Infertility, E., and Group, S. S. (1999). Infertility and subfecundity in population-based samples from Denmark, Germany, Italy, Poland and Spain. *The European Journal of Public Health*, 9(3):229–235.
- Karra, M., Canning, D., and Wilde, J. (2017). The effect of fertility decline on economic growth in Africa: A macrosimulation model. *Population and Development Review*, 43(S1):237–263.
- Kaufman, G. and Uhlenberg, P. (2000). The influence of parenthood on the work effort of married men and women. *Social Forces*, 78(3):931–947.
- Keim, S. (2011). *Social networks and family formation processes*. Springer.
- Keizer, R. (2010). *Remaining childless: Causes and consequences from a life course perspective*. PhD thesis, Utrecht University.
- Keizer, R., Dykstra, P. A., and Jansen, M. D. (2008). Pathways into childlessness: Evidence of gendered life course dynamics. *Journal of Biosocial Science*, 40(6):863–878.

- Keizer, R., Dykstra, P. A., and Poortman, A.-R. (2009). Life outcomes of childless men and fathers. *European Sociological Review*, 26(1):1–15.
- Keizer, R., Dykstra, P. A., and Poortman, A.-R. (2010). The transition to parenthood and well-being: the impact of partner status and work hour transitions. *Journal of Family Psychology*, 24(4):429–438.
- Keizer, R. and Ivanova, K. (2017). What's a (childless) man without a woman? The differential importance of couple dynamics for the wellbeing of childless men and women in the Netherlands. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 313–330. Springer.
- Keizer, R. and Schenk, N. (2012). Becoming a parent and relationship satisfaction: A longitudinal dyadic perspective. *Journal of Marriage and Family*, 74(4):759–773.
- Kelly, M. (2009). Women's voluntary childlessness: A radical rejection of motherhood? *Women's Studies Quarterly*, 37(2):157–172.
- Kendig, H., Dykstra, P. A., van Gaalen, R. I., and Melkas, T. (2007). Health of ageing parents and childless individuals. *Journal of Family Issues*, 28(11):1457–1486.
- Killewald, A. (2013). A reconsideration of the fatherhood premium: Marriage, coresidence, biology, and fathers' wages. *American Sociological Review*, 78(1):96–116.
- Koert, E. and Daniluk, J. C. (2017). When time runs out: reconciling permanent childlessness after delayed childbearing. *Journal of Reproductive and Infant Psychology*, 35(4):342–352.
- Kohler, H., Behrman, J., and Skytthe, A. (2005). Partner + children = happiness? The effects of partnerships and fertility on well-being. *Population and Development Review*, 31(3):407–445.
- Kohler, H.-P. (2001). *Fertility and social interaction: An economic perspective*. Oxford, United Kingdom: Oxford University Press.
- Kohler, H.-P., Behrman, J. R., and Watkins, S. C. (2001). The density of social networks and fertility decisions: Evidence from South Nyanza District, Kenya. *Demography*, 38(1):43–58.
- Kohler, H.-P., Billari, F. C., and Ortega, J. A. (2002). The emergence of lowest-low fertility in Europe during the 1990s. *Population and Development Review*, 28(4):641–680.
- Kohler, H.-P., Billari, F. C., and Ortega, J. A. (2006). Low fertility in Europe: Causes, implications and policy options. In Harris, F., editor, *The Baby Bust: Who will do the Work? Who Will Pay the Taxes?*, pages 48–109. Lanham, MD: Rowman & Littlefield Publishers.
- Kohler, H.-P. and Mencarini, L. (2016). The parenthood happiness puzzle: An introduction to special issue. *European Journal of Population*, 32(3):327–338.
- Köppen, K., Mazuy, M., and Toulemon, L. (2017). Childlessness in France. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 77–95. Springer.
- Koropeckyj-Cox, T. and Call, V. R. (2007). Characteristics of older childless persons and parents: Cross-national comparisons. *Journal of Family Issues*, 28(10):1362–1414.
- Koropeckyj-Cox, T. and Pendell, G. (2007). Attitudes about childlessness in the United States: Correlates of positive, neutral, and negative responses. *Journal of Family Issues*, 28(8):1054–1082.
- Koropeckyj-Cox, T., Pienta, A. M., and Brown, T. H. (2007). Women of the 1950s and the normative life course: The implications of childlessness, fertility timing, and marital status for psychological well-being in late midlife. *The International Journal of Ageing and Human Development*, 64(4):299–330.
- Kotte, M. and Ludwig, V. (2011). Intergenerational transmission of fertility intentions and behaviour in Germany: The role of contagion. *Vienna Yearbook of Population Research*, 9:207–226.
- Kravdal, Ø. (2001). The high fertility of college educated women in Norway: An artefact of the separate modelling of each parity transition. *Demographic Research*, 5(6):187–216.
- Kreyenfeld, M. and Konietzka, D. (2017a). Childlessness in East and West Germany: Long-Term Trends and Social Disparities. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 97–114. Springer.
- Kreyenfeld, M. and Konietzka, D. (2017b). *Childlessness in Europe: Contexts, Causes, and Consequences*. Springer.
- Kuhnt, A.-K., Kreyenfeld, M., and Trappe, H. (2017). Fertility ideals of women and men across the life course. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 235–251. Springer.
- Kuhnt, A.-K. and Trappe, H. (2016). Channels of social influence on the realization of short-term fertility intentions in Germany. *Advances in Life Course Research*, 27:16–29.
- Larsen, U. (1994). Sterility in sub-Saharan Africa. *Population Studies*, 48(3):459–474.

- Laughlin, L. L. (2010). Who's Minding the Kids? Child Care Arrangements: Spring 2005/Summer 2006. US Census Bureau Current Population Reports. Retrieved from: <https://files.eric.ed.gov/fulltext/ED585393.pdf>.
- Lechner, L., Bolman, C., and van Dalen, A. (2007). Definite involuntary childlessness: associations between coping, social support and psychological distress. *Human Reproduction*, 22(1):288–294.
- Lee, R. and Mason, A. (2014). Is low fertility really a problem? Population aging, dependency, and consumption. *Science*, 346(6206):229–234.
- Lesthaeghe, R. J. (2007). *Second demographic transition*. Wiley Online Library.
- Lesthaeghe, R. J. (2010). The unfolding story of the second demographic transition. *Population and Development Review*, 36(2):211–251.
- Lesthaeghe, R. J. and van de Kaa, D. J. (1986). Twee demografische transitie's. *Bevolking: Groei en Krimp*, pages 9–24.
- Letherby, G. (2002). Childless and bereft?: Stereotypes and realities in relation to 'voluntary' and 'involuntary' childlessness and womanhood. *Sociological Inquiry*, 72(1):7–20.
- Levine, H., Jørgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Mindlis, I., Pinotti, R., and Swan, S. H. (2017). Temporal trends in sperm count: a systematic review and meta-regression analysis. *Human Reproduction Update*, 23(6):646–659.
- Lois, D. and Becker, O. A. (2014). Is fertility contagious? Using panel data to disentangle mechanisms of social network influences on fertility decisions. *Advances in Life Course Research*, 21:123–134.
- Luthar, S. S. and Ciciolla, L. (2016). What it feels like to be a mother: Variations by children's developmental stages. *Developmental Psychology*, 52(1):143.
- Lynch, S. M. and Bartlett, B. (2019). Bayesian Statistics in Sociology: Past, Present, and Future. *Annual Review of Sociology*, 45.
- Lyngstad, T. H. and Prskawetz, A. (2010). Do siblings' fertility decisions influence each other? *Demography*, 47(4):923–934.
- Madsen, J. B., Moslehi, S., and Wang, C. (2017). What Has Driven the Great Fertility Decline in Developing Countries Since 1960? *The Journal of Development Studies*, 54(4):738–757.
- Margolis, R. and Myrskylä, M. (2011). A global perspective on happiness and fertility. *Population and Development Review*, 37(1):29–56.
- Mari, G. (2019). Is there a fatherhood wage premium? A reassessment in societies with strong male-breadwinner legacies. *Journal of Marriage and Family*, 81(5):1033–1052.
- Marmot, M. (2005). Social determinants of health inequalities. *The Lancet*, 365(9464):1099–1104.
- Mastekaasa, A. (1992). Marriage and psychological well-being: Some evidence on selection into marriage. *Journal of Marriage and the Family*, 54(4):901–911.
- Mayer, K. (2004). Whose lives? How history, societies, and institutions define and shape life courses. *Research in Human Development*, 1(3):161–187.
- Mayer, K. U. (2009). New directions in life course research. *Annual Review of Sociology*, 35:413–433.
- Mayer, K. U. and Müller, W. (1986). The state and the structure of the life course. In Sorensen, A., Weinert, F., and Sherrod, L., editors, *Human development and the life course: Multidisciplinary perspectives*, pages 217–245. Erlbaum.
- Mayer, K. U. and Schoepflin, U. (1989). The state and the life course. *Annual Review of Sociology*, 15(1):187–209.
- McDonald, P. (2000a). Gender equality, social institutions and the future of fertility. *Journal of Population Research*, 17(1):1–16.
- McDonald, P. (2000b). Gender equity in theories of fertility transition. *Population and Development Review*, 26(3):427–439.
- McDonald, P. (2008). Very low fertility: Consequences, causes and policy approaches. *Japanese Journal of Population*, 6:19–23.
- McQuillan, J., Greil, A. L., White, L., and Jacob, M. C. (2003). Frustrated fertility: Infertility and psychological distress among women. *Journal of Marriage and Family*, 65(4):1007–1018.
- Meier, A., Musick, K., Flood, S., and Dunifon, R. (2016). Mothering experiences: How single parenthood and employment structure the emotional valence of parenting. *Demography*, 53(3):649–674.
- Mencarini, L. and Tanturri, M. L. (2006). High fertility or childlessness: Micro-level determinants of reproductive behaviour in Italy. *Population*, 61(4):389–415.
- Merz, E.-M. and Liefbroer, A. C. (2012). The attitude toward voluntary childlessness in Europe: Cultural and institutional explanations. *Journal of Marriage and Family*, 74(3):587–600.

- Miettinen, A. (2010). Voluntary or Involuntary Childlessness? Socio-Demographic Factors and Childlessness Intentions among Childless Finnish Men and Women aged 25-44. *Finnish Yearbook of Population Research*, 45:5–24.
- Miettinen, A. and Paajanen, P. (2005). Yes, no, maybe: Fertility intentions and reasons behind them among childless Finnish men and women. *Finnish Yearbook of Population Research*, 41:165–184.
- Miettinen, A., Rotkirch, A., Szalma, I., Donno, A., and Tanturri, M.-L. (2015). Increasing childlessness in Europe: Time trends and country differences. *Families and Societies: Working Paper Series*, 33.
- Miettinen, A. and Szalma, I. (2014). Childlessness intentions and ideals in Europe. *Finnish Yearbook of Population Research*, 49:31–55.
- Mika, T. and Czaplicki, C. (2017). Fertility and women's old-age income in Germany. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 331–349. Springer.
- Mönkediek, B. and Bras, H. A. (2016). The interplay of family systems, social networks and fertility in Europe cohorts born between 1920 and 1960. *Economic History of Developing Regions*, 31(1):136–166.
- Montgomery, M. R. and Casterline, J. B. (1996). Social learning, social influence, and new models of fertility. *Population and Development Review*, 22:151–175.
- Musick, K., Meier, A., and Flood, S. (2016). How parents fare: Mothers' and fathers' subjective well-being in time with children. *American Sociological Review*, 81(5):1069–1095.
- Mynarska, M., Matysiak, A., Rybińska, A., Tocchioni, V., and Vignoli, D. (2015). Diverse paths into childlessness over the life course. *Advances in Life Course Research*, 25:35–48.
- Myrskylä, M. and Goldstein, J. R. (2013). Probabilistic forecasting using stochastic diffusion models, with applications to cohort processes of marriage and fertility. *Demography*, 50(1):237–260.
- Myrskylä, M. and Margolis, R. (2014). Happiness: Before and after the kids. *Demography*, 51(5):1843–1866.
- Nelson, S. K., Kushlev, K., English, T., Dunn, E. W., and Lyubomirsky, S. (2013). In defense of parenthood: Children are associated with more joy than misery. *Psychological Science*, 24(1):3–10.
- Neppl, T. K., Senia, J. M., and Donnellan, M. B. (2016). Effects of economic hardship: Testing the family stress model over time. *Journal of Family Psychology*, 30(1):12.
- Neyer, G., Hoem, J. M., and Andersson, G. (2017). Education and Childlessness: The Influence of Educational Field and Educational Level on Childlessness among Swedish and Austrian Women. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 183–207. Springer.
- Nomaguchi, K. and House, A. N. (2013). Racial-ethnic disparities in maternal parenting stress: The role of structural disadvantages and parenting values. *Journal of Health and Social Behavior*, 54(3):386–404.
- Nomaguchi, K. and Milkie, M. A. (2017). Sociological perspectives on parenting stress: How social structure and culture shape parental strain and the well-being of parents and children. In Keater-Deckard, K. and Panneton, R., editors, *Parental stress and early child development*, pages 47–73. Springer.
- Nomaguchi, K. and Milkie, M. A. (2020). Parenthood and well-being: A decade in review. *Journal of Marriage and Family*, 82(1):198–223.
- Nomaguchi, K. M. (2012). Parenthood and psychological well-being: Clarifying the role of child age and parent-child relationship quality. *Social Science Research*, 41(2):489–498.
- Noordhuizen, S., de Graaf, P., and Sieben, I. (2010). The public acceptance of voluntary childlessness in the Netherlands: From 20 to 90 per cent in 30 years. *Social Indicators Research*, 99(1):163–181.
- Offer, S. and Schneider, B. (2011). Revisiting the gender gap in time-use patterns: Multitasking and well-being among mothers and fathers in dual-earner families. *American Sociological Review*, 76(6):809–833.
- Oppenheimer, V. K. (1994). Women's rising employment and the future of the family in industrial societies. *Population and Development Review*, 20(2):293–342.
- Orgad, S. (2019). *Heading home: Motherhood, work, and the failed promise of equality*. New York, NY: Columbia University Press.
- Organisation for Economic Co-operation and Development [OECD] (2015). Sf2.5. childlessness. OECD - Social Policy Division - Directorate of Employment, Labour and Social Affairs. Retrieved from https://www.oecd.org/els/family/SF_2-5-Childlessness.pdf.

- Park, K. (2005). Choosing childlessness: Weber's typology of action and motives of the voluntarily childless. *Sociological Inquiry*, 75(3):372–402.
- Parliament of the United Kingdom (2015). Challenges of an ageing population. Retrieved from: <https://www.parliament.uk/business/publications/research/key-issues-parliament-2015/social-change/ageing-population/>.
- Payne, N., Seenan, S., and van den Akker, O. (2019). Experiences of involuntary childlessness and treatment in the UK: what has changed in 20 years? *Human Fertility*, 24(5):333–340.
- Pink, S., Leopold, T., and Engelhardt, H. (2014). Fertility and social interaction at the workplace: Does childbearing spread among colleagues? *Advances in Life Course Research*, 21:113–122.
- Plotnick, R. D. (2009). Childlessness and the economic well-being of older Americans. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 64(6):767–776.
- Poole, E., Speight, S., O'Brien, M., Connolly, S., and Aldrich, M. (2016). Who are non-resident fathers? A British socio-demographic profile. *Journal of Social Policy*, 45(2):223–250.
- Poston, Jr., D. L., Kramer, K. B., Trent, K., and Yu, M.-Y. (1983). Estimating voluntary and involuntary childlessness in the developing countries. *Journal of Biosocial Science*, 15(4):441–452.
- Poston, Jr., D. L. and Trent, K. (1982). International variability in childlessness: A descriptive and analytical study. *Journal of Family Issues*, 3(4):473–491.
- Raab, M. and Struffolino, E. (2020). The heterogeneity of partnership trajectories to childlessness in Germany. *European Journal of Population*, 36(1):53–70.
- Rendall, M., Aracil, E., Bagavos, C., Couet, C., DeRose, A., DiGiulio, P., Lappegard, T., Robert-Bobée, I., Rønsen, M., Smallwood, S., and Verropoulou, G. (2010). Increasingly heterogeneous ages at first birth by education in Southern European and Anglo-American family-policy regimes: A seven-country comparison by birth cohort. *Population Studies*, 64(3):209–227.
- Richter, N., Lois, D., Arránz Becker, O., and Kopp, J. (2012). Mechanismen des Netzwerkeinflusses auf Fertilitätsentscheidungen in Ost- und West-Deutschland [Mechanisms of social network influences on fertility decisions in East and West Germany]. In Huinink, J., Kreyenfeld, M., and Trappe, H., editors, *Special Issue 2012 of Journal of Family Research-Zeitschrift für Familienforschung*, pages 95–118. Verlag Barbara Budrich.
- Rijken, A. J. and Merz, E.-M. (2014). Double standards: Differences in norms on voluntary childlessness for men and women. *European Sociological Review*, 30(4):470–482.
- Rindfuss, R. R. and Bumpass, L. L. (1976). How old is too old? Age and the sociology of fertility. *Family Planning Perspectives*, 8(5):226–230.
- Rooney, K. L. and Domar, A. D. (2018). The relationship between stress and infertility. *Dialogues in Clinical Neuroscience*, 20(1):41.
- Rotkirch, A. and Miettinen, A. (2017). Childlessness in Finland. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 139–158. Springer.
- Rowland, D. (1998). Consequences of childlessness in later life. *Australasian Journal on Ageing*, 17(1):24–28.
- Rowland, D. T. (2007). Historical trends in childlessness. *Journal of Family Issues*, 28(10):1311–1337.
- Ruppanner, L., Perales, F., and Baxter, J. (2019). Harried and unhealthy? Parenthood, time pressure, and mental health. *Journal of Marriage and Family*, 81(2):308–326.
- Rutstein, S. O. and Shah, I. H. (2004). Infecundity infertility and childlessness in developing countries. DHS Comparative Reports. Retrieved from: <https://dhsprogram.com/pubs/pdf/CR9/CR9.pdf>.
- Rybińska, A. and Morgan, S. P. (2019). Childless expectations and childlessness over the life course. *Social Forces*, 97(4):1571–1602.
- Saez, E. and Zucman, G. (2016). Wealth inequality in the United States since 1913: Evidence from capitalized income tax data. *The Quarterly Journal of Economics*, 131(2):519–578.
- Schaeper, H., Grotheer, M., and Brandt, G. (2017). Childlessness and fertility dynamics of female higher education graduates in Germany. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 209–232. Springer.
- Schoon, I., Chen, M., Kneale, D., and Jager, J. (2012). Becoming adults in Britain: lifestyles and wellbeing in times of social change. *Longitudinal and Life Course Studies*, 3(2):173–189.
- Schoumaker, B. (2019). Male Fertility around the World and over Time: How Different is it from Female Fertility. *Population and Development Review*, 45(3):459–487.
- Seiz, M. (2013). Voluntary childlessness in southern Europe: The case of Spain. *Population Review*, 52(1).

- Shkolnikov, V. M., Andreev, E. M., Houle, R., and Vaupel, J. W. (2007). The concentration of reproduction in cohorts of women in Europe and the United States. *Population and Development Review*, 33(1):67–99.
- Simon, R. W. and Caputo, J. (2019). The costs and benefits of parenthood for mental and physical health in the United States: The importance of parenting stage. *Society and Mental Health*, 9(3):296–315.
- Simpson, R. (2007). Defying Nature? Contemporary Discourses around Delayed Childbearing and Childlessness in Britain. *GeNet Seminar: Low Fertility in Industrialised Countries*, London School of Economics.
- Singh, B. K. and Williams, J. S. (1981). Childlessness and family satisfaction. *Research on Ageing*, 3(2):218–227.
- Sobotka, T. (2004). *Postponement of childbearing and low fertility in Europe*. Amsterdam, the Netherlands: University Press Amsterdam.
- Sobotka, T. (2009). Sub-replacement fertility intentions in Austria. *European Journal of Population/Revue européenne de Démographie*, 25(4):387–412.
- Sobotka, T. (2017). Childlessness in Europe: Reconstructing long-term trends among women born in 1900–1972. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 17–53. Springer.
- Sobotka, T. (2020). Introduction: the relevance of studying fertility across time and space. *Vienna Yearbook of Population Research*, 18:1–24.
- Sobotka, T., Matysak, A., and Brzozowska, Z. (2020). Policy Responses to Low Fertility: How Effective Are They? New York, NY: UNFPA, Working Paper No. 1. Retrieved from: https://www.unfpa.org/sites/default/files/pub-pdf/Policy_responses_low_fertility_UNFPA_WP_Final_corrections_7Feb2020_CLEAN.pdf.
- Spence, N. J. (2008). The long-term consequences of childbearing: physical and psychological well-being of mothers in later life. *Research on Aging*, 30(6):722–751.
- Stegen, H., Switsers, L., and De Donder, L. (2020). Life stories of voluntarily childless older people: A retrospective view on their reasons and experiences. *Journal of Family Issues*, 42(7):1536–1558.
- Surkyn, J. and Lesthaeghe, R. (2004). Value orientations and the second demographic transition (SDT) in Northern, Western and Southern Europe: An update. *Demographic Research*, 3:45–86.
- Szalma, I. and Takács, J. (2015). Who remains childless? Unrealised fertility plans in Hungary. *Czech Sociological Review*, 51(6):1047–1076.
- Székely, Á. and Székely, T. (2012). Human behaviour: Sex ratio and the city. *Current Biology*, 22(17):R684–R685.
- Tanaka, K. and Johnson, N. E. (2016). Childlessness and mental well-being in a global context. *Journal of Family Issues*, 37(8):1027–1045.
- Tanturri, M. L. and Mencarini, L. (2008). Childless or childfree? Paths to voluntary childlessness in Italy. *Population and Development Review*, 34(1):51–77.
- Tanturri, M. L., Mills, M., Rotkirch, A., Sobotka, T., Takács, J., Miettinen, A., Faludi, C., Kantsa, V., and Nasiri, D. (2015). State-of-the-art report: Childlessness in Europe. *Families and Societies*, 32:1–53.
- Testa, M. R. (2012). Family sizes in Europe: Evidence from the 2011 Eurobarometer survey. Technical report, European Demographic Research Papers 2. Vienna: Vienna Institute of Demography of the Austrian Academy of Sciences.
- The World Bank (2018). Fertility rate, total (births per woman) - Sub-Saharan Africa. Retrieved from: <https://data.worldbank.org/indicator/SP.DYN.TFRT.IN?locations=ZG>.
- Twenge, J. M., Campbell, W. K., and Foster, C. A. (2003). Parenthood and marital satisfaction: A meta-analytic review. *Journal of Marriage and Family*, 65(3):574–583.
- Ugur, Z. B. (2020). Does having children bring life satisfaction in Europe? *Journal of Happiness Studies*, 21(4):1385–1406.
- Umberson, D., Pudrovska, T., and Reczek, C. (2010). Parenthood, childlessness, and well-being: A life course perspective. *Journal of Marriage and Family*, 72(3):612–629.
- United Nations (2012). World Fertility Report: 2012. United Nations Department of Economic and Social Affairs Population Division. Retrieved from https://www.un.org/en/development/desa/population/publications/dataset/fertility/wfr2012/WFR_2012/Report_WFR2012.pdf.
- United Nations Population Division (2017). Government policies to raise or lower the fertility level. Retrieved from: https://www.un.org/en/development/desa/population/publications/pdf/popfacts/PopFacts_2017-10.pdf.

- van Agtmaal-Wobma, E. and van Huis, M. (2008). De relatie tussen vruchtbaarheid en opleidingsniveau van de vrouw [the relationship between fertility and educational level of women]. *Bevolkingstrends*, 56(2):32–41.
- van Balen, F. (2008). Involuntary childlessness: A neglected problem in poor-resource areas. *ESHRE Monographs*, 2008(1):25–28.
- van Balen, F. and Bos, H. M. (2009). The social and cultural consequences of being childless in poor-resource areas. *Facts, Views & Vision in ObGyn*, 1(2):106.
- van Bavel, J. (2012). The reversal of gender inequality in education, union formation, and fertility in Europe. *Vienna Yearbook of Population Research*, 10:127–154.
- van Bavel, J. and Kok, J. (2010). Pioneers of the modern lifestyle?: Childless couples in the early-twentieth-century Netherlands. *Social Science History*, 34(1):47–72.
- van Bavel, J. and Reher, D. S. (2013). The baby boom and its causes: What we know and what we need to know. *Population and Development Review*, 39(2):257–288.
- van de Kaa, D. J. (1996). Anchored narratives: The story and findings of half a century of research into the determinants of fertility. *Population Studies*, 50(3):389–432.
- van de Kaa, D. J. (1997). Options and sequences: Europe’s demographic patterns. *Journal of Population Research*, 14(1):1–29.
- van de Kaa, D. J. (2001). Postmodern fertility preferences: From changing value orientation to new behavior. *Population and Development Review*, 27:290–331.
- Van Winkle, Z. and Fasang, A. E. (2020). Parenthood wage gaps across the life course: A comparison by gender and race. *Journal of Marriage and Family*, 82(5):1515–1533.
- Vikström, J., Bladh, M., Hammar, M., Marcusson, J., Wressle, E., and Sydsjö, G. (2011). The influences of childlessness on the psychological well-being and social network of the oldest old. *BMC Geriatrics*, 11(1):78.
- Vitzthum, V. J. (2008). Evolutionary models of women’s reproductive functioning. *Annual Review of Anthropology*, 37:53–73.
- Wagner, M., Huinink, J., and Liefbroer, A. C. (2019). Running out of time? Understanding the consequences of the biological clock for the dynamics of fertility intentions and union formation. *Demographic Research*, 40:1–26.
- Wenger, G. C. (2009). Childlessness at the end of life: evidence from rural Wales. *Ageing and Society*, 29(8):1243–1259.
- Wenger, G. C., Dykstra, P. A., Melkas, T., and Knipscheer, K. C. (2007). Social embeddedness and late-life parenthood: Community activity, close ties, and support networks. *Journal of Family Issues*, 28(11):1419–1456.
- White, L. K. and McQuillan, J. (2006). No longer intending: The relationship between relinquished fertility intentions and distress. *Journal of Marriage and Family*, 68(2):478–490.
- Wilensky, U. and Rand, W. (2015). *An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo*. Cambridge, MA: MIT Press.
- Yu, S. M. and Singh, G. K. (2012). High parenting aggravation among US immigrant families. *American Journal of Public Health*, 102(11):2102–2108.
- Zhang, W. and Liu, G. (2007). Childlessness, psychological well-being, and life satisfaction among the elderly in China. *Journal of Cross-Cultural Gerontology*, 22(2):185–203.
- Zhang, Z. and Hayward, M. D. (2001). Childlessness and the psychological well-being of older persons. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 56(5):S311–S320.

Chapter 2

Childlessness and Development in sub-Saharan Africa: Is There Evidence for a U-shaped Pattern?¹

Abstract

In high-income countries, women increasingly remain permanently childless. Little is known about the relationship between childlessness and socio-economic development in non-Western societies and particularly sub-Saharan Africa. At lower levels of development, poverty-driven (i.e. involuntary) childlessness may decrease with increasing levels of development, while at higher levels of development opportunity-driven (i.e. voluntary and circumstantial) childlessness may rise with development. Thus, we expect a U-shaped relationship between childlessness and development overall. We examine this idea for sub-Saharan Africa. We further contribute by differentiating between female and male childlessness, and between involuntary, voluntary and circumstantial childlessness. Moreover, we construct new indicators of subnational historical development to assess both inter- and intra-country variation, and distinguish between three development components (health, education and income) to investigate the drivers behind the hypothesised U-shaped relationship. Using 291 Demographic and Health Surveys between 1986 and 2018 from 38 countries and 384 regions, we find a U-shaped relationship between female childlessness and development, and a linear relationship for men. These relationships result from negative associations, albeit only for women, of involuntary childlessness with health and education; in conjunction with positive associations of voluntary and circumstantial childlessness with education and income, which are particularly strong amongst men. Besides development indicators, marriage systems and polygyny associate with childlessness levels. Our findings have implications for how we might expect childlessness rates to evolve with future levels of development.

Keywords Childlessness · Development · Sub-Saharan Africa · Demographic and Health Surveys · Fertility

¹A version of this chapter has been published as: Verkroost, F. C. J. & Monden, C. W. S. (2022). Childlessness and Development in Sub-Saharan Africa: Is There Evidence for a U-shaped Pattern? *European Journal of Population*, 38(8), 319–352. DOI: <https://doi.org/10.1007/s10680-022-09608-5>. This chapter is co-authored with Christiaan Monden; see Appendix 2.A for the authorship statement.

2.1 Introduction

Substantial increases in permanent childlessness have gained growing interest from researchers and policy makers over the past decades. This interest has mainly been expressed for developed regions such as Europe and the United States (see for instance Frejka, 2017; Kreyenfeld and Konietzka, 2017). However, childlessness in less developed regions, and sub-Saharan Africa in particular, has hardly been investigated. One reason for this is that fertility rates have historically been high in sub-Saharan Africa, equal to almost seven births per woman on average in 1980 (The World Bank, 2018). Although fertility rates have been decreasing in the region, they still equal almost twice the replacement level at an average of five births per woman in 2017. These high fertility rates have led to the assumption that childlessness is not significant in the region. While women in sub-Saharan Africa still have relatively many children on average, there is also a substantial number of women who never have children (Bongaarts and Castlerline, 2013; Inhorn and Patrizio, 2015; Larsen, 1994). This is particularly problematic as poverty may be the strongest driver of childlessness in sub-Saharan Africa (Baudin et al., 2020). Additionally, severe stigma and consequences are often attached to childlessness in the region, sometimes resulting in social exclusion, ostracism, divorce and abuse (Inhorn and Patrizio, 2015).

To better understand the extent to which childlessness can be viewed as a response to structural socio-economic conditions, we examine how childlessness varies across levels of socio-economic development. In the early 1980s, Poston Jr. and colleagues (Poston et al., 1985; Poston and El-Badry, 1987; Poston and Trent, 1982) hypothesised that there is an association between development and the share of individuals who do not have children before the end of the (female) reproductive period. According to these researchers, the nature of this association changes with the level of development, resulting in a U-shaped relationship. This hypothesis has been investigated previously for the United States and several developing (of which 14 sub-Saharan African) countries (Baudin et al., 2020, 2015). However, in these studies different reasons for childlessness are predicted from an economic model based on a set of assumptions about childbearing conditions. Such indirect estimates may carry substantial uncertainty, which is why we deduce childlessness types from questions in the data directly. Furthermore, Baudin et al. (2020, 2015) use education as a proxy for development. However, we expect there to be heterogeneity in the distribution of development across its main components (Permanyer et al., 2015). More importantly, specific dimensions of development may influence various types of childlessness differently. For example, health might be more strongly related to involuntary childlessness while education might be more influential for voluntary childlessness (Poston and Trent, 1982). Therefore, we consider development across its three domains of health, education and income. Finally, in the aforementioned studies (Baudin et al., 2020, 2015), the macro-level hypotheses are investigated on the national level. Nonetheless, levels of

development vary significantly within countries, and particularly low- and middle-developed countries (Permanyer and Smits, 2020). To ensure this variation is not lost we investigate these hypotheses on the subnational level.

In this study, we aim to fill the gaps in the literature by answering the following three questions for sub-Saharan Africa. First, how are permanent childlessness and indicators of development at the subnational level related? Second, how does this association differ across types of childlessness (i.e. involuntary, voluntary and circumstantial childlessness)? Third, are there gender differences with respect to the first two questions? We answer these questions by using hierarchical models in conjunction with data from 291 Demographic and Health Surveys collected between 1986 and 2018 throughout 38 sub-Saharan African countries and 384 subnational regions. We exploit various other data sets to construct innovative historical subnational-level development indicators and take into account other factors that may be related to childlessness, such as HIV prevalence and marriage market sex ratios. We define permanent childlessness as the percentage of individuals in a region-year combination that ‘have never born any children before reaching age 40’. That means that all infertile individuals, even those who have adopted children or have stepchildren, are classified as childless and that individuals whose only child or children died young are not defined as childless. In our framework, involuntary childlessness is due to infertility,² voluntary childlessness refers to the choice not to have children, and circumstantial childlessness is a consequence of not having (had) a partner to have children with.

The contribution of our study is fourfold. First, we provide a comprehensive overview of childlessness levels across sub-Saharan Africa and how these levels relate to development indicators. Previous research has shed light on the relationship between development and childlessness at lower levels of development by examining a limited selection of low-income countries in Asia, Central and Latin America and sub-Saharan Africa. These studies found support for the hypothesis that development is negatively related with involuntary childlessness and positively related with voluntary childlessness (Baudin et al., 2020; Poston et al., 1985; Poston and El-Badry, 1987; Poston and Trent, 1982). However, to date very little is known about the association between childlessness and development across the whole of sub-Saharan Africa, a region that has seen substantial improvement in development over the last decades. In this study, we shed more light on this association.

Second, by exploiting comparative data with large sample sizes, we can distinguish between involuntary, voluntary and circumstantial childlessness in the relationship with development. We may expect the association with development to be negative for involuntary childlessness due to reductions in poverty

²In this study, we define infertility as “the inability to bear any children, either due to the inability to conceive or the inability to carry a pregnancy to a live birth” (Rutstein and Shah, 2004, p. 3).

and poor health, but positive for voluntary and circumstantial childlessness due to economic and educational expansion, individualisation and changing norms on family formation, resulting in a U-shaped relationship between overall levels of childlessness and development (Baudin et al., 2020; Poston et al., 1983). To understand the drivers and mechanisms behind the potentially U-shaped relationship between overall childlessness and development, it is crucial to distinguish between different types of childlessness. However, hardly anything is currently known about the association between development and different types of childlessness in sub-Saharan Africa, as the main focus has always been on infertility (e.g. Casteline and Han, 2017; Inhorn and Patrizio, 2015; Larsen, 2000, 2003; Mascarenhas et al., 2012; Rutstein and Shah, 2004). Poston et al. (1983) have tried to distinguish between voluntary and involuntary female childlessness in Lesotho and Kenya, but their samples were too small to draw robust conclusions. Baudin et al. (2020) have also aimed to distinguish between poverty- and opportunity-driven childlessness, but by predicting these indicators from economic models rather than estimating them from available data directly. By constructing a decision tree and exploiting the richness of the DHS, we are able to examine different types of childlessness besides infertility.

Third, we construct completely new historical indicators for development components at the subnational level. This allows us to study the relationship between childlessness and development across a wider range of development than ever before. Not only does the distribution of development vary across its components (i.e. education, health and income), there is also substantial variation in development levels between and within countries (Permanyer et al., 2015). These sources of heterogeneity in development occur particularly in low- and middle-developed countries (Permanyer and Smits, 2020), and this variation is lost in most macro-level studies. By harmonising subnational information in our data and recovering historical indexes of development at the subnational level, we can examine not only inter- but also intra-country variation in childlessness and development.

Fourth, we analyse women and men separately to examine whether gender differences exist in the relationships between types of childlessness and indicators of development. For example, (female) educational and occupational attainment as well as autonomy increases with higher levels of development (World Economic Forum, 2018). As a result, voluntary childlessness may become more attractive for women in particular because of the increased opportunity cost of having children (Becker, 1960; Neyer et al., 2017). On the other hand, men may increasingly remain childless by circumstance as a consequence of being left behind on largely hypergamous mating markets (Kreyenfeld and Konietzka, 2017). Very little is currently known about male childlessness in sub-Saharan Africa, as female surveys have been collected for a longer period of time and childlessness research usually focused on females (Dyer et al., 2004). We aim to fill this gap by including men in our analyses.

2.2 U-shape of Childlessness and Development

In this section we discuss mechanisms at play in the relationship between (different indicators of) development and (different types of) childlessness. Some of these mechanisms concern factors that affect childlessness directly; others may have indirect effects as intentions for a smaller family size may lead to childlessness through childbirth postponement (Burkimsher and Zeman, 2017; Madsen et al., 2017).

At the lowest levels of development, childlessness is mainly caused by poverty-driven infertility (Baudin et al., 2020; Poston and Trent, 1982). Although fertility rates have generally been high in sub-Saharan Africa, infertility has also been prevalent (Bongaarts and Casterline, 2013). Infertility or involuntary childlessness may derive from for example malnutrition, famine, disease (mainly sexually transmitted or pelvic inflammatory), female circumcision, exposure to chemicals and radiation or a lack of good pre-, ante-, and post-natal care (in the case of secondary infertility) (Larsen, 1994; Poston et al., 1983). Increases in development in terms of nutrition as well as medical expertise and expenditure reduce the prevalence of poverty-driven infertility through better prevention and treatment of diseases and other health problems (Inhorn and Patrizio, 2015). With growing medical expertise and expenditure we also expect to see increasing usage of medically assisted reproduction (MAR), which will reduce infertility rates directly, and also indirectly by assuring positive birth outcomes despite postponement of childbearing (Casterline and Han, 2017; Marmot, 2005). Although the influence of MAR on childlessness levels may still be negligible in sub-Saharan Africa, given that these technologies have remained largely inaccessible throughout the region (Inhorn and Patrizio, 2015), it may be of increasing relevance for some of the most highly developed areas in our study.

At higher levels of development, especially driven by educational attainment and economic well-being, we might expect a larger contribution of voluntary and circumstantial childlessness to overall levels of childlessness (Poston and Trent, 1982). Sub-Saharan Africa has seen an increase in overall gender equality, also in terms of economic opportunity and educational attainment (World Economic Forum, 2018). These improvements are expected to be positively related to childlessness through two mechanisms. First, according to the ideas of Becker (1981), the quality of children is larger at higher levels of economic well-being, which results in a lower demand for children. Lower fertility intentions may result in childbirth postponement, which may in turn lead to age-related infertility or the choice to forego having children (Burkimsher and Zeman, 2017; Madsen et al., 2017). Second, higher levels of development come with higher levels of female educational and occupational attainment. On the one hand, this phenomenon drives voluntary childlessness particularly amongst women through increased opportunity cost of having children (Neyer et al., 2017), higher levels of autonomy and self-sustenance (Oppenheimer, 1994) and more diverse life opportunities (Rindfuss and Bumpass, 1976; Surkyn and

Lesthaeghe, 2004; van de Kaa, 1996). On the other hand, this process may increasingly leave men childless by circumstance, as they are left behind on the mating market (Kreyenfeld and Konietzka, 2017). That is, women tend to marry men with similar (homogamy) or higher (hypergamy) levels of education while men tend to marry women who are at most as highly educated as themselves (hypogamy), which may lead to an imbalance in the marriage market (Chudnovskaya, 2019; van Bavel, 2012). Although this mechanism may not be commonly in place in sub-Saharan Africa (yet), it could play a role in some of the most highly developed urban areas.

Further, higher levels of development, particularly through educational expansion, bring exposure to global culture, which may affect cultural norms and values about family formation and childbearing. In sub-Saharan Africa, there is a strong desire for children and childbearing has been nearly universal (Bongaarts and Casterline, 2013). There is a strong stigma associated to remaining childless, often resulting in social exclusion, divorce and abuse (Inhorn and Patrizio, 2015). Nevertheless, with increases in development sub-Saharan Africa has also seen increases in ages at first marriage (Shapiro and Gebreselassie, 2014), divorce (Clark and Brauner-Otto, 2015), fertility postponement (Moultrie et al., 2012), contraceptive use (Tsui et al., 2017) and cohabitation (Odimegwu et al., 2018) and a decline in the total fertility rate (Bongaarts and Casterline, 2013). Although this does not necessarily mean that we should expect patterns of fertility and family behaviour to simply follow a path of convergence to patterns observed in high-income countries (Pesando and GFC team, 2018; Thornton, 2013), these observed transitions may come with increased desires for feminism, autonomy and individualism. As a consequence, the concept of ‘childfree’ lives may emerge (Beaujouan et al., 2016; Letherby, 2002), whereby desires for recreational and luxurious opportunities can be met without the burden of children (van Bavel and Kok, 2010). This may also lead to postponement in marriage and childbearing, increasing the share of people foregoing having children (Burkimsher and Zeman, 2017; Madsen et al., 2017). With such shifts in cultural values, voluntary and circumstantial childlessness may become not only more prevalent but also more socially accepted (Burkimsher, 2014; van Balen, 2008; van Balen and Bos, 2009).

Summarising, we might expect that involuntary childlessness is negatively associated with development, and voluntary and circumstantial childlessness are positively associated with development (Poston and Trent, 1982). Involuntary childlessness is expected to contribute most strongly to overall childlessness levels at lower levels of development, while at higher levels of development voluntary and circumstantial childlessness are expected to drive overall childlessness levels (Baudin et al., 2020). Therefore, we hypothesise that childlessness declines with development at lower levels of development and increases with development at higher levels of development, resulting in a U-shaped relationship between childlessness and development (see Figure 2.1). Table 2.1 sums up expectations and mechanisms for the three different components of development by childlessness type. In our analyses, we first investigate whether

there is indeed a U-shape between overall levels of childlessness and overall levels of development, and then split childlessness into its different types (i.e. involuntary, voluntary and circumstantial) and development into its different components (i.e. health, education and income) to identify potential mechanisms operating behind this U-shape.

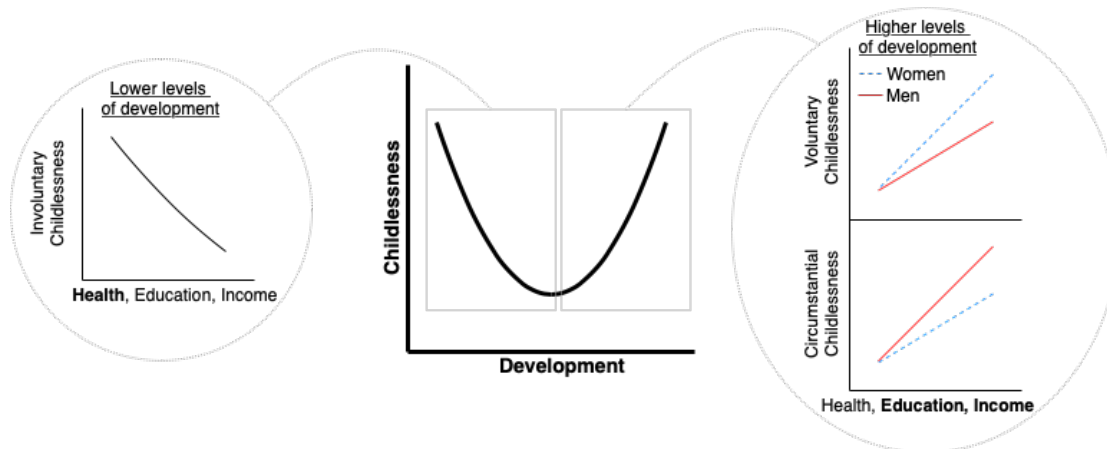


Figure 2.1: Overview of hypotheses regarding the relationship between childlessness types and components of development

Table 2.1: Overview of hypotheses regarding the relationship between childlessness types and indicators of development

Childlessness type	development indicator	Relationship	Development level	Mechanism(s)	Gender difference
Involuntary	Health	Negative	Lower	Better prevention and treatment of disease; more access to medically assisted reproductive technologies; more reassurance of positive birth outcomes	None
	Education			Indirect: more educational expertise and skills improve medical technologies and health(care), in turn increasing fertility	
	Income			Indirect: higher income improves nutrition and expenditure on health-relevant products, in turn increasing fertility	
Voluntary	Health	Positive	Higher	More control over (postponing) childbearing through contraception; lower child mortality and thus desire for children	Stronger for women
	Education			Changing family values; marriage and childbirth postponement; increased opportunity cost of children; higher quality of and thus lower demand for children; more diverse life opportunities besides family care	
	Income				
Circumstantial	Health	Positive	Higher	Less distorted marriage market sex ratios as consequence of epidemics (particularly HIV/AIDS)	Stronger for men
	Education			Changing family values; marriage and childbirth postponement; more competition amongst women for highly educated men	
	Income				

We need to consider two phenomena in our analyses that are particularly relevant to sub-Saharan Africa: polygyny and HIV. Although the prevalence of polygyny and HIV are not homogeneous across the region and both have started to decrease over the past years (Fenske, 2015; Steinbrook, 2008), they

may still be relevant for childlessness. Polygyny prevalence and overall childlessness may be expected to be negatively associated, because polygyny has been shown to increase both aggregate and individual fertility via fertility contagion and rising marriage rates (Cahu et al., 2014). The influence of polygyny prevalence on childlessness may be different for men and women, however. On the one hand, polygyny may decrease male childlessness through increased fertility via higher chances of pregnancy with multiple wives (Cahu et al., 2014; Musham, 1956; Rossi, 2019; Schoumaker, 2019). On the other hand, female childlessness is likely higher in regions where polygyny is high, mainly because of lower frequency of sexual intercourse, higher chances of venereal diseases, and the selection of infertile women into polygynous unions (i.e. female infertility incentivises husbands to practice polygyny) (Cahu et al., 2014; Lardoux and van de Walle, 2003; Musham, 1956). Further, we may expect that higher HIV prevalence increases childlessness and reduces fertility, especially in the presence of other sexually transmitted diseases (van Leeuwen et al., 2006). As HIV is more prevalent amongst (young) women in the region and may lead to AIDS and eventually death when left untreated (Hegdahl et al., 2016), HIV epidemics may lead to shortages of women on the marriage market and potentially a larger share of men remaining unmarried and childless.

2.3 Data

We use the Demographic and Health Surveys (DHS) Program data (ICF International, 2019). Note that we do not make use of the World Fertility Surveys as their sample sizes are too small for the purposes of our subnational-level analyses. The main advantages of the DHS for our purpose are the large sample sizes; the availability of both male and female surveys; and the possibility to assess inter- and intra-country differences in childlessness. As only a relatively small percentage of the population will remain permanently childless, large sample sizes are necessary to be able to draw reliable conclusions for this small group of the population. Comparability across countries and subnational regions provides us with the necessary variability in development needed for our analyses and also allows us to study differences across and within countries in the associations between types of childlessness and development.

We use data from all DHS surveys for sub-Saharan Africa that have information on childbirth and marital status as well as sufficient information on subnational regions to harmonise these subnational regions over time. We do not consider surveys that only interviewed ever-married women and men. A total of 291 individual-level (169 female and 122 male) surveys conducted between 1986 and 2018 throughout 38 sub-Saharan African countries and 384 subnational regions met these criteria. These 291 surveys are comprised of 255 standard DHS surveys, 27 Malaria Indicators Surveys (MIS) and 9 AIDS Indicator Surveys (AIS). A list of countries with sample sizes before and after data operationalisation is

included in 2.B.1 in Appendix 2.B. More information on all DHS surveys in our analysis can be found in Figure 2.C.1 in Appendix 2.C.

2.3.1 Aggregation

We aggregate the individual-level data in the DHS surveys to country- and subnational region-level data. Our main units of analysis are region-year combinations. We select individuals aged 40 and older because we aim to study permanent childlessness. The upper age limit for interviews is 49 for most female surveys and 59 for men. Two female and nine male surveys interviewed respondents up to age 64.³ While some men and women will have their first child after age 40, this group is very small (see Figure 2.E.1 in Appendix 2.E). Although a cut-off at age 40 might slightly overestimate childlessness, setting a higher cut-off age (e.g. 45) would limit the sample size too much and result in inaccurate estimates. Using the lower bound of 40 for both women and men therefore allows us to study permanent childlessness while maximising our sample size.

Our individual-level sample includes 269,514 women and 136,748 men. We have 1,749 subnational region-year combinations for women with an average sample size of 154 women. Each subnational region on average has 4.6 observations (i.e. years) ranging between 1986 and 2018. The rounded average most recent year of observation is 2014. For men, there are 1,213 subnational region-year combinations with an average sample size of 113 men. The average number of observations (i.e. years) per subnational region is 3.3. The years of observations vary between 1991 and 2018. The average most recent year of observation is 2013. Figure 2.F.1 in Appendix 2.F shows childlessness levels by sample size. Table 2.2 shows the descriptive statistics for our sample.

In the upcoming sections, it is important to keep in mind that indicators for development as well as HIV prevalence and marriage market sex balance are lagged to reflect the year in which the average age of the respondents in the region-year combination would have been 19 for women and 24 for men. These factors mostly play a role for childlessness during partnership formation and the early childbearing ages, and not so much after age 40 when the respondents are interviewed. We choose ages 19 for women and 24 for men, because these are the median childbearing ages in our samples, corresponding to the numbers found by [Dunlop et al. \(2018\)](#); [Westoff \(2003\)](#).

2.3.2 Childlessness

Our dependent variable represents the percentage of childless individuals aged 40+ in a particular subnational region-year combination. This variable has been constructed by aggregating individual-level

³The age distributions for women and men per country are shown in Figure 2.D.1 in Appendix 2.D.

Table 2.2: Descriptive statistics for subnational regional-level data

	Men				Women			
	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
Number of individuals	112.735	118.264	2	1552	154.096	166.659	1	2950
Average age at first birth	26.827	2.546	20.943	60	23.042	7.627	15.182	43.250
Average age at first marriage/cohabitation	25.546	2.308	19.250	37	18.808	2.260	12.286	27.826
Average age at first sex	19.878	2.187	14.699	28.077	16.962	1.408	12.833	22.091
HIV prevalence (%)	0.652	1.138	0	11.200	2.288	3.398	0	28.400
Number of women per 100 men	100.508	3.827	89.968	117.813	100.182	3.434	89.107	120.045
Urban residence (%)	31.318	24.761	0	100	30.973	24.667	0	100
Polygyny prevalence (%)	21.229	15.169	0	100	34.225	19.887	0	100
Year	2005.655	7.379	1991	2018	2006.17	8.243	1986	2018
Average age	47.440	2.334	41	59.567	43.987	0.853	40	51.135
SHIH								
Overall	0.169	0.063	0.049	0.420	0.179	0.060	0.052	0.433
Education	0.107	0.070	0.006	0.366	0.122	0.073	0.006	0.409
Health	0.143	0.042	0.044	0.284	0.149	0.040	0.032	0.295
Income	0.362	0.087	0.188	0.775	0.357	0.084	0.168	0.780
Childlessness								
Overall (%)	3.499	3.734	0	32.653	2.860	2.650	0	20.690
Voluntary (%)	0.300	1.086	0	18.367	0.127	0.434	0	5
Involuntary (%)	1.090	1.707	0	20	1.490	1.890	0	20.690
Circumstantial (%)	2.067	2.665	0	17.647	0.628	1.163	0	11.454
Marital Status								
Married/cohabiting/relationship (%)	90.876	7.565	47.059	100	78.996	12.953	0	100
Never married (%)	2.492	4.430	0	39.286	3.206	10.404	0	100
Divorced/separated (%)	4.767	4.495	0	40	8.693	6.006	0	36.957
Widowed (%)	1.865	2.473	0	20	9.106	6.259	0	34.127
Number of subnational regions	372				384			
Number of subnational region-year combinations	1,213				1,749			

dichotomous childlessness based on the number of total children ever born (i.e. ‘1’ if the total number of children equals zero and ‘0’ if this number is larger than or equal to one). Stillbirths, miscarriages and other forms of terminated pregnancies are not included as live births. We do not take into account adopted children nor stepchildren.

Three different variables represent the percentage of involuntarily, voluntarily and circumstantially childless individuals in a particular subnational region-year combination. These variables have been aggregated from an individual-level categorical variable that has been constructed on the basis of the possible combinations of responses to three questions, namely i) a question that asks about fertility preferences; ii) a question regarding the ideal number of children one would have had if they could turn back time and irrespective of fertility outcomes; and iii) marital status. Figure 2.2 shows a decision tree for this classification. If respondents aged 40+ have never had any children and are not pregnant at the time of interview, they are classified as childless. If these childless respondents report that they are not fecund (i.e. they/their partner cannot get pregnant regardless of whether they desire to have children), or report that they are fecund, want to have children and are currently married but still have not been able to get pregnant, they are classified as involuntarily childless. Voluntarily childless adults are those who do not

want to have any children. Those who are fecund, want to have children, but are currently not married (either because of never having been married or because of having been separated, divorced or widowed) are classified as circumstantially childless. Respondents who do not know whether they want to have children and what their ideal number of children is, have been classified as undecided. We do not make inferences for this group because they would be uninformative and the group is relatively small.

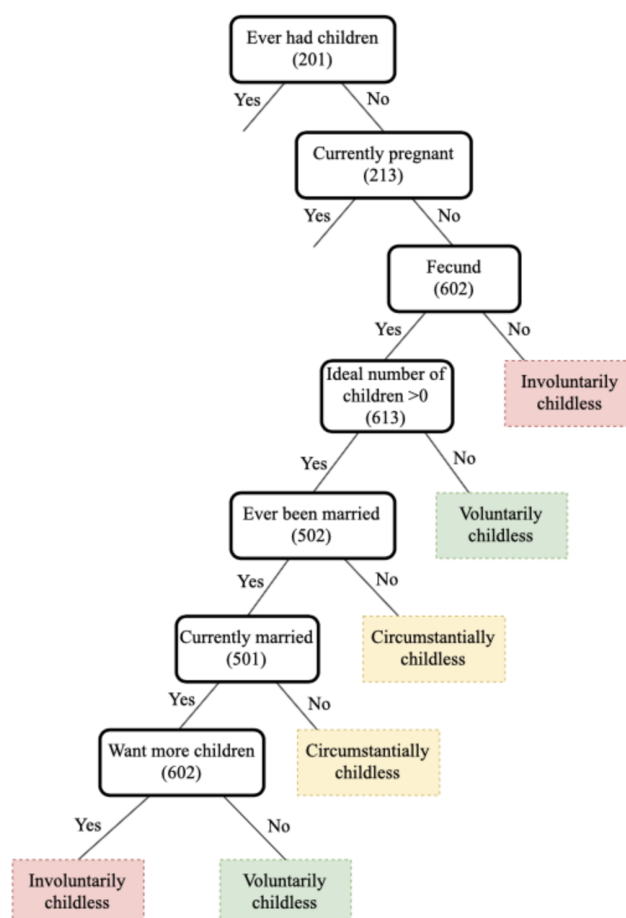


Figure 2.2: Decision tree for the classification of types of childlessness (DHS question number indicated between brackets)

2.3.3 Development

We construct our main independent variable by combining the national-level Historical Index of Human Development (HIHD) (Prados de la Escosura, 2015a,b) with the non-historical Subnational Human Development Index (SHDI) (Smits and Permanyer, 2019) to create our own Subnational Historical Index of Human Development (SHIHD). The HIHD is a cross-country comparative indicator and a composite measure of life expectancy at birth, educational enrolment rates, adult literacy and gross domestic product per capita. The HIHD indicators are available approximately every five years in the period relevant to us and we linearly interpolate the years in-between. The SHDI is constructed in the same way as the

Human Development Index (HDI) (UNDP, 2015), namely from life expectancy at birth, expected years of schooling, average years of schooling and gross national income per capita, and coincides with the HDI on the national level. We further distinguish between the three main components of development, namely education, income and health, which are separately available for both the HIHD and SHDI. Both the HIHD and SHDI components are measured on a zero-to-one scale.

For the overall SHIHD as well as its three components, we use the national-to-subnational ratios of the earliest available year (usually 1990) of the SHDI (component), and then we use these ratios in combination with the national-level HIHD (component) to obtain subnational development indicators for years before 1990. For example, if we want to construct the SHIHD for the Atacora region in Benin in 1950 and the SHDI for Benin in 1990 is 0.348 overall and 0.304 for the Atacora region, and the HIHD for Benin is 0.055 in 1950, then we construct the 1950 SHIHD for the Atacora region as $0.304/0.348 \cdot 0.055 = 0.048$. We thus assume that during the years leading up to 1990, the ratios of subnational and national development are homogeneous over time. The country-specific trends of national and subnational SHDI components in Appendix 2.G show that this is a reasonable assumption for both indicators as these ratios are generally stable over the period for which we do have data (1990-2017). Finally, for every subnational region-year combination, we use the SHIHD indicator for the year in which the average age of the respondents in that subnational region was 19 (women) or 24 (men), as aforementioned. For example, the Rift Valley subnational region in Kenya in 2014 had 2,950 female respondents aged at least 40 with an average age of 43.8. For this subnational region-year combination the relevant development indicator would come from year $(2014 - (43.8 - 19)) \approx 1989$.

To obtain a better understanding of the substantive meaning of the SHIHD, it is important to note that our SHIHD indicator as well as its components (education, income and health) follow the scale of the HIHD (Prados de la Escosura, 2015a,b), which is based on the UNDP's version of the HDI (UNDP, 2015). Following Prados de la Escosura (2015b, p. 227-228), we use the same bounds as the UNDP but apply a non-linear rather than linear transformation to the 0-1 scale, as explained below. Health is measured in terms of life expectancy at birth, i.e. the average number of years alive remaining for individuals reaching the specified ages if they were subjected to the mortality rates corresponding to the year(s) these life expectancies relate to. Therefore, from here onwards we will refer to the health component as 'life expectancy'. Education is a composite measure (i.e. unweighted geometric average) of the adult literacy rate (i.e. the share of the population aged 15+ who are able to write and read) and gross enrolment rate (i.e. the share of the population aged 5-24 enrolled in education (primary, secondary or tertiary)). Income is expressed in terms of GDP per capita, measured by 1990 dollars corrected for its purchasing-power (i.e. the difference in cross-country price levels, Geary-Khamis 1990 \$). The three measures are non-linearly transformed to a zero-to-one scale for comparability across countries and indices. Life expectancy and

education are transformed as

$$\text{Life expectancy} = \frac{\ln(85 - 20) - \ln(85 - \text{Life expectancy})}{\ln(85 - 20)} \quad (2.1)$$

and

$$\text{Education} = \frac{\ln(100 - 0) - \ln(100 - \text{Education})}{\ln(100 - 0)} \quad (2.2)$$

in order to take into account that increases of the same absolute size are more significant at higher than lower levels of the index. Income is log-transformed by

$$\text{Income} = \frac{\ln(\text{Income}) - \ln(100)}{\ln(46949) - \ln(100)} \quad (2.3)$$

to ensure returns decline as the level of the index increases. The overall HIHD is then computed as the geometric mean of these three transformed indices. The lower and upper bounds for each indicator ('goal-posts', e.g. 20 and 85 for life expectancy) are similar to those used to compute the HDI (United Nations Development Programme [UNDP], 2019). Note, however, that because of the log transformations of the SHIHD components, life expectancy and education are well-defined in the [0, 84] and [0, 99] ranges, respectively. While this means the indicators are ill-defined beyond 84 respectively 99, this does not pose any problems for our study as these upper bounds are not reached anywhere in sub-Saharan Africa. Substantively, a high score (close to one) on one of the indices means that the value of this indicator is close to the upper bound (e.g. a life expectancy score close to one indicates life expectancy close to 84 years), whereas a low score (close to zero) indicates proximity to the lower bound (e.g. an income score close to zero indicates GDP per capita in G-K 1990 dollars close to log 100 \$). To illustrate, the 2015 EU-28⁴ and sub-Saharan African averages on the indicators were 0.74 respectively 0.27 for the overall HIHD; 0.80 resp. 0.23 for education; 0.83 resp. 0.42 for income and 0.62 resp. 0.23 for life expectancy. Further, to obtain a sense of how the HIHD and its components have developed since 1938 in sub-Saharan Africa, Figure 2.H.1 in Appendix 2.H shows the trends of the HIHD and its components per country.

2.3.4 Other Factors

The percentage of individuals living in an urban area is measured by the de facto place of residence (rather than de jure place of residence, see Caselli et al. (2005)) and is calculated for each subnational region-year combination.

⁴Czech Republic and Luxembourg were excluded from these calculations because data on the HIHD and its components were missing for these countries.

Marital status is reflected by the percentage of individuals who are i) never married; ii) married, in a relationship or cohabiting; iii) divorced or separated; or iv) widowed for a particular subnational region-year combination. Four variables are constructed on the basis of responses to questions about current and former marital status.

As an indicator for marriage market sex balance, we use the number of women per 100 men in the age group between 15 and 24. We choose this age group because in our data the median ages at which most women and men marry are 17 and 23, respectively, which also corresponds with findings by [Marston et al. \(2009\)](#). This variable is available only on the national level because of a lack of age and sex specific population data at the subnational level. We use the sex-specific 2017 World Population Prospects by the United Nations Desa/Population Division ([United Nations Desa/Population Division, 2017a,b](#)) for the year when the average age of all individuals in the subnational region would have been 19 (women) or 24 (men) to approximate the sex balance at the age at which childbearing usually takes place in sub-Saharan Africa.

Polygyny is represented as the percentages of men and women in a particular subnational region-year combination who respectively report having multiple wives or their partner having at least one other wife. As there seems to be more uncertainty about polygyny in the female data, likely because women may not always be aware of their husband having multiple wives, we impute polygyny prevalence for region-year combinations from the male data when missing or mostly uncertain in the female data. Respondents who are not in a relationship are classified as being monogynous. There are 32 surveys for which the polygyny variable only consists of 'not applicable' responses, of which five are standard DHS and 27 are MIS. No further information is given by the data collectors as to why the polygyny information is missing in the standard DHS samples. For all 27 MIS, the polygyny question has not been asked.

We include three indicators to have an idea of family postponement: average ages at first sex, first marriage and first childbirth. Postponement may play an important role in childlessness. We use the average first ages for all individuals in each particular subnational region and year. We use the age at first cohabitation as a proxy for the age at first marriage for surveys where the latter was not asked.

Sex-specific HIV prevalence indicators are added for every subnational region-year combination. As most individuals in sub-Saharan Africa make childbearing decisions around the age of 20, we use HIV prevalence indicators for individuals aged between 15 and 24 and we match these to the year when the average age of the respondents in the subnational region would have been 19 (women) or 24 (men). We obtain national-level data from the [Joint United Nations Programme on HIV/AIDS \(UNAIDS\) \(2017a\)](#) and subnational-level data for different sets of countries from the [United States Agency for International Development \(2018\)](#) and [Joint United Nations Programme on HIV/AIDS \(UNAIDS\) \(2017b\)](#). As

national-level data is available from 1990 to 2017 for the majority of the countries, we use a similar approach as with the SHIHD. That is, we compute ratios of subnational HIV prevalence to national HIV prevalence of the year closest to the year where we have the indicators available at both levels. We use these ratios to estimate subnational HIV prevalence from national HIV prevalence for the years when only national HIV prevalence data is available. For countries for which no subnational-level HIV data is available (i.e. Central African Republic, Comoros, Madagascar, Sudan and Swaziland), we use national-level estimates for all regions in those countries. We extrapolate the data for years between 1970 and 1990 according to an exponential growth model starting at zero in 1970, assuming that HIV spreads exponentially (Faria et al., 2014; Morris and Kretzschmar, 1997). We set the HIV prevalence indicators to zero for all years before 1970, as HIV was not identified before this time.

2.3.5 Missing Data

We use multiple imputation by chained equations (MICE) to deal with missing values. Figures 2.I.2 and 2.I.1 in Appendix 2.I show aggregation plots for missingness in our aggregated subnational-level data. The variables with the highest proportion of missing values are the average ages at first marriage (18%) and sex (23%), polygyny (18%) and marital status (18%) for women. For men, age at first birth has the highest proportion of missingness (33%). Most of the missingness in our data is the result from particular questions not being asked in certain surveys (such as the age at first childbirth for men) or from missingness in external data (such as the HIV and (S)HIHD data). MICE replaces missing values in a data set under certain assumptions about the missingness mechanism, and imputes these values M times (creating M different data sets) to take into account the uncertainty of imputation (for more information, see Azur et al., 2011). The algorithm loops through the data, imputing every variable by means of predicting it using the other variables, and repeating this cycle as the data are updated. The statistical analyses are performed on each of these M data sets and then combined (i.e. pooled) as explained in Appendix 2.J. The number of imputations used equals the percentage of incomplete observations (i.e. region-year combinations for which at least one variable is missing) in the female ($M = 28$) and male ($M = 34$) data, as recommended by Bodner (2008); White et al. (2011). As multiple imputation incorporates between-data uncertainty resulting from the imputation (i.e. estimation) of missing values in the standard errors, accurate and unbiased estimates will be produced.

2.4 Methods

Our analysis proceeds in four steps. First, we document descriptive levels and trends of childlessness across sub-Saharan Africa. Second, we examine the bivariate relationship between childlessness and

development on both the national and subnational level. Third, we estimate two-level hierarchical models to examine whether childlessness and development relate according to a U-shape. Fourth, we split overall childlessness into its types (i.e. involuntary, voluntary and circumstantial) and overall development into its components (i.e. life expectancy, education and income). We then examine the bivariate relationships between these types and components to investigate the drivers and mechanisms of the association between overall childlessness and development.

In the third part of our analyses, we estimate two-level hierarchical (i.e. multilevel) models where subnational regions are nested within countries. We use hierarchical modelling to take the clustered structure of our data into account (for a more detailed explanation, see [Snijders and Bosker, 2011](#)). Our model is specified as

$$Childlessness_{trc} = \pi_{0c} + \pi_{1c} \underline{SHIHD}_{trc} + \pi_2 \underline{X}_{trc} + e_{trc} \quad (2.4)$$

where r and c represent subnational regions and countries, respectively, t represents time (year minus sample minimum year) and underlined objects represent vectors. Our independent

$$\underline{SHIHD}_{trc} = [\text{poly}(SHIHD_{trc} - 1) \text{ poly}(SHIHD_{trc} - 2)]' \quad (2.5)$$

has dimension (2×1) and represents the second-order polynomials of the SHIHD term. Note that we use orthogonal rather than raw polynomial terms of SHIHD in the regression. As the raw polynomial terms of SHIHD (i.e. $SHIHD_{trc}$, $SHIHD_{trc}^2$, $SHIHD_{trc}^3$, etc.) are highly correlated with each other, the resulting standard errors would be inflated due to multicollinearity, yielding larger confidence intervals and therefore biased significance tests for the regression coefficients. As a consequence, the regression results might lead us to incorrectly conclude that there is no U-shape in the relationship between SHIHD and childlessness, while in reality there is. To avoid this from happening, we use orthogonal (i.e. uncorrelated) rather than raw polynomial terms of SHIHD (see Appendix 2.K or [Kennedy and Gentle \(1980, p. 343-344\)](#) for a more detailed explanation of how these terms are computed).

Note that $Childlessness_{trc}$, π_{0c} and e_{trc} are scalars, whereas π_2 and π_{1c} are vectors of length two and k , respectively. Further, $\underline{X}_{trc}$ is a matrix of dimension $(k \times 1)$ containing k explanatory variables for time t , region r in country c . In our baseline model (M1), $\underline{X}_{trc}$ only consists of the second-order orthogonal polynomials of the time variable ($k = 2$), which we add to the model to capture secular time trends (i.e. changes in childlessness over time that are not captured by changes in the SHIHD). In models M2 through M4, we add sets of variables to the $\underline{X}_{trc}$ of M1, namely either average age and proportion of urban residence in M2 ($k = 4$); marital status and postponement in M3 ($k = 8$); polygyny and HIV prevalence

as well as marriage market sex balance in M4 ($k = 6$). In M5, X_{trc} contains all variables included in X_{trc} throughout models M1 to M4. The correlation plots in Figures 2.L.1 and 2.L.2 in Appendix 2.L show that multicollinearity should not pose any problems in the analyses.

We allow the intercept π_{0c} and coefficients $\pi_{1c} = [\pi_{11c} \ \pi_{12c}]'$ for the second-order orthogonal SHIHD terms to vary across countries, as is standard procedure in multilevel modelling (Snijders and Bosker, 2011). With this specification, the residual variance can be partitioned into between-country (country-level) and within-country (subnational-level) components. The country-level residuals stand for unobserved country characteristics that result in correlated outcomes for regions within the same country. More formally,

$$\begin{aligned}\pi_{0c} &= \gamma_{00} + \gamma_{01}W_{tc} + u_{0c} \\ \pi_{11c} &= \gamma_{101} + \gamma_{111}W_{tc} + u_{11c} \\ \pi_{12c} &= \gamma_{102} + \gamma_{112}W_{tc} + u_{12c}\end{aligned}\tag{2.6}$$

Note that in this specification W_{tc} contains country-level variables, and so in our case W_{tc} is a scalar containing the number of women per 100 men for country c at time t .

Our strategy for pooling the results from the regressions on all imputed data is explained in Appendix 2.J. Note that we assess model fit using the pooled Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), following the pooling approach of Knowles and Frederick (2018) according to $\overline{IC} = \sum_{i=1}^M IC_i$. As recommended by Burnham et al. (2011), we conclude one model is better than another if the AIC difference between the models is larger than nine.

As population estimates are not available on the subnational level and our goal is not necessarily to draw conclusions about the average sub-Saharan African case, we do not age-adjust these childlessness levels nor weigh the regressions for country size. As the absolute difference between age-adjusted and raw childlessness levels on the national level is 0.04% on average and 0.8% at maximum, this decision should not affect our conclusions.

2.5 Results

We first document national-level childlessness trends by gender. Figure 2.3 shows the level of childlessness for three periods: 1997-2001 (red circle), 2005-2009 (green triangle) and 2011-2015 (blue square);⁵

⁵The first, second and third quartiles of the year of observation across surveys are 1999, 2007 and 2013, respectively. As some surveys are collected not exactly in but close to these years, we consider surveys collected as closely as possible to each of these quartiles within two years before or after one of the quartiles, resulting in the ranges 1997-2001, 2005-2009 and 2011-2015.

the raw trends are shown in Figure 2.M.1 in Appendix 2.M. We observe that national levels of childlessness vary between almost one percent and 12 percent. Some of these highest levels of childlessness occur amongst men rather than women, and there is also more variation across time and place in male than female childlessness. For each of the three periods considered, male childlessness is higher than female childlessness for about 60 to 65% of the countries for which both female and male surveys were collected. There is substantial variation across countries in the trends in childlessness. Over the periods considered, we observe increases in male childlessness in 14 countries, whereas 11 countries show a stable pattern or decrease. For female childlessness, we observe increasing trends in 11 countries, and stable or decreasing trends in 16 countries. Note that while the time between two surveys collected for a given country will usually be sufficient (see Figure 2.C.1 in Appendix 2.C), the time differences between the periods might be small in some cases.

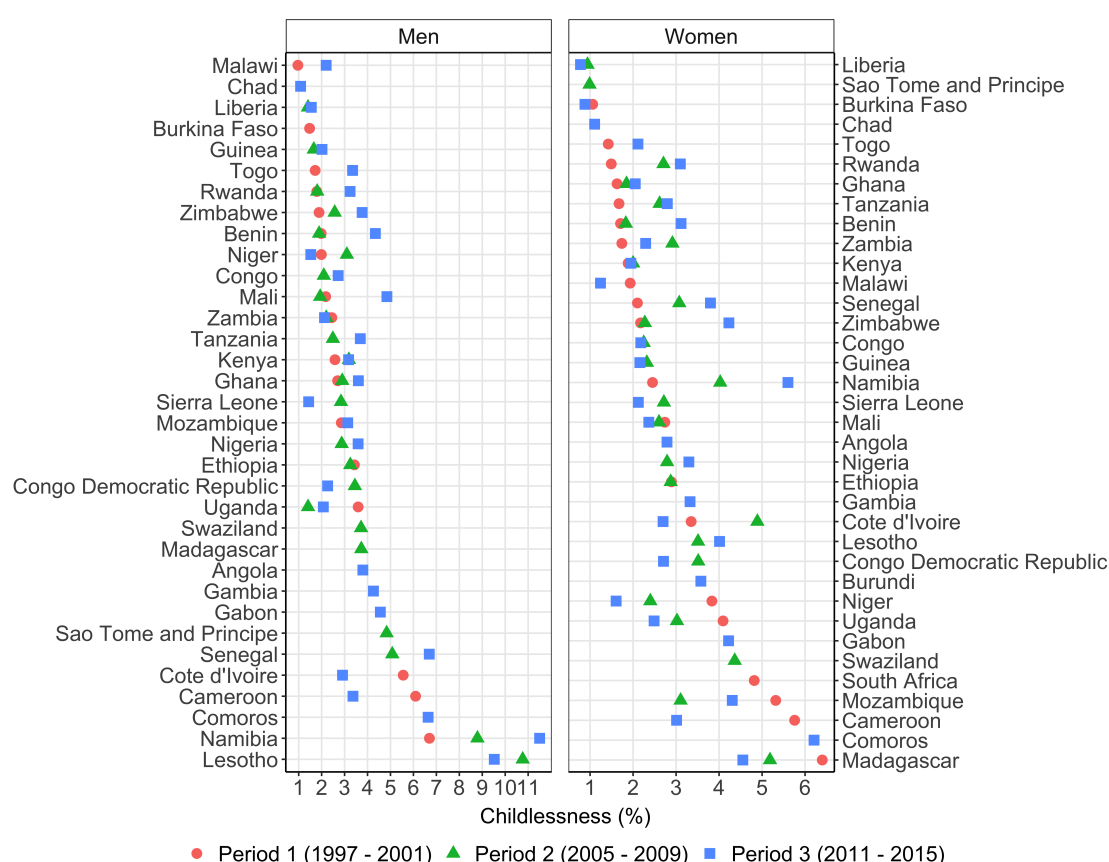


Figure 2.3: National childlessness levels for men and women in 1997-2001 (red circle), 2005-2009 (green triangle) and 2011-2015 (blue square)

Moving to the sub-national level, Figure 2.4 shows the most recently available level of childlessness separately for men and women in 372 respectively 384 subnational regions. The unweighted average for male childlessness is 3.5%, slightly higher than the average for females of 2.9%. Although there is

substantial variation, particularly amongst men, at least one fifth of the subnational regions have childlessness levels exceeding five percent. Regions with some of the highest female childlessness levels ($\sim 16\%$) include Addis in Ethiopia as well as Abia, Borno, Imo and Anambra in Nigeria. These regions have in common that they either include the country capital, or that they are some of the most populated areas in their country. However, some of the highest levels of childlessness do not occur amongst women, but rather amongst men. In some regions in South Africa (Western Cape), Central African Republic (Basse Kotto, Mbornou, Houte Mbormo), and Namibia (Omusati, Caprivi, Khomas and Oshana), male childlessness levels achieve between 16 and 33%. These are regions which are densely populated compared to other regions in the same country, or regions where infertility has generally been high (Larsen, 2003). In 215 (56%) of the regions for which both male and female data are available, the most current levels of male childlessness are higher than those of female childlessness. In 30 out of those 215 regions (14%), childlessness amongst men is at least five percentage points (p.p.) higher than amongst women.

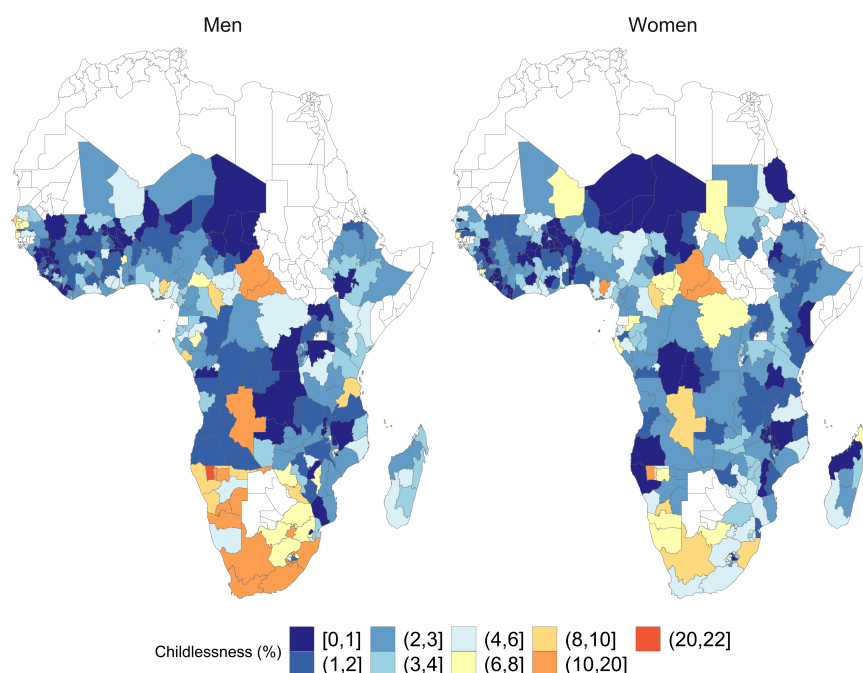


Figure 2.4: Male and female childlessness levels across 372 respectively 384 subnational regions in sub-Saharan Africa

What does the relationship between overall levels of childlessness and development look like, and (how) is this different on the national and subnational levels? In Figures 2.5a and 2.5b, we visualise the relationship between childlessness and development on the national respectively subnational levels by means of scatter plots and fitted lines representing the best performing of linear or quadratic bivariate models. Note that in all scatter plots, the points represent combinations of countries or subnational regions with years and are slightly transparent to better distinguish between overlapping points. We observe from Figures 2.5a and 2.5b that on the subnational level, we have much more variation in both childlessness

levels and development than on the national level. On the national level, the bivariate association between childlessness and development is best described as a quadratic U-shaped relationship for men and a linear relationship for women. On the subnational level, where we have much more variation, both female and male childlessness associate with development according to a U-shape. These observations are supported by the model fits in Tables 2.N.1 and 2.N.2 in Appendix 2.N.

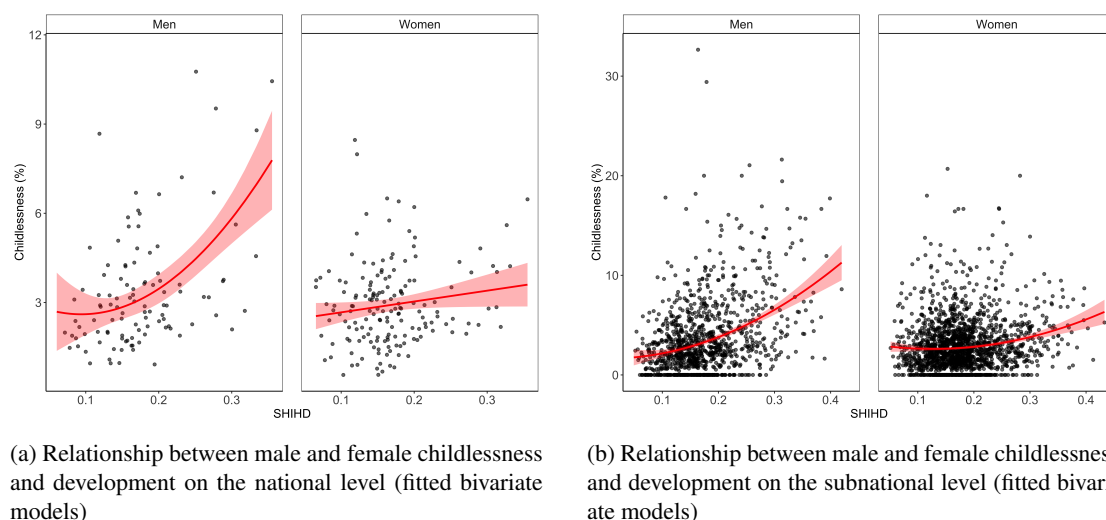


Figure 2.5: Relationship between male and female childlessness and development on the (a) national and (b) subnational level (fitted bivariate models)

As we have a much larger sample of subnational region-year combinations ($N_{men} = 1,213$ and $N_{women} = 1,749$) than we do of national country-year combinations ($N_{men} = 119$ and $N_{women} = 165$) and there is substantial within-country variation in both childlessness and development, we continue our analysis from a subnational perspective. In doing so, we estimate five hierarchical models for women and men separately. We allow the intercept and effect of the first-order orthogonal polynomial term of SHIHD to vary across countries because it significantly improves the model fit (see Table 2.O.1 in Appendix 2.O). Further, the results for the controlled models with random effects showed that linear models fit better for men, while quadratic models fit better for women (Table 2.N.3 in Appendix 2.N). Therefore, our multivariate models include only first-order orthogonal polynomials (1st OP) of SHIHD for men but also second-order orthogonal polynomials of SHIHD (2nd OP) for women. Table 2.P.1 in Appendix 2.P contains the random effects. These show that the effect(s) of the SHIHD polynomial(s) vary substantially across countries, supporting our choice for random effects models. Furthermore, there is a positive correlation between intercept and the effect of the SHIHD polynomial(s), indicating that countries with higher levels of childlessness at baseline also experience a steeper growth in childlessness as development increases.

Does the relationship between childlessness and development remain when taking other factors into account? Figure 2.6 shows the predicted relationship between childlessness and development for the full

control model (M5). We observe that the relationship between female childlessness and development is indeed U-shaped. The hierarchical model results in Table 2.3 further show that development is still related to childlessness even when controlling for other factors. For men, this is not the case, however. Instead of a U-shaped pattern, we observe that a positive linear function describes the relationship between male childlessness and development (Figure 2.6). Additionally, in contrast with the results for women, overall levels of development are not statistically significantly related to male childlessness when controlling for other factors (Table 2.3). Further, there is no secular time trend for men, whereas the first- and second-order orthogonal polynomials of time are generally statistically significant throughout the models for women.

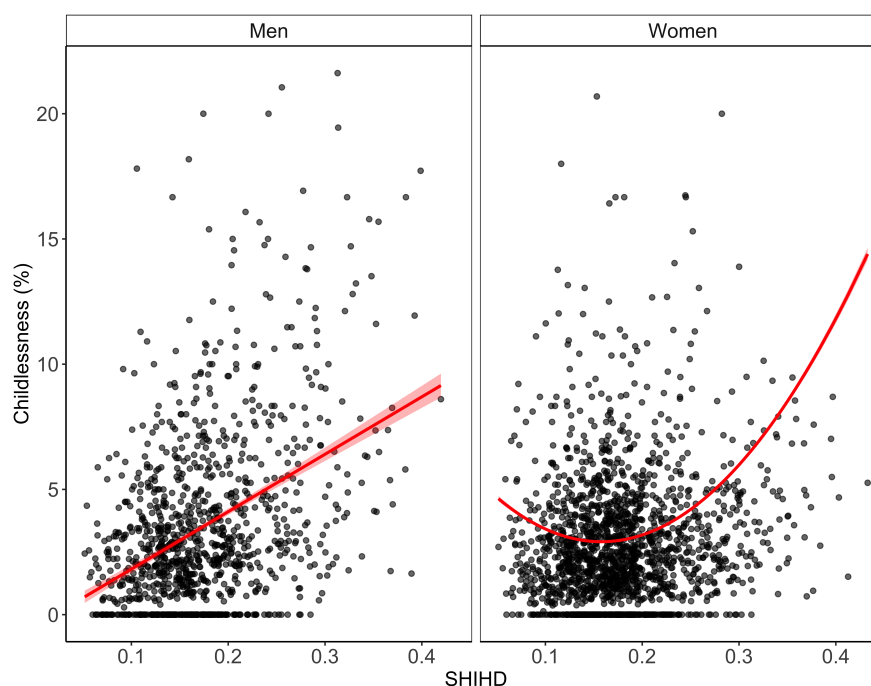


Figure 2.6: Fitted values for the multivariate regressions estimating male and female childlessness from development on the subnational level (model M5)

While overall levels of development are not statistically significantly associated with male childlessness, do any of the other factors in our models show significant correlations? Table 2.3 shows the regression coefficients for the subnational-level multivariate hierarchical models estimating childlessness. Figure 2.Q.1 in Appendix 2.Q shows the marginal effect of each of the independent variables (*ceteris paribus*) for the full control model (M5, linear for men and quadratic for women). These marginal effects help give a sense of the relative size and nature of the model associations, given that the regression coefficients may be difficult to interpret directly because of the hierarchical nature of the models and the use of orthogonal polynomials. Amongst men, childlessness seems to be driven mainly by postponement or even a complete lack of marriage, given that the effect of SHIHD is not statistically significant in the models controlling for marital status and postponement indicators (M3 and M5). Male childlessness

is substantially larger in regions where singlehood and divorce are more common relative to marriage. However, it is not only the lack of marriage but also the postponement of marriage by men that leads to higher levels of male childlessness, given the statistically significant positive coefficients for the average age at first marriage or cohabitation for males. Taking into account the range of values occurring in the data for each of the independent variables, Figure 2.Q.1a in Appendix 2.Q shows that the prevalence of male singlehood has by far the strongest relationship with male childlessness: for example, an increase from 20% to 40% of never married men is associated with an average increase from 12% to 22% in male childlessness. Similarly, female childlessness is also driven by divorce, although amongst women the prevalence of singlehood does not affect childlessness when controlling for other factors. Rather, higher prevalences of HIV as well as urbanisation are associated with female childlessness. Another factor strongly related to both male and female childlessness is polygyny: childlessness is substantially lower in regions where polygyny is more common. For women, however, SHIHD is most strongly related to childlessness compared to other predictors, considering the realistically occurring values of these predictors (Figure 2.Q.1b in Appendix 2.Q). To illustrate, while there is substantial variation across subnational regions, on average the SHIHD across these regions increased from approximately 0.1 around 1990 to 0.2 around 2010. This increase in development would be associated with an initial decrease from 4% to 2% followed by an increase to 3%. For some of the more developed regions, which have gone from about 0.2 to 0.3 or 0.3 to 0.4 on the SHIHD scale in the same period, female childlessness would have increased on average from about 2-3% to 5-6% respectively 5-6% to 11-12%.

What drives the U-shape between female childlessness and development? And why do we not observe such a U-shape amongst men? To answer these questions, we estimate linear bivariate models between childlessness types (i.e. involuntary, voluntary and circumstantial) and development components (i.e. life expectancy, education and income) according to our hypotheses in Figure 2.1. Figure 2.7 shows the plotted fitted values and Table 2.R.1 in Appendix 2.R contains the regression coefficients. We estimate linear models because we have no reason to believe that childlessness types and development components are non-linearly related, and we expect that these linear relationships together result in an overall U-shape in the association between childlessness and development (as illustrated in Figure 2.1). We observe that voluntary and circumstantial childlessness are positively related with life expectancy and particularly education and income, especially amongst men. Further, involuntary childlessness and income are positively associated for both men and women. The associations of involuntary childlessness with education and life expectancy are different for men and women, however: while female involuntary childlessness decreases with education and life expectancy, male involuntary childlessness remains unchanged with life expectancy and even increases slightly with education.

Table 2.3: Regression coefficients of the subnational regional-level multivariate hierarchical models estimating childlessness from development for men and women

	Men (N = 1,239)					Women (N = 1,775)				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	0.035*** (0.000)	-0.025 (0.464)	-0.030* (0.045)	0.017 (0.766)	-0.071 (0.163)	0.036*** (0.000)	0.036 (0.280)	0.030* (0.021)	0.118** (0.007)	0.094 (0.111)
Time (1 st OP)	-0.019 (0.675)	0.018 (0.674)	-0.030 (0.457)	-0.022 (0.646)	-0.003 (0.941)	-0.078** (0.009)	-0.061* (0.040)	-0.070* (0.033)	-0.079* (0.021)	-0.082* (0.030)
Time (2 nd OP)						0.069** (0.007)	0.063* (0.013)	0.067* (0.012)	0.076** (0.003)	0.057* (0.034)
SHIHD (1 st OP)	0.404*** (0.000)	0.380*** (0.000)	0.054 (0.449)	0.293** (0.004)	0.005 (0.945)	0.434** (0.008)	0.331* (0.040)	0.339* (0.038)	0.359* (0.026)	0.224 (0.155)
SHIHD (2 nd OP)						0.396*** (0.001)	0.368*** (0.001)	0.396*** (0.000)	0.395*** (0.000)	0.359*** (0.001)
Average age		0.001 ⁺ (0.091)			0.001 (0.176)		0.000 (0.918)			0.000 (0.916)
Urban residence (%)		0.003 (0.456)			0.003 (0.464)		0.008** (0.006)			0.006* (0.036)
Never married ^a (%)			0.498*** (0.000)		0.493*** (0.000)			0.015 ⁺ (0.068)		0.011 (0.205)
Divorced/separated ^a (%)			0.072*** (0.001)		0.069*** (0.001)			0.049*** (0.001)		0.035* (0.018)
Widowed ^a (%)			0.073 ⁺ (0.076)		0.060 (0.142)			-0.008 (0.559)		-0.014 (0.292)
Average age at first birth			0.000 (0.356)		0.000 (0.393)			0.000 (0.897)		0.000 (0.268)
Average age at first marriage/cohabitation			0.001* (0.017)		0.001* (0.035)			0.001 ⁺ (0.051)		0.001 (0.156)
Average age at first sex			0.000 (0.967)		0.000 (0.957)			-0.001 (0.133)		-0.001 (0.139)
Polygyny prevalence (%)				-0.035*** (0.000)	-0.014 ⁺ (0.074)				-0.015** (0.001)	-0.013* (0.015)
HIV prevalence (%)				0.020 (0.860)	0.000 (0.998)				0.040 ⁺ (0.095)	0.040 ⁺ (0.097)
Number of women per 100 men				0.000 (0.664)	0.000 (0.910)				-0.001 ⁺ (0.073)	-0.001 (0.205)
AIC	-4927.427	-4907.640	-5191.312	-4914.396	-5141.966	-8097.594	-8081.931	-8060.544	-8089.681	-8018.600
BIC	-4891.721	-4861.732	-5125.001	-4863.388	-5050.151	-8031.992	-8005.396	-7962.141	-8007.679	-7892.864
Log. Lik.	2470.713	2462.820	2608.656	2467.198	2588.983	4060.797	4054.965	4048.272	4059.841	4032.300

^a The reference category for marital status is 'married, cohabiting or in a relationship'.⁺ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

2.6 Conclusion and Discussion

Although childlessness has gained increasing interest from researchers and policy makers, little was known about childlessness in sub-Saharan Africa. We filled this gap by presenting the first comprehensive overview of male and female childlessness in relation with development in sub-Saharan Africa. Moreover, we constructed a subnational historical index of development to examine the relationship between childlessness and development at the subnational level. We were able to exploit maximum variation in development and take into account substantive within-country variation in development and childlessness. We also analysed the relationship between different types of childlessness and development components as well as the gender differences in this relationship.

We have firstly shown that permanent childlessness in sub-Saharan Africa is substantial, particularly amongst men. This finding contradicts the common perception that childlessness in sub-Saharan Africa

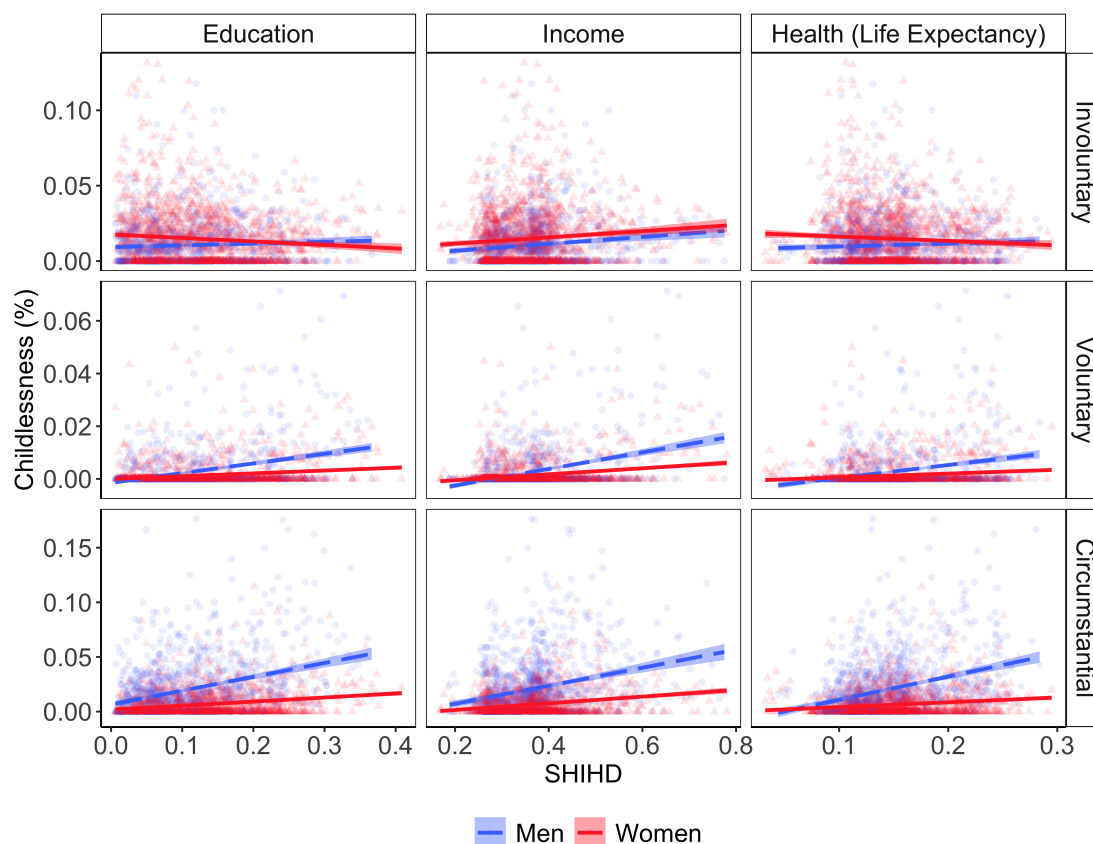


Figure 2.7: Fitted values for the bivariate regressions estimating male and female childlessness types from development components on the subnational level

is mainly a female ‘issue’ and that it hardly occurs amongst men (World Health Organization, 2014). This evidence stresses the importance not only of further expanding research on childlessness in sub-Saharan Africa, but also focusing on males besides females in doing so. Additionally, we have been able to distinguish between different types of childlessness to shed more light on the prevalence of childlessness not stemming from infertility. We have shown that involuntary childlessness is still the most common type of childlessness in sub-Saharan Africa (Baudin et al., 2020), particularly amongst women. Nevertheless, voluntary and especially circumstantial childlessness also prevail, and more so with increasing levels of development. By distinguishing between different types of childlessness and different components of development, we were also able to further investigate the drivers behind the observed U-shaped relationship between overall levels of female childlessness and development. We found that involuntary childlessness is negatively associated with life expectancy and education, albeit only amongst women, and that voluntary and circumstantial childlessness positively relate with life expectancy and particularly education and income amongst both men and women. These findings are in line with previous studies for other low-income regions (Baudin et al., 2020; Poston et al., 1985; Poston and El-Badry, 1987; Poston and Trent, 1982) and seem to suggest that the observed U-shape indeed is the result of involuntary childlessness

declining with life expectancy and education, and voluntary and circumstantial childlessness associating positively with life expectancy and particularly education and income. On the one hand, these findings highlight the importance of taking additional measures to further reduce poverty and infertility. On the other hand, increasing shares of individuals not partnering or choosing not to have children might support speculations that the drivers of childlessness in high-income countries are operating, although perhaps to a smaller extent, in sub-Saharan Africa too (Wilson, 2011).

For men, however, we do not find any evidence for a U-shaped relationship, but rather a positive linear association. This may perhaps be the result of the absence of negative associations of male involuntary childlessness with life expectancy and education, which we do observe for women. Why might we not observe these negative associations for men? Under-reporting infertility may be more common amongst men as infertile men even more than women carry the burden of being stigmatised for a lack of virility and sexual impotency (Agarwal et al., 2015; Runganga et al., 2001). Additionally, male infertility may actually have increased with development as a consequence of rises in chemical exposure, stress, psychoses, drug and alcohol abuse, epidemics, hormone imbalance and tobacco consumption, a phenomenon we have also observed in more developed regions (Levine et al., 2017; Poston and Kramer, 1983; Sengupta et al., 2017). Interestingly, the positive relationships of voluntary and circumstantial childlessness with life expectancy, education and income are stronger amongst men than women. This finding corresponds to the expectation that more low-status men will be left behind on the marriage market as women emancipate (Chudnovskaya, 2019; Kreyenfeld and Konietzka, 2017; van Bavel, 2012), but contradicts our hypotheses that advancements in education and income have a greater impact on women and advancements in life expectancy affect men and women to a similar extent. A possible explanation for this finding may be perhaps that sub-Saharan Africa still knows relatively low levels of gender equality, and that the positive effects of education and income are still more pronounced amongst men than women (Browne and Millington, 2015).

While for female childlessness the positive relationship with overall levels of development remains even when controlling for other factors, male childlessness can rather be explained, in a statistical sense, by changes in marital status and polygyny. Our multivariate models suggest that male childlessness in sub-Saharan Africa is mainly driven by a lack of marriage, which seems plausible because childbearing in sub-Saharan Africa is usually higher amongst married couples than amongst single or divorced individuals (Rutstein and Shah, 2004). Another important driver for childlessness is polygyny. Higher polygyny prevalence is associated with lower male childlessness, which makes sense simply because men in polygynous unions have more female partners and thus chances to have children with (Rossi, 2019; Schoumaker, 2019). Surprisingly, we find that higher polygyny also relates to lower female childlessness, while we had expected polygyny to positively associate with female childlessness through lower

frequency of sexual intercourse, higher chances of venereal diseases and the selection of infertile women into polygynous unions (Cahu et al., 2014; Lardoux and van de Walle, 2003; Musham, 1956). Perhaps in regions where polygyny is common, childbearing is much more important and desired and daughters are seen as a good investment, thereby increasing the willingness to have a child as well as the competition between co-wives to bear children (Rossi, 2019; Tertilt, 2005).

Our study has some limitations that need to be considered. First, a common difficulty is to assess permanent childlessness amongst men, as the end of the reproductive period is not as clearly marked as for women. To retain sufficient sample sizes, we used a cut-off age of 40. Although our results are robust to using higher cut-offs up to the mid 40s, we cannot fully rule out that this early cut-off age produces a small upward bias in our estimates, especially for men. Second, and perhaps more importantly, our estimates of childlessness may be downwardly biased as a consequence of over-reporting fertility due to the stigma attached to childlessness in sub-Saharan Africa (Larsen, 1989; van Balen and Bos, 2009). Similarly, voluntary childlessness may be overestimated as a consequence of ex-post rationalisation, whereby responses to questions about fertility ideals are aligned to one's actual fertility outcomes to mitigate social and individual hardship that may stem from childlessness (Pritchett, 1994). Although men may equally over-report fertility, they may also under-report fertility if they are not aware of having produced children (Rendall et al., 1999; Schoumaker, 2017). Under-reporting may also occur when parents do not include the birth of a child who has died. Note, however, that the DHS explicitly ask for all live births regardless of survival. Moreover, while this may affect the total number of children, it is unlikely to affect childlessness status. To limit bias from misreporting fertility, we use the 'total number of (own) children ever born' variable to estimate childlessness, which has been shown to be the most accurate variable to be used for estimating fertility in the DHS data (Schoumaker, 2017). Finally, we may have overestimated childlessness because we cannot include women who deceased during pregnancy or delivery. We were not able to account for such selection because accurate measures of maternal mortality were not sufficiently available. We refrain from speculating about the sum of these limitations; they may cancel each other out or produce a small bias.

What are the implications of our results for how we might expect childlessness rates to evolve with future levels of development in sub-Saharan Africa? It seems plausible that involuntary childlessness will continue to decrease with further progress in life expectancy and education. One of the most interesting questions is whether circumstantial and voluntary childlessness will follow patterns observed in high-income countries, especially amongst highly educated women in urbanised areas. On the one hand, we might expect similar patterns and some level of convergence as the main drivers of childlessness in high income countries –female education and labour market position, technological change, increasing wealth and autonomy, and urbanisation– seem to be operating in sub-Saharan Africa too (Wilson, 2011).

On the other hand, despite similarity in these large socio-economic forces, it has been both argued and documented that patterns observed in highly developed countries need not simply apply in a straightforward way to low- and middle-developed countries as they become more developed (e.g. [Esteve and Florez-Paredes, 2018](#); [Furstenberg Jr, 2013](#); [Thornton, 2013](#)). Moreover, although our analyses highlight the important role marriage systems play in childlessness, heterogeneity in family change within and between African countries ([Pesando and GFC team, 2018](#)) suggests we should not expect a pattern of universal convergence of childlessness types across the region. Our study has shown that (changes in) childlessness in sub-Saharan Africa are associated with development, but that there is much variation herein. Both observations call for further analyses with a focus on heterogeneity in developments within sub-Saharan Africa. Empirical and conceptual challenges have to be addressed to make progress on this topic. Conceptually we need a framework that acknowledges that structural change in development is embedded in different contexts and therefore may result in different outcomes. Empirically, for instance, we may need to turn to other data sources that provide enough statistical power to explore sub-populations and geographic variation in sufficient detail. Still, for our current level of analysis, new rounds of DHS will show us whether the U-shape becomes more pronounced or not with increasing levels of development.

References

- Agarwal, A., Mulgund, A., Hamada, A., and Chyatte, M. R. (2015). A unique view on male infertility around the globe. *Reproductive Biology and Endocrinology*, 13(37):1–9.
- Azur, M. J., Stuart, E. A., Frangakis, C., and Leaf, P. J. (2011). Multiple imputation by chained equations: what is it and how does it work? *International Journal of Methods in Psychiatric Research*, 20(1):40–49.
- Barnard, J. and Rubin, D. B. (1999). Small-sample degrees of freedom with multiple imputation. *Biometrika*, 86(4):948–955.
- Baudin, T., De la Croix, D., and Gobbi, P. (2020). Endogenous childlessness and stages of development. *Journal of the European Economic Association*, 18(1):83–133.
- Baudin, T., De La Croix, D., and Gobbi, P. E. (2015). Fertility and childlessness in the United States. *American Economic Review*, 105(6):1852–1882.
- Beaujouan, E., Brzozowska, Z., and Zeman, K. (2016). The limited effect of increasing educational attainment on childlessness trends in twentieth-century Europe, women born 1916–65. *Population Studies*, 70(3):275–291.
- Becker, G. (1960). An economic analysis of fertility. In Roberts, G., editor, *Demographic and Economic Change in Developed Countries*, pages 209–240. New York, NY: Columbia University Press.
- Becker, G. (1981). *A treatise on the family*. Cambridge, MA: Harvard University Press.
- Bodner, T. E. (2008). What improves with increased missing data imputations? *Structural Equation Modeling*, 15(4):651–675.
- Bongaarts, J. and Casterline, J. (2013). Fertility transition: is sub-Saharan Africa different? *Population and Development Review*, 38:153–168.
- Browne, E. and Millington, K. A. (2015). Social development and human development: Topic guide. Governance and Social Development Resource Centre (GSDRC). Retrieved from: https://gsdrc.org/wp-content/uploads/2015/10/SD_HD.pdf.
- Burkimsheer, M. (2014). Is religious attendance bottoming out? An examination of current trends across Europe. *Journal for the Scientific Study of Religion*, 53(2):432–445.
- Burkimsheer, M. and Zeman, K. (2017). Childlessness in Switzerland and Austria. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 115–137. Springer.
- Burnham, K. P., Anderson, D. R., and Huyvaert, K. P. (2011). AIC model selection and multimodel inference in behavioral ecology: some background, observations, and comparisons. *Behavioral Ecology and Sociobiology*, 65(1):23–35.
- Cahu, P., Fall, F., and Pongou, R. (2014). Beauty, Polygyny and Fertility: Theory and Evidence. MPRA Paper No. 59009. Retrieved from: <http://mpa.ub.uni-muenchen.de/59009/>.
- Caselli, G., Vallin, J., and Wunsch, G. (2005). *Demography: Analysis and Synthesis: A Treatise in Population*. Academic Press.
- Casterline, J. and Han, S. (2017). Unrealized fertility: Fertility desires at the end of the reproductive career. *Demographic Research*, 36:427–454.
- Chudnovskaya, M. (2019). Trends in childlessness among highly educated men in Sweden. *European Journal of Population*, 35:939–958.
- Clark, S. and Brauner-Otto, S. (2015). Divorce in sub-Saharan Africa: Are unions becoming less stable? *Population and Development Review*, 41(4):583–605.
- Dunlop, C. L., Benova, L., and Campbell, O. (2018). Effect of maternal age on facility-based delivery: Analysis of first-order births in 34 countries of sub-Saharan Africa using demographic and health survey data. *BMJ Open*, 8(4):e020231.
- Dyer, S. J., Abrahams, N., Mokoena, N., and van der Spuy, Z. M. (2004). ‘You are a man because you have children’: Experiences, reproductive health knowledge and treatment-seeking behaviour among men suffering from couple infertility in South Africa. *Human Reproduction*, 19(4):960–967.
- Esteve, A. and Florez-Paredes, E. (2018). The Stability Paradox: Why Expansion of Women’s Education Has Not Delayed Early Union Formation or Childbearing in Latin America. *Studies in Family Planning*, 49(2):127–142.
- Faria, N., Rambaut, A., Suchard, M., Baele, G., Bedford, T., Ward, M., Tatem, A., Sousa, J., Arinaminpathy, N., Pépin, J., Posada, D., Peeters, M., Pybus, O., and Lemey, P. (2014). The early spread and epidemic ignition of HIV-1 in human populations. *Science*, 346(6205):56–61.

- Fenske, J. (2015). African polygamy: Past and present. *Journal of Development Economics*, 117:58–73.
- Frejka, T. (2017). Childlessness in the United States. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 159–179. Springer.
- Furstenberg Jr, F. F. (2013). Transitions to adulthood: What we can learn from the West. *The Annals of the American Academy of Political and Social Science*, 646(1):28–41.
- Hegdahl, H. K., Fylkesnes, K. M., and Sandøy, I. F. (2016). Sex differences in HIV prevalence persist over time: Evidence from 18 countries in sub-Saharan Africa. *PloS One*, 11(2):e0148502.
- ICF International (2019). Demographic and Health Surveys (various, 1986–2018) [Data sets]. Calverton, Maryland: ICF International [Distributor], 2019. Retrieved from: <https://dhsprogram.com/data/available-datasets.cfm>.
- Inhorn, M. C. and Patrizio, P. (2015). Infertility around the globe: New thinking on gender, reproductive technologies and global movements in the 21st century. *Human Reproduction Update*, 21(4):411–426.
- Joint United Nations Programme on HIV/AIDS (UNAIDS) (2017a). National HIV prevalence among young men and women, 15–24 [Data set]. Retrieved from: <http://aidsinfo.unaids.org>.
- Joint United Nations Programme on HIV/AIDS (UNAIDS) (2017b). Regional HIV prevalence among young men and women, 15–24 [Data set]. Retrieved from: <http://aidsinfo.unaids.org>.
- Kennedy, W. J. and Gentle, J. E. (1980). *Statistical computing*. Routledge.
- Knowles, J. and Frederick, C. (2018). merTools: Tools for analyzing mixed effect regression models. R package version 0.4.1. Retrieved from: <https://CRAN.R-project.org/package=merTools>.
- Kreyenfeld, M. and Konietzka, D. (2017). *Childlessness in Europe: Contexts, Causes, and Consequences*. Springer.
- Lardoux, S. and van de Walle, E. (2003). Polygyny and fertility in rural Senegal. *Population*, 58(6):717–744.
- Larsen, U. (1989). A Comparative Study of the Levels and Differentials of Sterility in Cameroon, Kenya, and Sudan. In Lesthaeghe, R., editor, *Reproduction and Social Organization in sub-Saharan Africa*, pages 167–211. Berkeley, CA: University of California Press.
- Larsen, U. (1994). Sterility in sub-Saharan Africa. *Population Studies*, 48(3):459–474.
- Larsen, U. (2000). Primary and secondary infertility in Sub-Saharan Africa. *International Journal of Epidemiology*, 29(2):285–291.
- Larsen, U. (2003). Infertility in Central Africa. *Tropical Medicine & International Health*, 8(4):354–367.
- Letherby, G. (2002). Childless and bereft?: Stereotypes and realities in relation to ‘voluntary’ and ‘involuntary’ childlessness and womanhood. *Sociological Inquiry*, 72(1):7–20.
- Levine, H., Jørgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Mindlis, I., Pinotti, R., and Swan, S. H. (2017). Temporal trends in sperm count: a systematic review and meta-regression analysis. *Human Reproduction Update*, 23(6):646–659.
- Madsen, J. B., Moslehi, S., and Wang, C. (2017). What Has Driven the Great Fertility Decline in Developing Countries Since 1960? *The Journal of Development Studies*, 54(4):738–757.
- Marmot, M. (2005). Social determinants of health inequalities. *The Lancet*, 365(9464):1099–1104.
- Marston, M., Slaymaker, E., Cremin, I., Floyd, S., McGrath, N., Kasamba, I., Lutalo, T., Nyirenda, M., Ndyababo, A., Mupambireyi, Z., and Zaba, B. (2009). Trends in marriage and time spent single in sub-Saharan Africa: a comparative analysis of six population-based cohort studies and nine Demographic and Health Surveys. *Sexually Transmitted Infections*, 85(Suppl 1):i64–i71.
- Mascarenhas, M. N., Flaxman, S. R., Boerma, T., Stevens, G. A., and Van der Poel, S. (2012). National, regional, and global trends in infertility prevalence since 1990: A systematic analysis of 277 health surveys. *PLoS Medicine*, 9(12):e1001356: 1–12.
- Morris, M. and Kretzschmar, M. (1997). Concurrent partnerships and the spread of HIV. *Aids*, 11(5):641–648.
- Moultrie, T. A., Sayi, T. S., and Timæus, I. M. (2012). Birth intervals, postponement, and fertility decline in Africa: A new type of transition? *Population Studies*, 66(3):241–258.
- Musham, H. (1956). Fertility of polygamous marriages. *Population Studies*, 10(1):3–16.
- Neyer, G., Hoem, J. M., and Andersson, G. (2017). Education and Childlessness: The Influence of Educational Field and Educational Level on Childlessness among Swedish and Austrian Women. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 183–207. Springer.
- Odimegwu, C., Ndagurwa, P., Mwiza, G. S., and Ololade, B. (2018). Cohabitation in sub-Saharan Africa: A regional analysis. *Southern African Journal of Demography*, 18:111–170.

- Oppenheimer, V. K. (1994). Women's rising employment and the future of the family in industrial societies. *Population and Development Review*, 20(2):293–342.
- Permayer, I., Esteve-Palos, A., Garcia, J., and McCaa, R. (2015). Human development index-like small area estimates for Africa computed from IPUMS-international integrated census microdata. *Journal of Human Development and Capabilities*, 16(2):245–271.
- Permayer, I. and Smits, J. (2020). Inequality in human development across the globe. *Population and Development Review*, 46(3):583–601.
- Pesando, L. and GFC team (2018). Global Family Change: Persistent Diversity with Development. *Population and Development Review*, 45:133–168.
- Poston, Jr., D. L., Briody, E., Trent, K., and Browning, H. L. (1985). Modernization and Childlessness in the states of Mexico. *Economic Development and Cultural Change*, 33(3):503–519.
- Poston, Jr., D. L. and El-Badry, S. M. (1987). Modernization and childlessness among the governorates of the Arab Republic of Egypt, 1976. *Journal of Biosocial Science*, 19(2):181–193.
- Poston, Jr., D. L. and Kramer, K. B. (1983). Voluntary and involuntary childlessness in the United States, 1955–1973. *Social Biology*, 30(3):290–306.
- Poston, Jr., D. L., Kramer, K. B., Trent, K., and Yu, M.-Y. (1983). Estimating voluntary and involuntary childlessness in the developing countries. *Journal of Biosocial Science*, 15(4):441–452.
- Poston, Jr., D. L. and Trent, K. (1982). International variability in childlessness: A descriptive and analytical study. *Journal of Family Issues*, 3(4):473–491.
- Prados de la Escosura, L. (2015a). Historical Index of Human Development. Retrieved from: https://espacioinvestiga.org/00REPO/TablasExcel_HIHD_Dimensiones/_Ing/HIHD.xls.
- Prados de la Escosura, L. (2015b). World human development: 1870–2007. *Review of Income and Wealth*, 61(2):220–247.
- Pritchett, L. H. (1994). Desired fertility and the impact of population policies. *Population and Development Review*, 20(1):1–55.
- Rendall, M. S., Clarke, L., Peters, H. E., Ranjit, N., and Verropoulou, G. (1999). Incomplete reporting of men's fertility in the United States and Britain: A research note. *Demography*, 36(1):135–144.
- Rindfuss, R. R. and Bumpass, L. L. (1976). How old is too old? Age and the sociology of fertility. *Family Planning Perspectives*, 8(5):226–230.
- Rossi, P. (2019). Strategic choices in polygamous households: Theory and evidence from Senegal. *The Review of Economic Studies*, 86(3):1332–1370.
- Runganga, A. O., Sundby, J., and Aggleton, P. (2001). Culture, identity and reproductive failure in Zimbabwe. *Sexualities*, 4(3):315–332.
- Rutstein, S. O. and Shah, I. H. (2004). Infecundity infertility and childlessness in developing countries. DHS Comparative Reports. Retrieved from: <https://dhsprogram.com/pubs/pdf/CR9/CR9.pdf>.
- Schoumaker, B. (2017). Measuring male fertility rates in developing countries with Demographic and Health Surveys: An assessment of three methods. *Demographic Research*, 36:803–850.
- Schoumaker, B. (2019). Male Fertility around the World and over Time: How Different is it from Female Fertility. *Population and Development Review*, 45(3):459–487.
- Sengupta, P., Nwagha, U., Dutta, S., Krajewska-Kulak, E., and Izuka, E. (2017). Evidence for decreasing sperm count in African population from 1965 to 2015. *African Health Sciences*, 17(2):418–427.
- Shapiro, D. and Gebreselassie, T. (2014). Marriage in sub-Saharan Africa: Trends, determinants, and consequences. *Population Research and Policy Review*, 33(2):229–255.
- Smits, J. and Permayer, I. (2019). The Subnational Human Development Database. *Scientific Data*, 6.
- Snijders, T. A. and Bosker, R. J. (2011). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. Sage Publications.
- Steinbrook, R. (2008). The aids epidemic: a progress report from Mexico City. *New England Journal of Medicine*, 359(9):885–887.
- Surkyn, J. and Lesthaeghe, R. (2004). Value orientations and the second demographic transition (SDT) in Northern, Western and Southern Europe: An update. *Demographic Research*, 3:45–86.
- Tertilt, M. (2005). Polygyny, fertility, and savings. *Journal of Political Economy*, 113(6):1341–1371.
- The World Bank (2018). Fertility rate, total (births per woman) - Sub-Saharan Africa. Retrieved from: <https://data.worldbank.org/indicator/SP.DYN.TFRT.IN?locations=ZG>.
- Thornton, A. (2013). *Reading history sideways: The fallacy and enduring impact of the developmental paradigm on family life*. Chicago, IL: University of Chicago Press.
- Tsui, A. O., Brown, W., and Li, Q. (2017). Contraceptive practice in sub-Saharan Africa. *Population and Development Review*, 43(Suppl 1):166–191.

- UNDP (2015). Statistics of the Human Development Report. UNDP Human Development Report Office, New York. Retrieved from: <http://hdr.undp.org/en/statistics/>.
- United Nations Desa/Population Division (2017a). Annual population by five-year age groups - female. De facto population as of 1 July of the year indicated classified by five-year age groups (0-4, 5-9, 10-14, ..., 95-99, 100+) [data set]. Retrieved from: [https://esa.un.org/unpd/wpp/DVD/Files/1_Indicators%20\(Standard\)/EXCEL_FILES/1_Population/WPP2017_POP_F15_3_ANNUAL_POPULATION_BY_AGE_FEMALE.xlsx](https://esa.un.org/unpd/wpp/DVD/Files/1_Indicators%20(Standard)/EXCEL_FILES/1_Population/WPP2017_POP_F15_3_ANNUAL_POPULATION_BY_AGE_FEMALE.xlsx).
- United Nations Desa/Population Division (2017b). Annual population by five-year age groups - male. De facto population as of 1 July of the year indicated classified by five-year age groups (0-4, 5-9, 10-14, ..., 95-99, 100+) [data set]. Retrieved from: [https://esa.un.org/unpd/wpp/DVD/Files/1_Indicators%20\(Standard\)/EXCEL_FILES/1_Population/WPP2017_POP_F15_2_ANNUAL_POPULATION_BY_AGE_MALE.xlsx](https://esa.un.org/unpd/wpp/DVD/Files/1_Indicators%20(Standard)/EXCEL_FILES/1_Population/WPP2017_POP_F15_2_ANNUAL_POPULATION_BY_AGE_MALE.xlsx).
- United Nations Development Programme [UNDP] (2019). Human development report: Technical notes. United Nations Development Programme (UNDP) Human Development Report Office, New York. Retrieved from: http://hdr.undp.org/sites/default/files/hdr2019_technical_notes.pdf.
- United States Agency for International Development (2018). Regional HIV prevalence among young men and women, 15–24 [Data set]. Retrieved from: <https://www.statcompiler.com/en/>.
- van Balen, F. (2008). Involuntary childlessness: A neglected problem in poor-resource areas. *ESHRE Monographs*, 2008(1):25–28.
- van Balen, F. and Bos, H. M. (2009). The social and cultural consequences of being childless in poor-resource areas. *Facts, Views & Vision in ObGyn*, 1(2):106.
- van Bavel, J. (2012). The reversal of gender inequality in education, union formation, and fertility in Europe. *Vienna Yearbook of Population Research*, 10:127–154.
- van Bavel, J. and Kok, J. (2010). Pioneers of the modern lifestyle?: Childless couples in the early-twentieth-century Netherlands. *Social Science History*, 34(1):47–72.
- van de Kaa, D. J. (1996). Anchored narratives: The story and findings of half a century of research into the determinants of fertility. *Population Studies*, 50(3):389–432.
- van Leeuwen, E., Prins, J. M., Jurriaans, S., Boer, K., Reiss, P., Repping, S., and van der Veen, F. (2006). Reproduction and fertility in human immunodeficiency virus type-1 infection. *Human Reproduction Update*, 13(2):197–206.
- Westoff, C. F. (2003). Trends in marriage and early childbearing in developing countries. Calverton Maryland ORC Macro MEASURE DHS+ 2003 Jul. DHS Comparative Reports. Retrieved from: <https://www.dhsprogram.com/pubs/pdf/CR5/CR5.pdf>.
- White, I. R., Royston, P., and Wood, A. M. (2011). Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine*, 30(4):377–399.
- Wilson, C. (2011). Understanding global demographic convergence since 1950. *Population and Development Review*, 37(2):375–388.
- World Economic Forum (2018). The Global Gender Gap Report 2018. Retrieved from: http://www3.weforum.org/docs/WEF_GGGR_2018.pdf.
- World Health Organization (2014). Sexual and reproductive health: infertility is a global public health issue. Retrieved from: <http://www.who.int/reproductivehealth/topics/infertility/>.

Appendices

Appendix 2.A Authorship Statement

The study presented as written work in this chapter is co-authored with Christiaan Monden. For the co-authorship statement, please see below.

<u>Co-Authorship Declaration Form</u>
I. Student to complete:
Name: Florianne Celeste Johanna Verkroost
Thesis Title: A Computational Perspective on the Reproduction of Socio-Economic Inequalities by Parental Status and Gender
Title of Chapter which is co-authored: Childlessness and Development in Sub-Saharan Africa: Is There Evidence for a U-shaped Pattern?
2. Co-Author to complete:
Name: Christiaan Willem Simon Monden
Describe your contribution to this chapter:
<i>Florianne is the first author. We jointly formulated the main idea after my suggestion, but all empirical work and writing-up is her work.</i>
"I hereby declare that this chapter is predominantly original work by the student named above"
Signature & Date:
<i>24/1/2019</i> <i>[Signature]</i>

Appendix 2.B Countries and Original and Selected Sample Sizes

Table 2.B.1: Countries under analysis and original and selected sample sizes

Country	ISO3	Men		Women	
		Selected	Original	Selected	Original
Angola	AGO	1001	5684	1721	25940
Benin	BEN	6033	22340	9804	62031
Burkina Faso	BFA	4055	15398	8881	58102
Burundi	BDI	3072	11832	4900	35777
Cameroon	CMR	3830	15847	5095	35454
Central African Republic	CAF	415	1729	886	5884
Chad	TCO	2183	9455	4489	31258
Comoros	COM	726	2962	1179	8379
Congo	COG	2040	8291	4806	30283
Congo Democratic Republic	COD	3447	13413	4255	28822
Cote d'Ivoire	CIV	2093	8573	4637	30885
Ethiopia	ETH	11953	48126	11510	77318
Gabon	GAB	1733	5654	1611	8422
Gambia	GMB	728	3821	1173	10233
Ghana	GHA	4726	16819	7195	39046
Guinea	GIN	2226	8936	3260	23849
Kenya	KEN	8734	38424	17482	106762
Lesotho	LSO	2065	9045	3687	21340
Liberia	LBR	2121	10127	5613	34196
Madagascar	MDG	3035	11018	11147	65513
Malawi	MWI	4445	22157	12578	87012
Mali	MLI	5986	19103	10861	69037
Mozambique	MOZ	3778	14553	11703	60087
Namibia	NAM	2489	11350	5303	31998
Niger	NER	3982	12589	4876	34463
Nigeria	NGA	8389	35191	18151	103112
Rwanda	RWA	6452	27518	11243	72931
Sao Tome and Principe	STP	600	2296	506	2615
Senegal	SEN	9076	32041	18130	127331
Sierra Leone	SLE	3008	10542	4973	32533
South Africa	ZAF	1044	3618	3844	20249
Sudan	SDN			1170	5860
Swaziland	SWZ	538	4156	825	4987
Tanzania	TZA	3427	16588	18938	113298
Togo	TGO	2011	8295	4093	26083
Uganda	UGA	2797	14092	14408	85954
Zambia	ZMB	5764	25267	6560	46296
Zimbabwe	ZWE	6746	36197	8021	54224

Appendix 2.C Overview of DHS Surveys

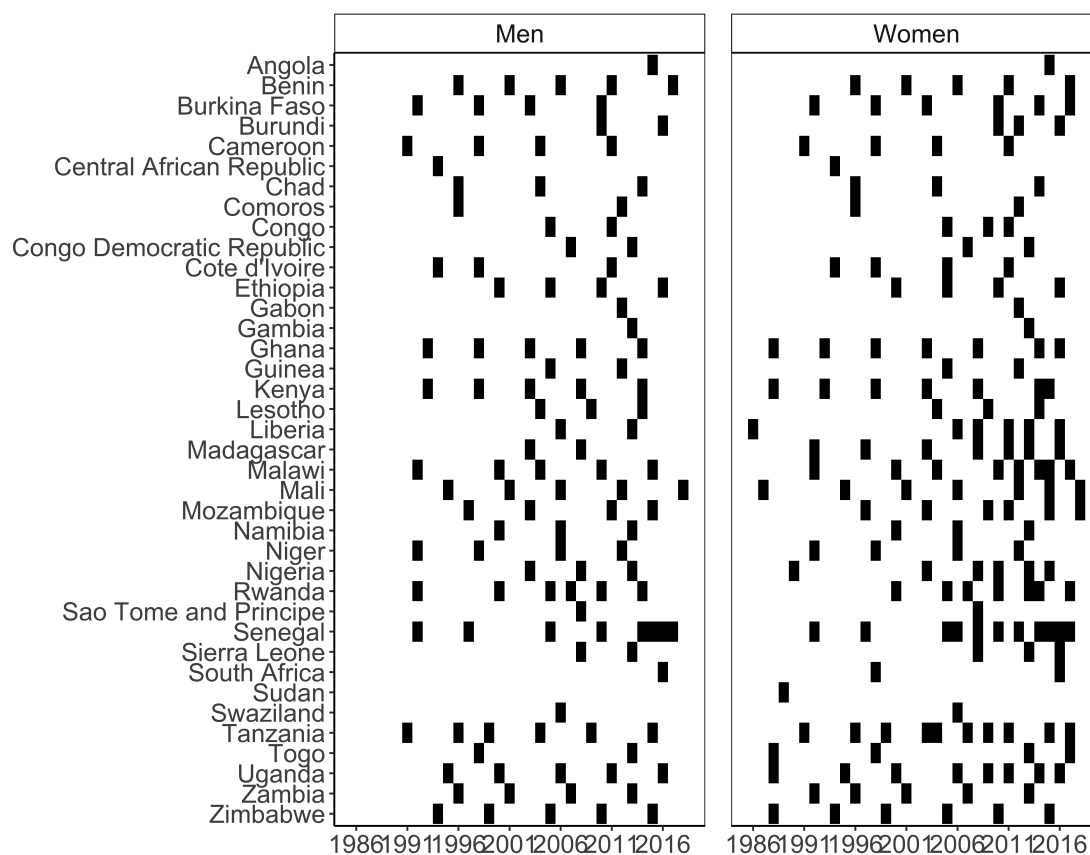


Figure 2.C.1: Overview of male and female DHS surveys (black squares indicate survey years)

Appendix 2.D Age Distributions per Country

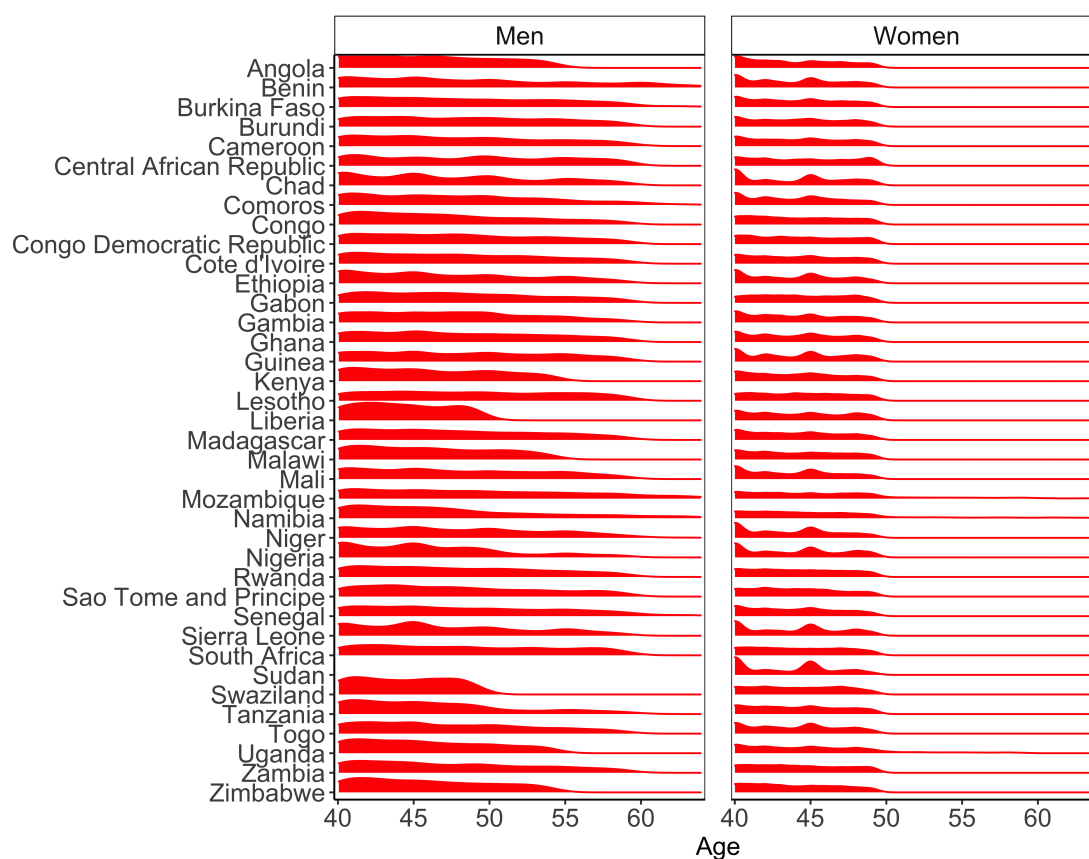


Figure 2.D.1: Distribution of male and female ages per country

Appendix 2.E Distribution of Childlessness and Age at First Birth

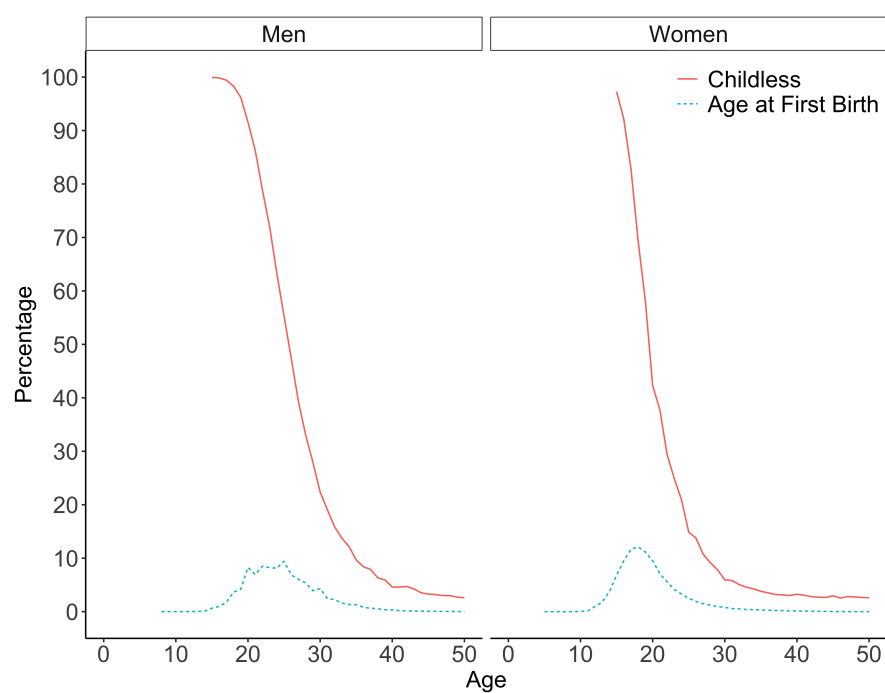


Figure 2.E.1: Distribution of male and female childlessness and age at first birth across age

Appendix 2.F Childlessness and Sample Size

Theoretically, aggregating individual-level childlessness to the percentage of childlessness in subnational region-year combinations may lead to many zeros in our dependent variable in the case of small sample sizes for region-year combinations. Figure 2.F.1 shows a scatter plot of sample sizes against childlessness percentages for unique subnational region-year combinations, and shows that there are relatively few (16% for women and 18% for men) zeros in our dependent variable and that these are not necessarily due to aggregation of data from small samples, as the zeros range between sample sizes of 1 and 265.

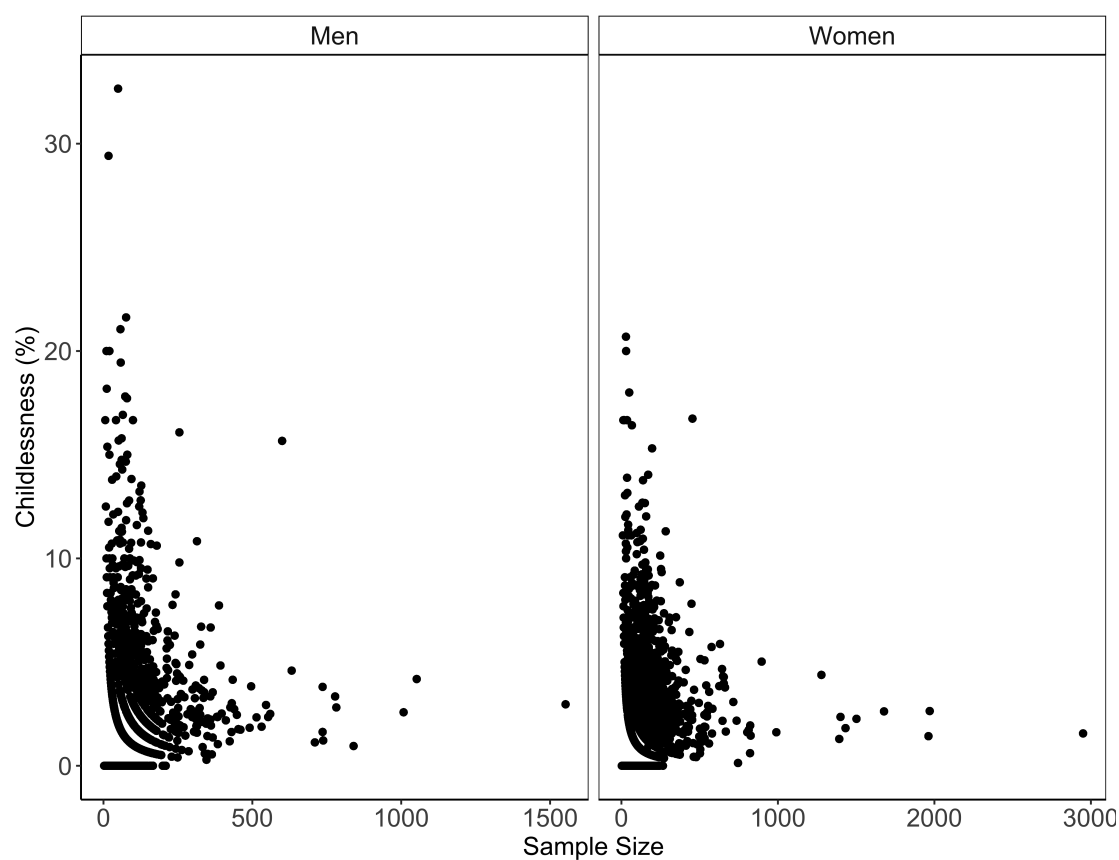


Figure 2.F.1: Scatter plot of sample sizes and childlessness levels (each point represents a unique subnational region-year combination)

Appendix 2.G Trends of SHIHD

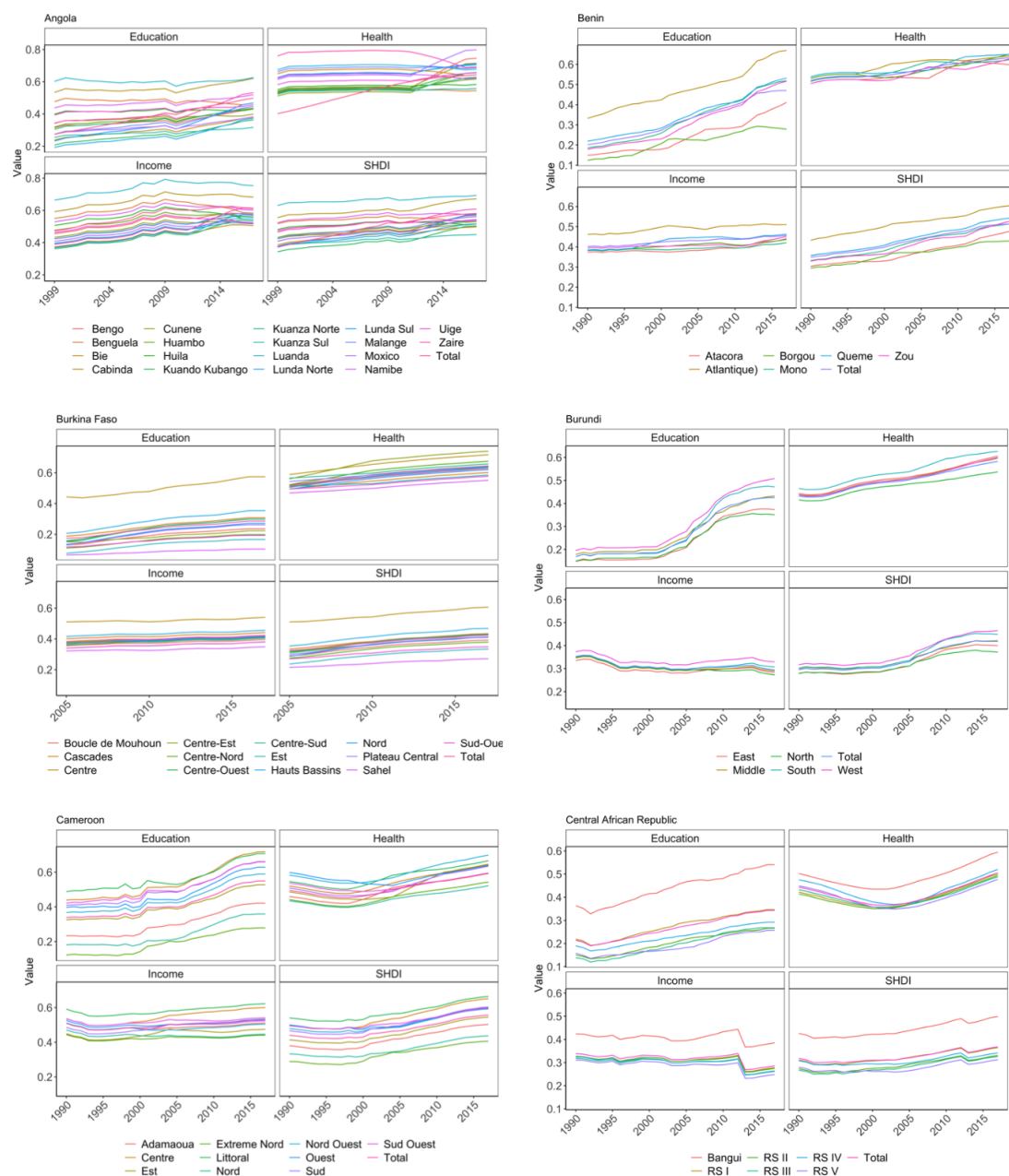


Figure 2.G.1: SHDI trends per component by country and subnational region

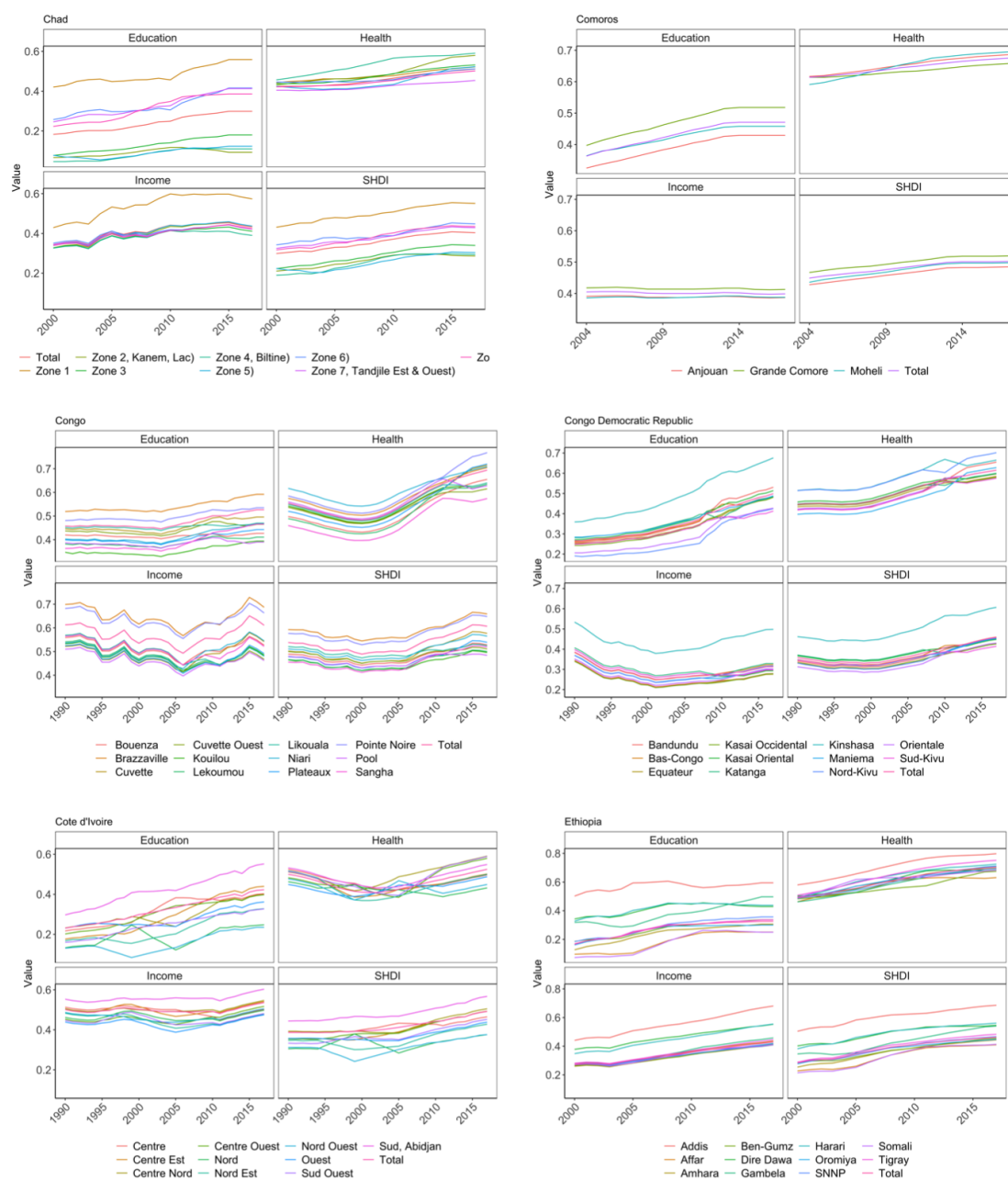


Figure 2.G.1 (cont.): (continued) SHDI trends per component by country and subnational region

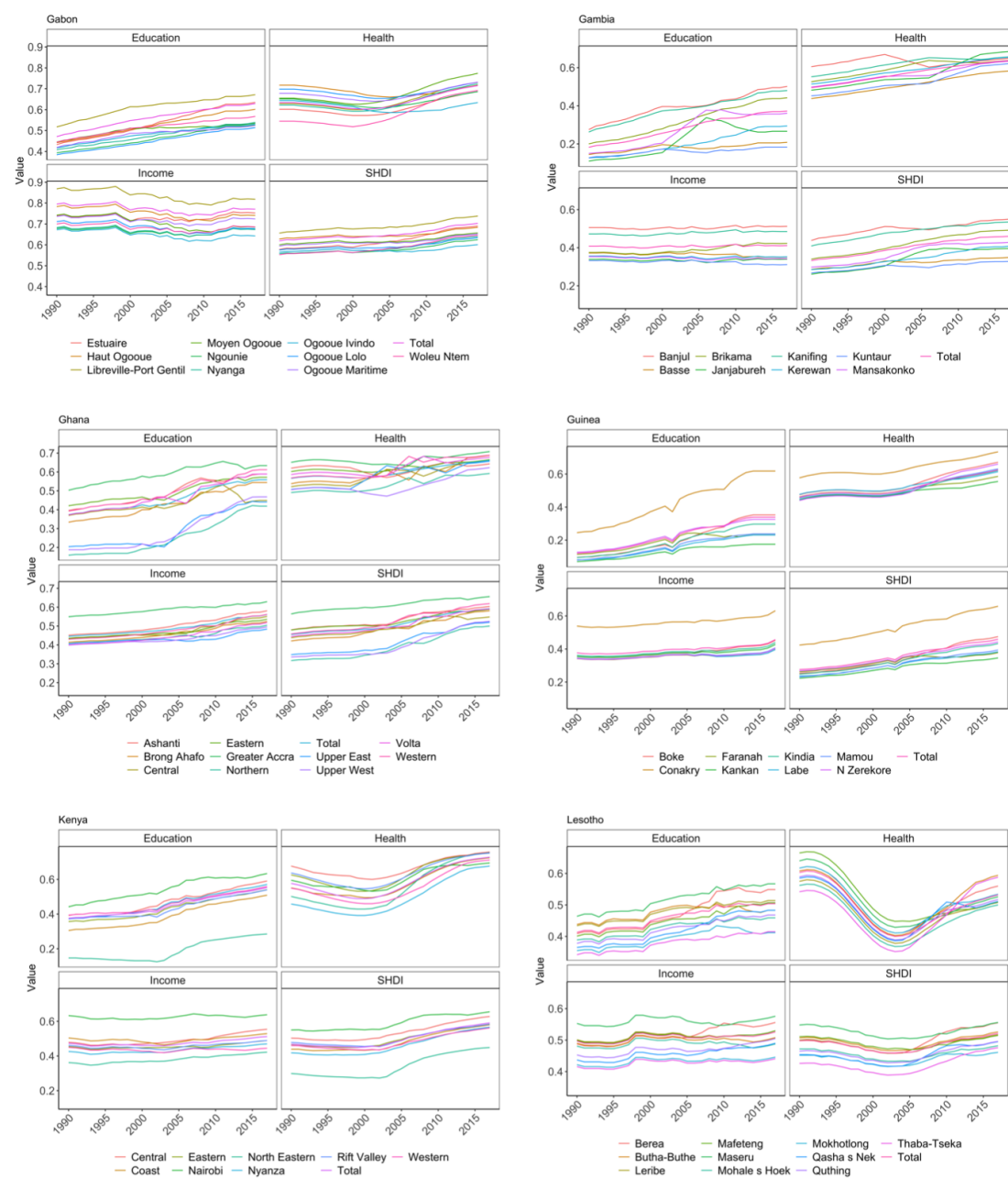


Figure 2.G.1 (cont.): (continued) SHDI trends per component by country and sub-national region

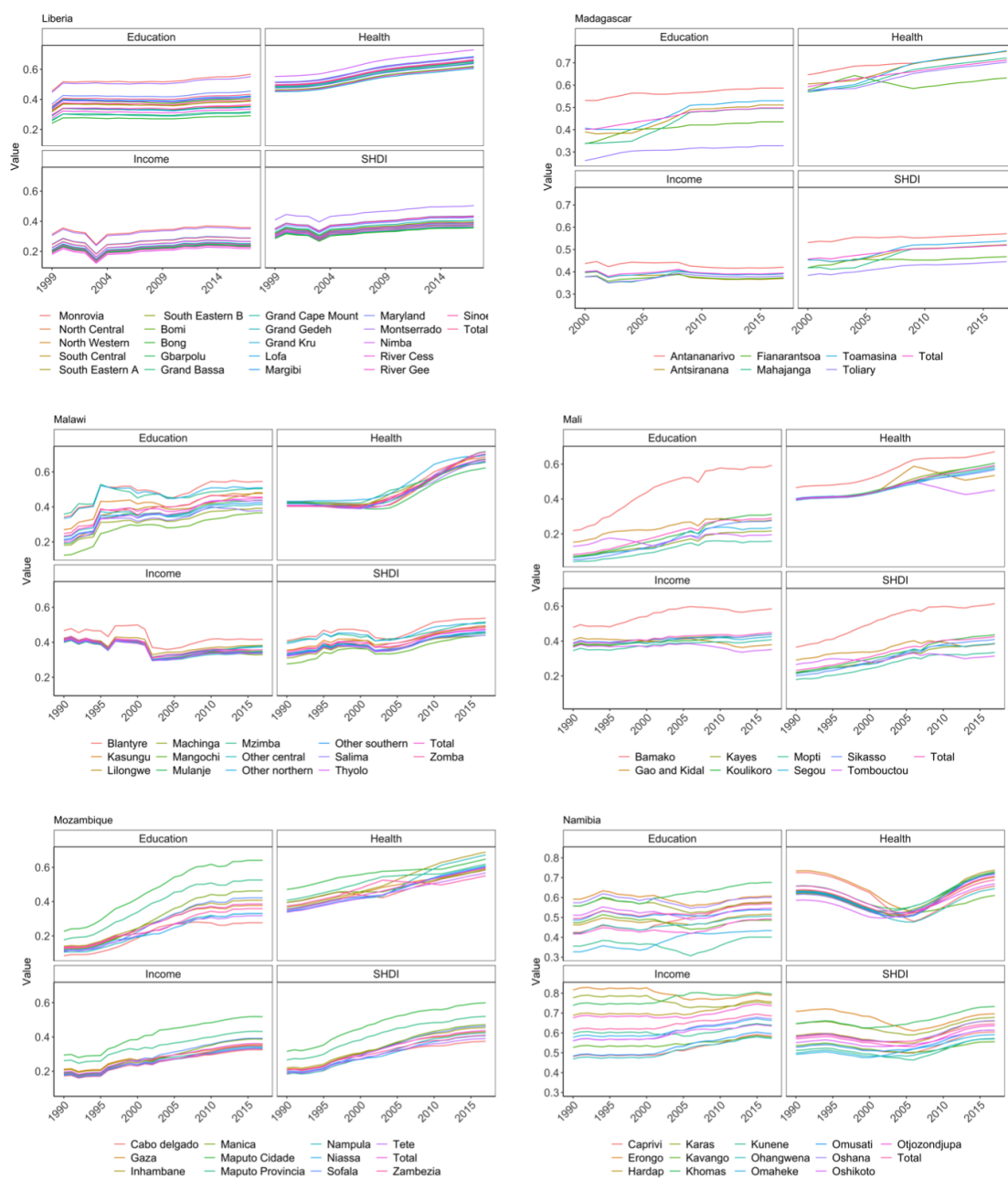


Figure 2.G.1 (cont.): (continued) SHDI trends per component by country and subnational region

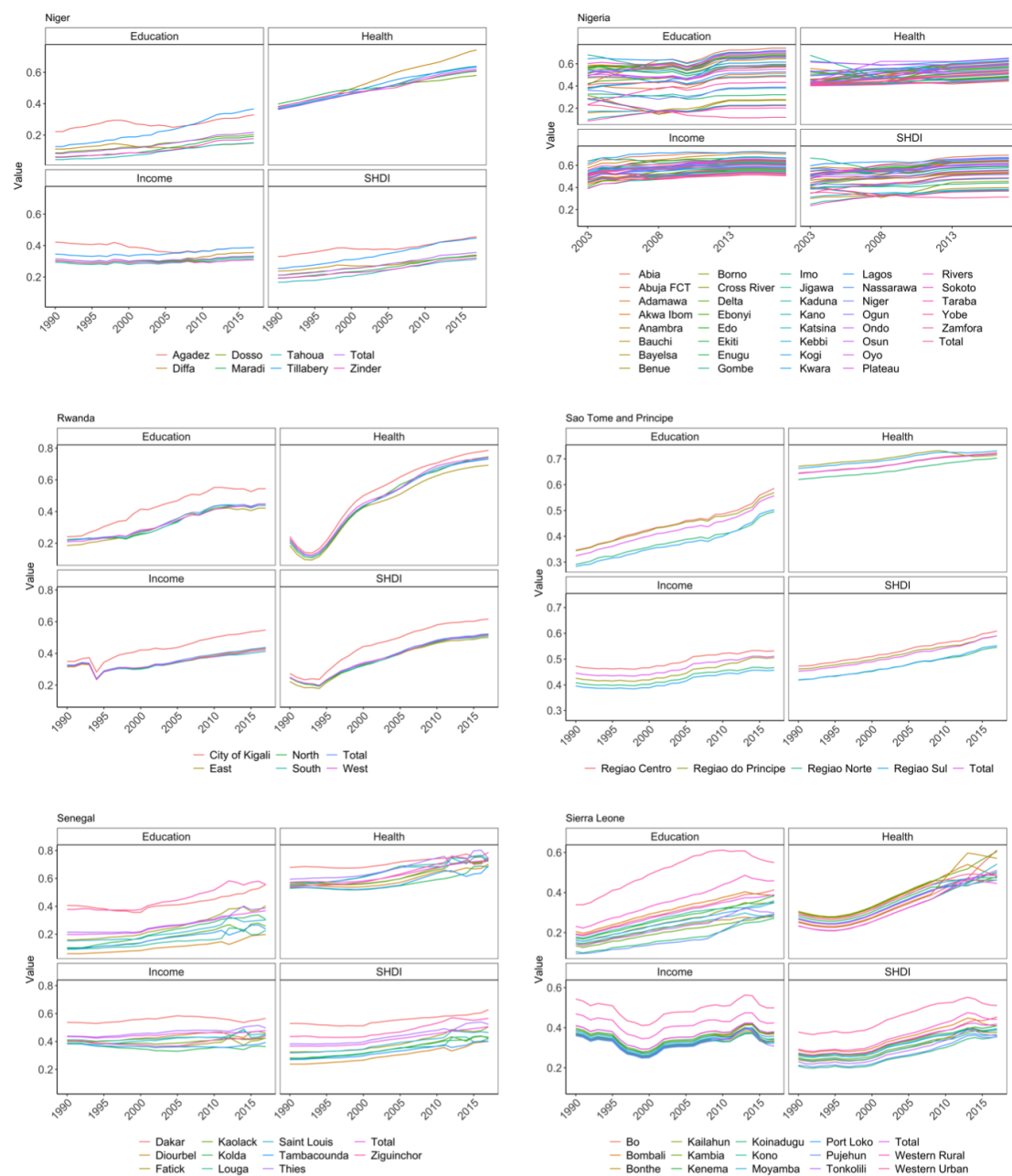


Figure 2.G.1 (cont.): (continued) SHDI trends per component by country and subnational region

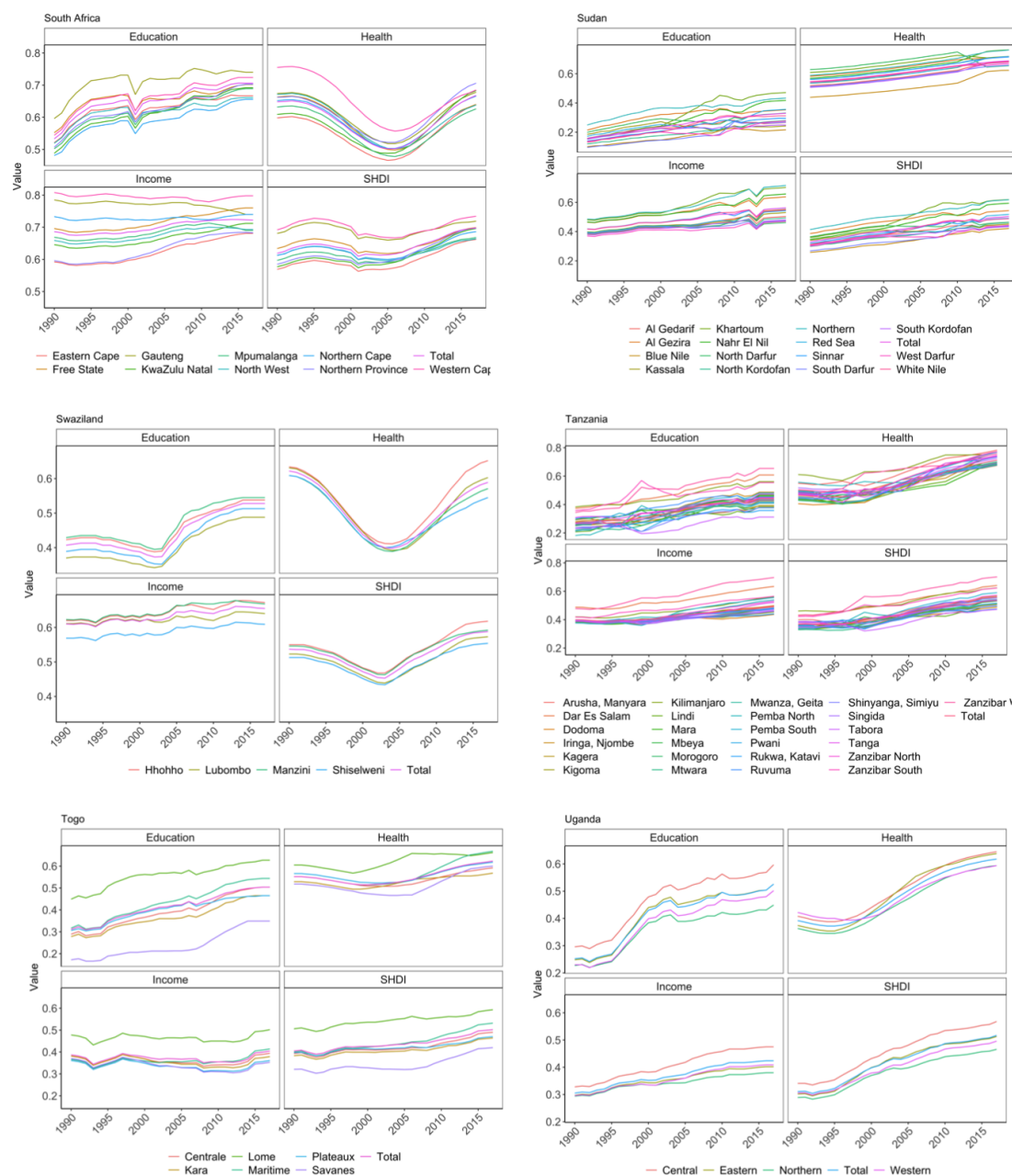


Figure 2.G.1 (cont.): (continued) SHDI trends per component by country and sub-national region

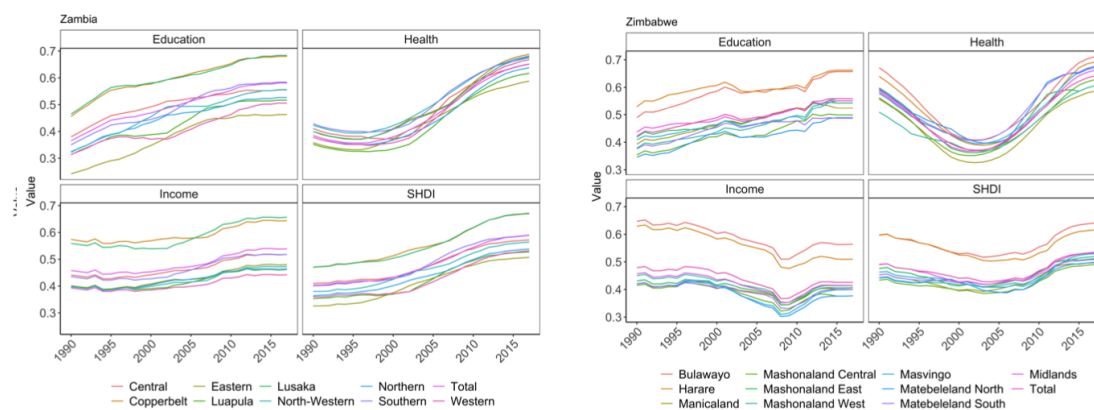


Figure 2.G.1 (cont.): (continued) SHDI trends per component by country and sub-national region

Appendix 2.H Trends of HIHD and Components for sub-Saharan Africa

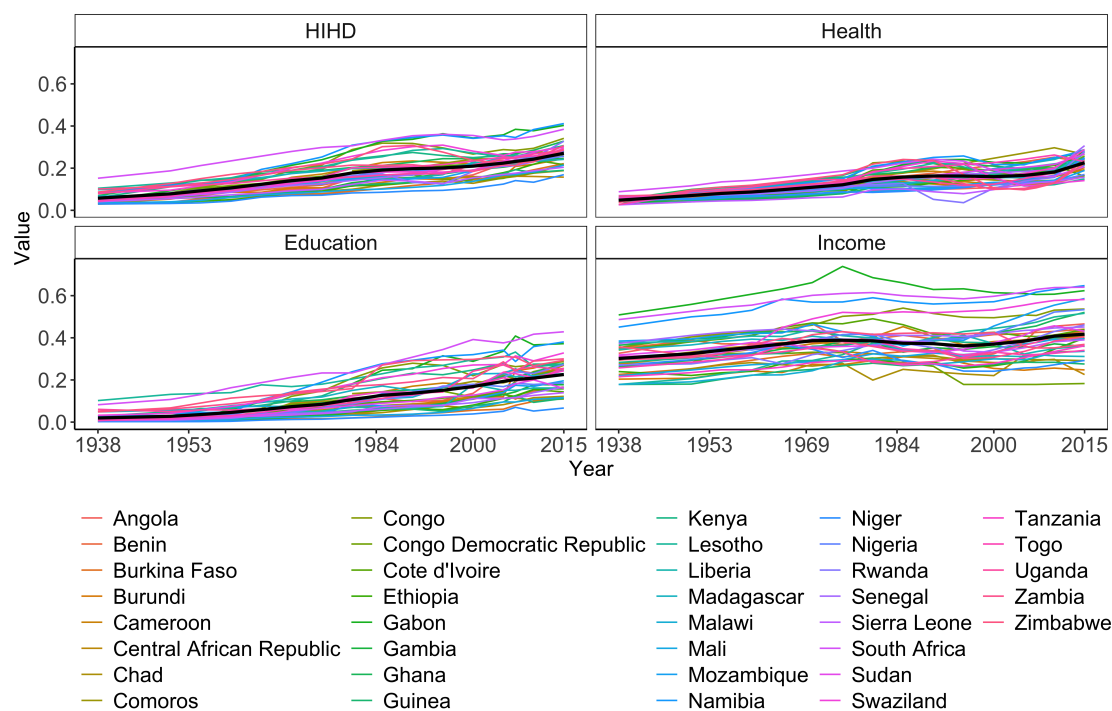


Figure 2.H.1: Trend of the HIHD and its components by country (black line shows unweighted average across sub-Saharan African countries)

Appendix 2.I Missingness in the Data

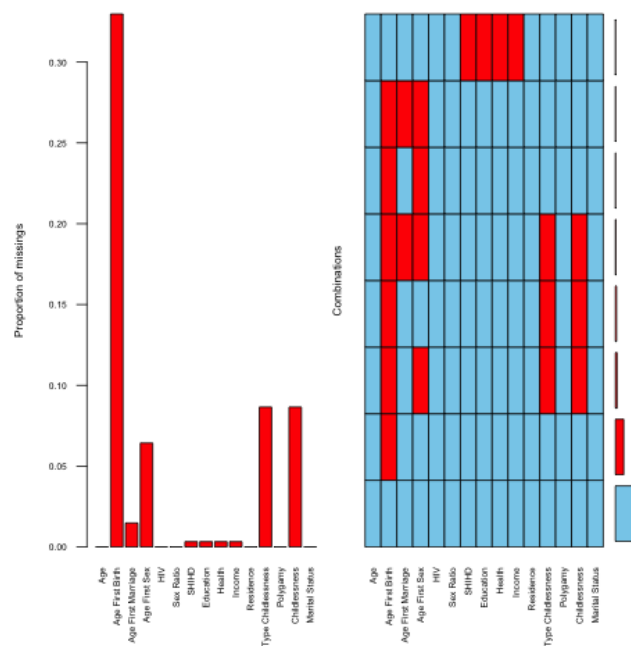


Figure 2.I.1: Aggregation plot for missingness in male data

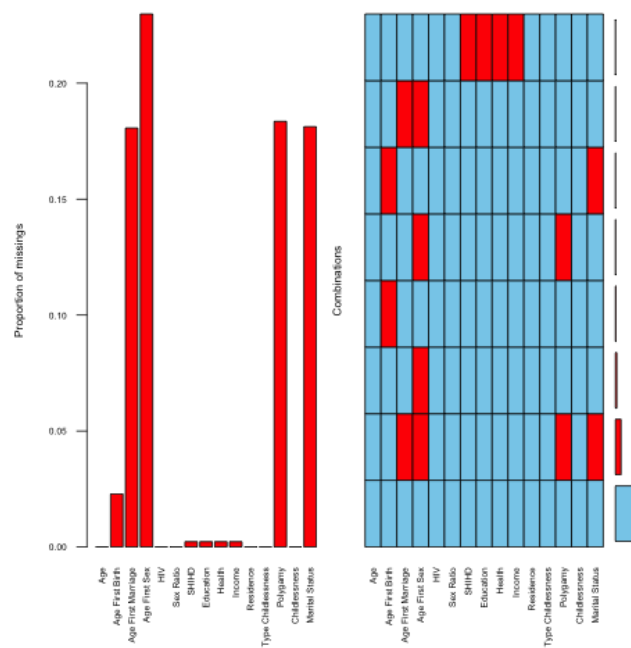


Figure 2.I.2: Aggregation plot for missingness in female data

Appendix 2.J Pooling Strategy for Hierarchical Regression Results after Multiple Imputation

We impute our data $M = 34$ and $M = 28$ times respectively for men and women, approximately equalling the percentage of incomplete observations as recommended by [Bodner \(2008\)](#); [White et al. \(2011\)](#). We run each of the aforementioned models on each of these M imputed data sets and we pool the results by taking the mean of the resulting M k -length vectors of coefficients $\underline{\pi}_1^*, \underline{\pi}_2^*, \dots, \underline{\pi}_M^*$ as

$$\underline{\hat{\pi}}^* = \frac{1}{M} \sum_{i=1}^M \underline{\pi}_i^* \quad (2.7)$$

and by computing the pooled variance as

$$\begin{aligned} \underline{\hat{V}}^* &= \underline{\hat{W}}^* + \frac{M+1}{M} \underline{\hat{B}}^* \\ &= \frac{1}{M} \sum_{i=1}^M \underline{U}_i^* + \frac{M+1}{M} \frac{1}{M-1} \sum_{i=1}^M (\underline{\pi}_i^* - \underline{\hat{\pi}}^*)^2 \end{aligned} \quad (2.8)$$

where $\underline{\hat{W}}^*$ is the average within-imputation variance; $\underline{U}_i^*$ is the within-imputation variance (i.e. the variance of $\underline{\pi}$ that would be observed if the imputed data would be the true observed data); and $\underline{\hat{B}}^*$ is the between-imputation variance. Note that $\underline{\hat{V}}^*, \underline{\hat{W}}^*$ and $\underline{\hat{B}}^*$ are vectors of length k . We further adjust the distribution of $\underline{\hat{\pi}}^*$ for small sample sizes as recommended by [Barnard and Rubin \(1999\)](#) by basing the inference for the coefficient of variable $j = 1, \dots, k$ on a t-distribution rather than asymptotic normal distribution using

$$\tilde{v}_{M,j} = \frac{\frac{M-1}{\gamma_{M,j}^2} v_{obs,j}}{\frac{M-1}{\gamma_{M,j}^2} + v_{obs,j}} \quad (2.9)$$

degrees of freedom, where

$$v_{obs,j} = \frac{v_{comp} + 1}{v_{comp} + 3} v_{comp} (1 - \hat{\gamma}_{M,j}) \quad (2.10)$$

denotes the estimated observed-data degrees of freedom with $v_{comp} = n - k - 1$ the complete-data degrees of freedom and $\hat{\gamma}_{M,j} = \frac{M}{M+1} \frac{\hat{B}_{jj}^*}{\hat{V}_{jj}^*}$ the estimated proportion of missing information for the j^{th} variable.

Appendix 2.K Computation of Orthogonal Polynomials

For a vector $\underline{x}$ of length n , we can generate monic orthogonal polynomials of degree d , $P_0(\underline{x}), P_1(\underline{x}), \dots, P_d(\underline{x})$, as follows (Kennedy and Gentle, 1980, p. 343-344):

1. Center $\underline{x}$ by its mean as $\underline{x} = \underline{x} - \bar{\underline{x}}$.
2. Set $P_{-1}(\underline{x}) = 0, P_0(\underline{x}) = 1, P_1(\underline{x}) = \underline{x}$ (notice the orthogonality here).
3. For $i = 0, 1, \dots, d$, define $l_i = \langle P_i(\underline{x}), P_i(\underline{x}) \rangle$ and $\alpha_i = \frac{\langle P_i^2(\underline{x}), \underline{x} \rangle}{l_i}$ and for $i = 1, 2, \dots, d$ define $\beta_i = \frac{l_i}{l_{i-1}}$.
4. For $i = 2, 3, \dots, d$ derive $P_i(\underline{x})$ as $P_i(\underline{x}) = (x - \alpha_{i-1})P_{i-1}(\underline{x}) - \beta_{i-1}P_{i-2}(\underline{x})$.
5. For $i = 0, 1, \dots, d$ scale $P_i(\underline{x})$: $P_i(\underline{x}) = \frac{P_i(\underline{x})}{\sqrt{l_i}}$.
6. Use $P_1(\underline{x}), P_2(\underline{x}), \dots, P_d(\underline{x})$ as regressors.

Appendix 2.L Correlation Between Independent Variables

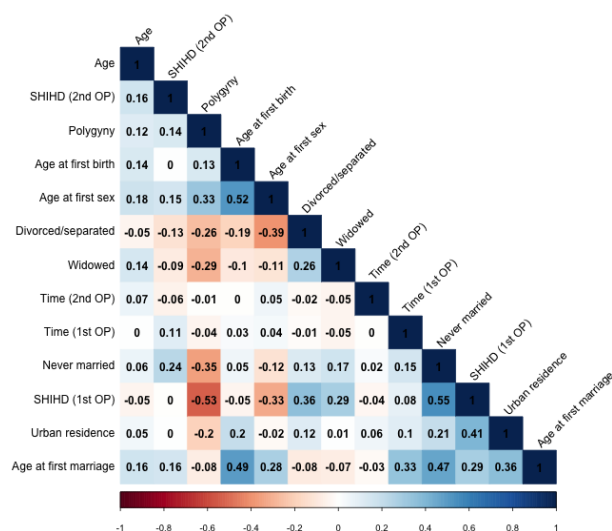


Figure 2.L.1: Correlation between independent variables in male data

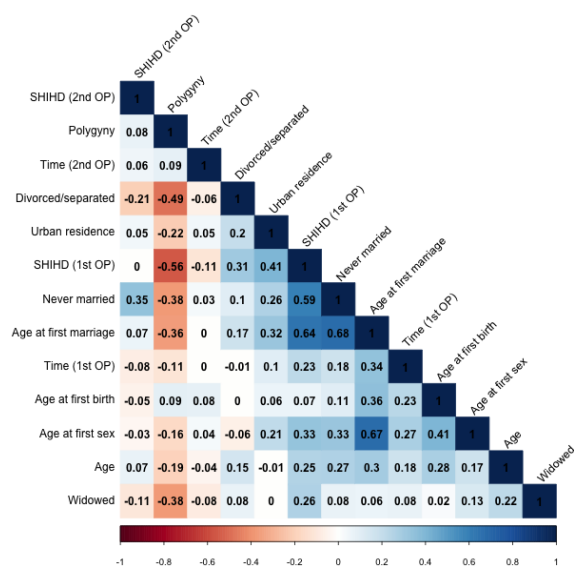


Figure 2.L.2: Correlation between independent variables in female data

Appendix 2.M Childlessness Trends by Country, Gender and Type

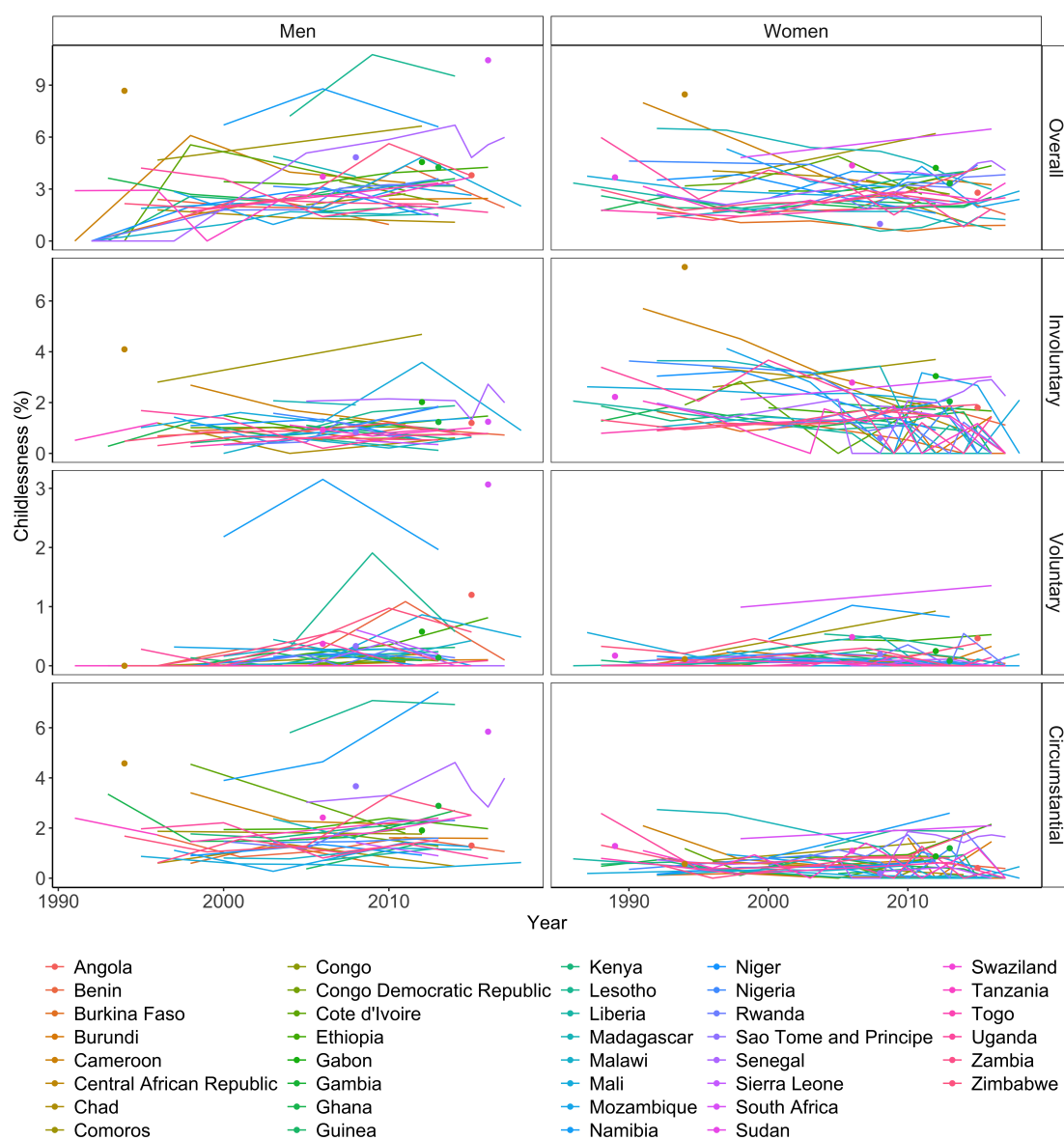


Figure 2.M.1: National trends in overall, involuntary, voluntary and circumstantial childlessness by country and gender

Appendix 2.N Goodness-of-Fit Measures for Sub-National-Level Models

Table 2.N.1 shows the linear and quadratic goodness-of-fit measures for the national-level bivariate regression with the percentage of childlessness as the dependent variable and the second-order orthogonal polynomials of the SHIHD term as the independent variables. The p-values shown in the table refer to the p-values resulting from ANOVA used to compare linear models against their quadratic counterparts, with a significance threshold of 0.001.

Table 2.N.1: Goodness-of-fit measures and ANOVA p-values for national-level bivariate models for childlessness and SHIHD

Component	Fit	Men				Women			
		AIC	BIC	RMSE	P-value	AIC	BIC	RMSE	P-value
SHIHD	Linear	445.484	453.530	1.851		575.401	584.700	1.373	
	Quadratic	442.681	453.409	1.810	0.031	574.411	586.810	1.361	0.087
Education	Linear	449.736	457.782	1.888		575.754	585.053	1.375	
	Quadratic	442.240	452.968	1.807	0.002	573.994	586.394	1.359	0.055
life expectancy	Linear	451.978	460.024	1.907		578.914	588.214	1.388	
	Quadratic	450.324	461.053	1.875	0.060	576.542	588.942	1.369	0.039
Income	Linear	449.427	457.473	1.885		566.129	575.428	1.335	
	Quadratic	450.172	460.901	1.874	0.271	567.828	580.228	1.334	0.588

Table 2.N.2 shows the linear and quadratic goodness-of-fit measures for the subnational-level bivariate regression with the percentage of childlessness as the dependent variable and orthogonal polynomial terms of SHIHD as the independent variable(s). The p-values shown in the table refer to the p-values resulting from ANOVA used to compare linear models against their quadratic counterparts.

Table 2.N.2: Goodness-of-fit measures and ANOVA p-values for subnational-level bivariate models for childlessness and SHIHD

Component	Fit	Men				Women			
		AIC	BIC	RMSE	P-value	AIC	BIC	RMSE	P-value
SHIHD	Linear	5886.668	5901.688	3.471		8325.861	8342.255	2.625	
	Quadratic	5879.635	5899.662	3.457	0.003	8316.169	8338.027	2.616	0.001
Education	Linear	5908.421	5923.441	3.505		8332.759	8349.152	2.630	
	Quadratic	5892.644	5912.670	3.477	0.000	8319.850	8341.708	2.619	0.000
life expectancy	Linear	5925.342	5940.362	3.532		8357.599	8373.992	2.649	
	Quadratic	5923.063	5943.089	3.525	0.039	8346.887	8368.745	2.639	0.000
Income	Linear	5927.555	5942.575	3.536		8275.367	8291.761	2.587	
	Quadratic	5929.180	5949.207	3.535	0.541	8276.987	8298.845	2.587	0.538

Table 2.N.3 shows the linear and quadratic goodness-of-fit measures for the subnational-level multivariate regression with the percentage of childlessness as the dependent variable.

Table 2.N.3: Goodness-of-fit measures for subnational-level multivariate models for childlessness

Model	Fit	Men				Women			
		AIC	BIC	RMSE	P-value	AIC	BIC	RMSE	P-value
SHIHD	Linear	-4927.427	-4891.721	0.030		-8010.891	-7972.623	0.023	
	Quadratic	-4916.195	-4854.985	0.029	0.002	-8097.594	-8031.992	0.022	0.000
Age & Residence	Linear	-4907.640	-4861.732	0.030		-7997.235	-7948.034	0.023	
	Quadratic	-4896.052	-4824.641	0.029	0.003	-8081.931	-8005.396	0.022	0.000
Marriage & Postponement	Linear	-5191.312	-5125.001	0.026		-7974.960	-7903.892	0.023	
	Quadratic	-5175.319	-5083.503	0.026	0.903	-8060.544	-7962.141	0.022	0.000
Polygyny, HIV & Sex Ratio	Linear	-4914.396	-4863.388	0.029		-8002.168	-7947.500	0.023	
	Quadratic	-4900.304	-4823.792	0.029	0.089	-8089.681	-8007.679	0.022	0.000
Total	Linear	-5141.966	-5050.151	0.026		-7945.014	-7846.612	0.022	
	Quadratic	-5125.666	-5008.346	0.026	0.992	-8018.600	-7892.864	0.022	0.000

Appendix 2.O Model Comparison for Basic Models

Table 2.O.1 shows the goodness-of-fit measures for the subnational-level univariate basic models used to build the hierarchical model. The *intercept* model predicts childlessness with only a fixed intercept; the *randomIntercept* model predicts childlessness with an intercept allowed to vary across countries; the *shihdRI* model adds a first-order SHIHD orthogonal polynomial term to the *randomIntercept* model; the *shihdRS* model additionally allows the effect of a first-order SHIHD orthogonal polynomial term to vary across countries; and the *shihdQ* model is the same as *shihdRS* model but then with second-order orthogonal polynomials of the SHIHD term. As the random effects specifications for the models in Table 2.O.1 differ, we have compared model fits between two models A and B by executing a χ^2 -test with two degrees of freedom and as parameter the difference between the $-2 \cdot \log$ -likelihood of models A and B. As adding the second-order orthogonal polynomial term for SHIHD does not significantly improve the model for men, we fit our hierarchical models linearly for men.

Table 2.O.1: Goodness-of-fit measures and χ^2 p-values for basic univariate models

Model	Men				Women			
	AIC	BIC	RMSE	P-value	AIC	BIC	RMSE	P-value
intercept	-4572.314	-4562.112	0.037		-7733.605	-7722.671	0.026	
randomIntercept	-4825.503	-4810.200	0.031	0.000	-7922.381	-7905.981	0.024	0.000
shihdRI	-4905.384	-4884.981	0.030	0.000	-7934.131	-7912.264	0.024	0.001
shihdRS	-4933.597	-4902.992	0.030	0.000	-8004.982	-7972.182	0.023	0.000
shihdQ	-4927.688	-4876.680	0.029	0.351	-8103.317	-8048.649	0.022	0.000

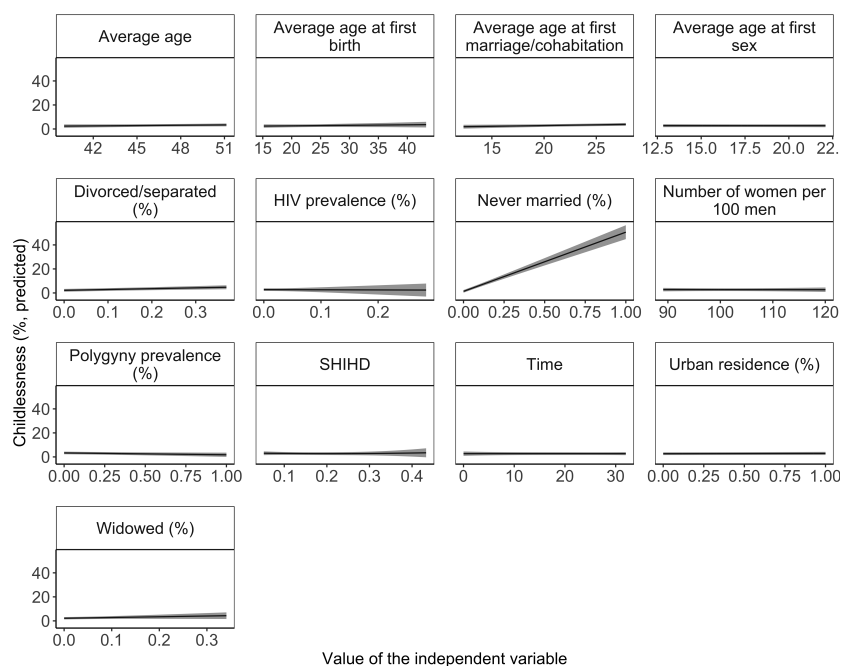
Appendix 2.P Random Effects for Hierarchical Models

The random effects of the total male and female models (M5) in Table 2.P.1 show that while the baseline childlessness level hardly varies across countries, the effects of the linear (and, in the case of women, quadratic) SHIHD terms vary quite substantially across countries. Further, there is a positive correlation between the baseline childlessness level and the effect of the first- and, in the case of females, second-order orthogonal polynomial terms, suggesting that the effect of SHIHD is larger for countries where the baseline childlessness level is higher. Finally, there is a positive correlation between the effects of the linear and quadratic terms of SHIHD amongst women.

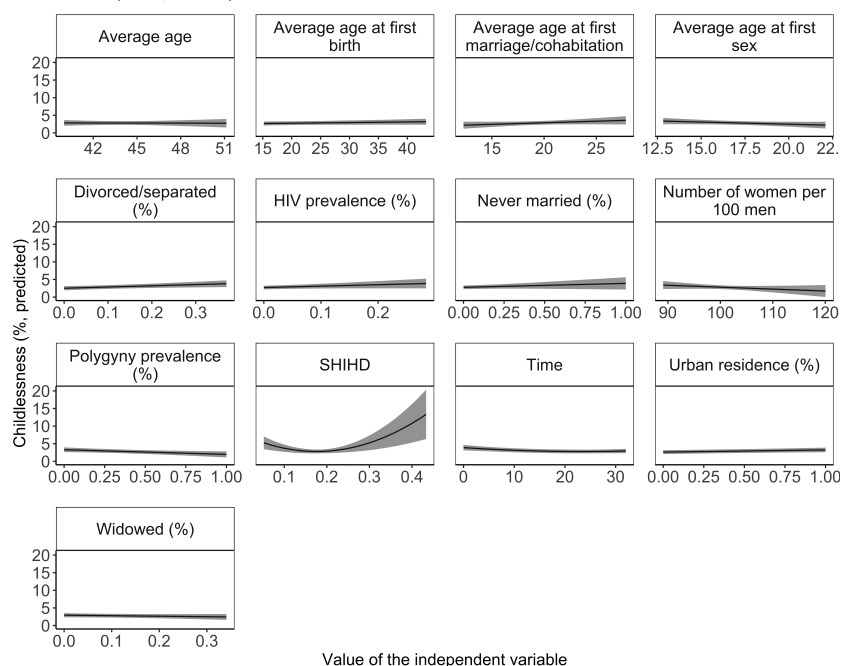
Table 2.P.1: Random effects for subnational-level multivariate total models for childlessness (M5)

Group	Variable 1	Variable 2	Men			Women		
			Var.	St. Dev.	Corr.	Var.	St. Dev.	Corr.
Country	Intercept		0.000	0.009		0.000	0.015	
Country	SHIHD (1 st order polynomial)		0.046	0.213		0.556	0.746	
Country	SHIHD (2 nd order polynomial)					0.156	0.395	
Country	Intercept	SHIHD (1 st order polynomial)	0.001	0.555	0.702	0.003	0.228	0.170
Country	Intercept	SHIHD (2 nd order polynomial)				0.003	0.472	0.441
Country	SHIHD (1 st order polynomial)	SHIHD (2 nd order polynomial)				0.194	0.659	0.735
Residual			0.001	0.027		0.000	0.022	

Appendix 2.Q Marginal Effects of Independent Variables on Childlessness



(a) Marginal effect on childlessness of each independent variable from full control model M5 (men, linear)



(b) Marginal effect on childlessness of each independent variable from full control model M5 (women, quadratic)

Figure 2.Q.1: Marginal effect on childlessness of each independent variable from full control model M5

Appendix 2.R Bivariate Regression Results for Types of Childlessness and development Components

Table 2.R.1: Regression coefficients of the subnational regional-level bivariate models estimating childlessness types from development components for men and women

Component	Coefficient	Men (N = 1,104)			Women (N = 1,745)		
		Involuntary	Voluntary	Circumstantial	Involuntary	Voluntary	Circumstantial
Education	Intercept	0.011*** (0.001)	0.003*** (0.000)	0.021*** (0.001)	0.015*** (0.000)	0.001*** (0.000)	0.006*** (0.000)
	poly(Education, 1)	0.031+ (0.017)	0.098*** (0.010)	0.296*** (0.025)	-0.073*** (0.019)	0.033*** (0.004)	0.113*** (0.011)
	AIC	-5849.414	-6928.039	-4993.595	-8905.145	-14083.404	-10681.836
	BIC	-5834.394	-6913.018	-4978.575	-8888.751	-14067.010	-10665.442
	RMSE	0.017	0.010	0.025	0.019	0.004	0.011
Income	Intercept	0.011*** (0.001)	0.003*** (0)	0.021*** (0.001)	0.015*** (0)	0.001*** (0)	0.006*** (0)
	poly(Income, 1)	0.055** (0.017)	0.107*** (0.010)	0.237*** (0.026)	0.071*** (0.019)	0.040*** (0.004)	0.107*** (0.011)
	AIC	-5856.538	-6945.046	-4945.349	-8904.525	-14112.250	-10671.220
	BIC	-5841.518	-6930.026	-4930.329	-8888.131	-14095.856	-10654.827
	RMSE	0.017	0.010	0.026	0.019	0.004	0.011
Life expectancy	Intercept	0.011*** (0.001)	0.003*** (0.000)	0.021*** (0.001)	0.015*** (0.000)	0.001*** (0.000)	0.006*** (0.000)
	poly(Life expectancy, 1)	0.027 (0.017)	0.084*** (0.011)	0.288*** (0.025)	-0.052** (0.019)	0.025*** (0.004)	0.074*** (0.012)
	AIC	-5848.650	-6905.219	-4986.693	-8897.880	-14058.215	-10625.295
	BIC	-5833.630	-6890.199	-4971.673	-8881.486	-14041.822	-10608.901
	RMSE	0.017	0.011	0.025	0.019	0.004	0.012

Note:

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Chapter 3

A Bayesian Multivariate Hierarchical Growth Curve Model of Cumulative Socio-economic (Dis)advantage amongst Childless Adults and Parents¹

Abstract

Childlessness and socio-economic well-being interact dynamically throughout the life course, possibly resulting in an accumulation of socio-economic (dis)advantage. Methods commonly used to investigate this hypothesis are unable to simultaneously acknowledge that childlessness entails a heterogeneous and processual ‘non-event’ which interrelates with multiple life domains. I use Bayesian hierarchical growth curve modelling to facilitate synchronous incorporation of these substantive complexities. I construct prospective interdependent life course trajectories of socio-economic well-being for eventual parents and permanently childless adults, distinguishing voluntary, involuntary, circumstantial and indecisive childlessness. Using the 1970 British Cohort Study, I find that parents and voluntarily childless adults are more satisfied with life than non-voluntarily childless adults. Voluntarily and circumstantially childless women earn most and mothers least, while fathers earn more than childless men. Economic and male social (dis)advantage accumulate throughout the life course. Group differences in partnerships, employment, education and health, more than childbearing behaviours themselves, explain the (growth of) these socio-economic differentials. The findings have implications for policies addressing socio-economic inequalities by both parental status and gender. The proposed approach provides valuable for assessing cumulative (dis)advantage in interrelated life domains via an unclearly marked heterogeneous process, not only in the context of childlessness but also other life course topics.

Keywords Bayesian Multivariate Hierarchical Growth Curve Model · Life Course Trajectories · Cumulative (Dis)advantage · Childlessness · Socio-economic Well-being · Gender

¹A version of this chapter has been published as: Verkroost, F. C. J. (2022). A Bayesian multivariate hierarchical growth curve model to examine cumulative socio-economic (dis) advantage among childless adults and parents. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 185(4), 2234–2276. DOI: <https://doi.org/10.1111/rssa.12917>.

3.1 Introduction

Substantial increases in permanent childlessness worldwide have gained growing interest from sociological and demographic researchers and policy makers over the past decades. In the United Kingdom (UK), for instance, childlessness rates have doubled from approximately 10% amongst women born in 1945 to 20% amongst the 1965 female birth cohort (Sobotka, 2017). Increasing differences in childbearing outcomes may contribute to the reproduction of socio-economic inequalities over the life course. That is, the association between (foregoing) childbearing and socio-economic well-being (SEWB) may be bidirectional (Bijlsma and Wilson, 2020; Plotnick, 2009; Umberson et al., 2010), and its direction might depend on the life course stage. In other words, SEWB may influence childbearing intentions and behaviours earlier in life, and childbearing outcomes may in turn influence SEWB in later life. As a result, socio-economic (dis)advantage, and thus inequality, may accumulate throughout the life course via childbearing behaviours (Elder Jr et al., 2003). To illustrate, lower-earning women might accumulate earnings disadvantage over the life course compared to highly earning women, because they may first be selected into motherhood via lower opportunity cost of having children (Becker, 1981), and then face a further earnings disadvantage by interrupting their career to bear children (Gangl and Ziefle, 2009). On the other hand, unhappier men with lower earnings potential may more likely remain childless than happier and highly earning men because of struggling to find a mating partner in largely hypergamous marriage markets (e.g. Jalovaara and Fasang, 2017; Tanturri and Mencarini, 2008), and may face further SEWB deficits as a consequence of remaining single and being disadvantaged by male marriage and/or fatherhood premiums (e.g. Keizer and Ivanova, 2017; Killewald, 2013; Kohler et al., 2005).

An accurate and holistic overview of cumulative socio-economic (dis)advantage (CSEAD) and the role childbearing behaviours play in this process has been lacking, however. This is mainly because an accurate model of the relationship between childlessness and SEWB needs to satisfy a number of requirements based on substantive and conceptual features of the problem at hand, and commonly applied methodologies in the field are unable to facilitate the simultaneous consideration of these features altogether. For instance, childlessness and its relationship with socio-economic well-being (SEWB) should be conceptualised as a dynamic and continuous interplay over longer periods of the life course (Abbott, 2005; Giele and Elder Jr, 1998). Cross-sectional research designs, which have dominated the field, are unable to do so given that they focus on specific events (e.g. Elder Jr et al., 2003; Umberson et al., 2010). Longitudinal studies, on the other hand, have mostly focused on either examining the pathways into childlessness (e.g. Hagestad and Call, 2007; Keizer et al., 2008; Raab and Struffolino, 2020) or the (old-age) consequences of having remained childless (Cwikel et al., 2006; Koropecj-Cox and Call, 2007;

Tanturri et al., 2008). However, the life course paradigm of *life-span development* asserts that past experiences shape current and future events (Elder Jr et al., 2003; Kok, 2007). As such, this “developmental impact of a succession of life transitions” (Elder Jr, 1998, p. 3) may contribute to the accumulation of (dis)advantage over the life course (Elder Jr et al., 2003). It is therefore crucial to examine SEWB before, during and after the process of remaining childless within the same individuals. Hereby, an accurate model of the relationship between childlessness and SEWB would similarly need to acknowledge that childlessness is often not a clearly marked event, but rather a process of “a sequence of socially defined events and roles that the individual enacts over time” (Abbott, 2005; Giele and Elder Jr, 1998, p. 22) which becomes definitive only towards the end of the reproductive period (Keizer et al., 2009).

The process of remaining childless is often varied and complex in nature as well (e.g. Berrington, 2017): while some individuals may choose early on not to have children, others anticipate becoming parents but turn out to be infertile, never meet someone to have children with, or ‘perpetually’ postpone childbearing until they can no longer have children. Therefore, a complete and consistent picture of the relationship between childlessness and SEWB would need to acknowledge the heterogeneity in the group of childless individuals, not only by reason for childlessness but also gender (e.g. Raab and Struffolino, 2020). Nonetheless, the majority of life course studies examining socio-economic differentials between childless adults and parents consider a variety of family trajectories and pathways into childlessness, but do not necessarily distinguish between different reasons for childlessness explicitly (e.g. Comolli et al., 2021; Jalovaara and Fasang, 2020; Kahn et al., 2014; Mynarska et al., 2015; Van Winkle and Fasang, 2020), albeit with some exceptions (e.g. Buhr and Huinink, 2017; Tanturri and Mencarini, 2008). Further, while researchers in the field increasingly consider multiple life domains (e.g. family, occupation and happiness) simultaneously (e.g. Comolli et al., 2021; Frech and Damaske, 2019), the majority of relevant studies still tend to focus on single life domains (e.g. Doren, 2019; Van Winkle and Fasang, 2020). However, the life course tenet of *life course multidimensionality* suggests that individuals participate in different social spheres at the same time, and that (their roles and experiences in) these different life domains are interdependent (Heinz, 2003; Kok, 2007). Hence, an accurate representation of the relationship between childbearing behaviour and SEWB requires the simultaneous modelling of multiple trajectories across such interdependent life domains. Finally, given the vast amount of evidence for moderating effects of for example partnership status, educational attainment or physical health (e.g. Nomaguchi and Milkie, 2020), the role of such time-varying factors on both childlessness and SEWB should be considered as well.

The lifelong dynamic interplay between childlessness and SEWB clearly is complex substantively, and this complexity raises methodological issues for empirical research. Commonly used methods in

the field have been able to only partially account for some of the aforementioned substantive complexities, but have not been as effective in incorporating all of them simultaneously in one model whilst also converging. That is, to assess CSEAD and the role childbearing behaviours play in this process, it is necessary to holistically examine the (time-varying factors influencing the) life course trajectories in subjective (SWB) and economic (EWB) well-being of those who have ever become parents and those who have remained permanently childless for different reasons, and understand which differences between the groups exist and at which life course stage they emerge. To do so, I propose using a methodological approach involving Bayesian hierarchical growth curve models (HGCMs), which is able to take into account and facilitate the modelling of these substantive complexities altogether. The goal here is not to critique commonly used approaches, but rather to broaden the methodological toolkit of sociological and/or life course researchers. While Bayesian HGCMs are not novel models in themselves, their application to the field of sociology, and questions of CSEAD in relation to childlessness in particular, is (Lynch and Bartlett, 2019). That is, Bayesian HGCMs have rarely been applied in sociology, and in the scarce cases they were employed, they were used for forecasting or spatial analyses (*ibid.*). Further, ‘standard’ (i.e. frequentist) HGCMs have been applied to studies of cumulative (dis)advantage (CAD) (e.g. Willson et al., 2007), although not necessarily about questions of CSEAD and childlessness, because of their effectiveness in modelling trajectories of continuous variables (e.g. Steele, 2008). While these models could theoretically incorporate the aforementioned substantive complexities, the estimation of such a complex HGCM with a large number of parameters (e.g. from interactions and random effects) using available panel data with limited sample sizes would result in failure to converge, given that frequentist HGCMs rely on asymptotic properties. Bayesian inference, on the other hand, does not rely on asymptotic properties, and hence is better suited for accurate estimation of the model parameters in these kinds of situations with high model complexity and limited sample sizes (McNeish, 2016). As will also be elaborated on later in this chapter, Bayesian methods offer some additional advantages over frequentist methods that make their application even more suited for the question at hand: for example, the ability to include prior beliefs about parameter distributions through specifying a prior (Lynch and Bartlett, 2019); to include cross-level interactions between time-varying and time-invariant factors (Raudenbush and Bryk, 2002); to compare non-nested models and hence the relative importance of various (sets of) explanatory factors (Raftery, 1995); and to provide more accurate predictions and intuitive interpretations of multilevel models through hierarchical prior specification (O’Hagan and Forster, 2004).

As such, this chapter makes interlinked contributions to the methodological and applied substantive literature. From an applied perspective, Bayesian inference for HGCMs is applied from statistics to sociology, and questions of CSEAD and childlessness in particular. This approach enables the incorporation and modelling of the relevant substantive complexities of the question at hand, thereby acknowledging

that childlessness is often a product of a complex life course process which is not clearly marked; might not be definitive at the time of measurement; may have different reasons; and may associate with multiple life domains simultaneously and contemporaneously. As such, I am able to provide a holistic substantive overview of the relationship between CSEAD and childlessness over the life course. More broadly, though, applying a Bayesian approach to a research question in sociology, a discipline in which Bayesian approaches have rarely been applied (Lynch and Bartlett, 2019), helps demonstrate its advantages to a wider audience beyond statisticians. While this study focuses on an application in the context of childlessness and SEWB, I believe it represents more generally the first use of Bayesian HGCMs to examine the development of inequalities for different groups of people over their life course. A methodological contribution of this work is therefore to demonstrate how Bayesian HGCMs can be used to assess CAD, specifically in the case of a dynamic interplay between an unclearly marked and heterogeneous ‘non-event’, interdependent life domains represented on continuous scales, and various time-varying factors. For example, beyond the context of childlessness and SEWB, researchers might want to assess CAD in the interdependent life domains of physical and financial well-being for those who have achieved a particular work performance before retiring and those who have not (and for different reasons so) by the time of retirement, thereby incorporating the role of relevant factors such as working hours and physical activity.

The proposed method using Bayesian HGCMs is able to successfully incorporate all of the aforementioned substantive complexities simultaneously in one model, while commonly used methods in the field of sociology and/or life course studies currently struggle to do so. For instance, sequence analysis (SA), or variations thereof, is commonly applied to assess life course trajectories in categorical ‘states’ such as being married or in education (Ritschard and Studer, 2018). Given that these models are often used to examine pathways into childlessness but not also implicitly the consequences of childlessness at the same time, they generally do not conceptualise childlessness and socio-economic well-being as both outcome and determinant in a dynamic interplay over the life course. In this respect, SA-based models are often combined with regression analysis to assess the relationship between earlier-life trajectories and some cross-sectional later-life outcome, and to examine CAD by investigating the extent to which pre-trajectory determinants affect this relationship (e.g. Comolli et al., 2021; Jalovaara and Fasang, 2020; Rossignon et al., 2018). As such, however, these approaches do not longitudinally examine the development of the outcome of interest over the life course, nor do they assess the contemporary relationship between sources and outcomes of interest at different stages of the life course. This is important, though, because these experiences may interact continuously throughout life course. Further, to examine how this sequential and interactive process might result in CAD in the context of an unclearly marked process like childlessness, it is crucial to investigate SEWB before, during and after the transition from temporary

to permanent status within the same individuals. Moreover, SA neither allows for examining the impact of time-varying factors on such trajectories nor for modelling multiple trajectories across different life domains simultaneously (Ritschard and Studer, 2018). While the sequence analysis multistate model respectively multichannel sequence (typology) analysis overcome these limitations of SA, these methods still model trajectories in categorical ‘states’ rather than metric variables (e.g. income) (Comolli et al., 2021; Gauthier et al., 2010; Studer et al., 2018). Although metric variables can be categorised into nominal ones to be able to use these models nevertheless, doing so is generally undesirable because it often results in arbitrary categorisations and/or a loss of information (Altman and Royston, 2006).

Other commonly applied methods include group-based trajectories or group-mixture models, which identify different groups rather than distinguishing them on beforehand (Frech and Damaske, 2019; Nagin, 2010). While this feature might be desired in exploratory contexts where there is no prior belief about clusters of individuals, often it is actually desired in the social sciences to assess (differences between) trajectories of a number of pre-defined groups (e.g. by gender, race or reason for childlessness) (Hoekstra and Twisk, 2015). Further, fixed effects models (FEMs) are often used to assess life course differences between groups of individuals (e.g. Doren, 2019; Kahn et al., 2014; Van Winkle and Fasang, 2020). However, in contrast to hierarchical models, FEMs cannot estimate the effect of time-invariant variables but can merely ‘partial them out’ (Allison, 2009). This is problematic for the current study because to compare eventually childless adults with eventual parents, it is necessary to accurately estimate the effect of a time-invariant categorical eventual parental status variable. Event history analysis, on the other hand, explores the risk of experiencing some event given a number of characteristics (Wu, 2003). This model is not suitable for the question at hand either, mainly because childlessness is not a clearly marked event but rather its non-concomitant absence (Tanturri and Mencarini, 2008). For this same reason, causal frameworks, such as path models and difference-in-difference models, are equally unsuitable in this context. While childlessness is the counter-factual of *ever* having had a child, it is not the counter-factual of having a child *at the same time* as parents in the ‘treatment group’. As a result, some of those in the childless ‘control group’ may be classified as permanently childless, while they might actually have a child at some later life stage following a (quasi-)experiment. Furthermore, some of the main assumptions for causal inference are violated in the context of childbearing (Botosaru and Gutierrez, 2018): anticipatory responses to childbearing are likely; parallel socio-economic trajectories in the absence of childbearing are unlikely; and random treatment is unlikely.

This study demonstrates the use of the proposed approach by estimating a Bayesian multivariate multiple HGCM to estimate prospective SWB and EWB trajectories simultaneously for those who have ever had a child before age 46 and those who have eventually remained voluntarily (by personal choice), involuntarily (because of infertility or health problems), circumstantially (because of financial, housing

or partnership circumstances) and indecisively (for no clear reason) childless up to age 46. Hereby, I consider the potential roles partnerships, education, employment and health may play in influencing both permanent childlessness and SEWB. The goal of this approach is not to make causal inferences about the effect of SEWB on childlessness or the reverse effect of childlessness on SEWB, but rather to examine how SEWB differentials between parents and childless adults behave throughout the life course (i.e. whether socio-economic (dis)advantage accumulates throughout life) and what factors contribute to (the development of) these differentials. As such, I will provide answers to the questions of whether socio-economic (dis)advantage accumulates throughout the life course via permanent childlessness; how the social and economic domains moderate each others' association with permanent childlessness; what factors besides permanent childlessness influence (the development of) socio-economic differentials between childless adults and parents; and what gender differences exist with respect to these questions. Hereby, I consider childlessness and SEWB as continually both outcome and determinant in a dynamic interplay over longer periods of the life course.

I focus on the British 1970 birth cohort, which is one of the most recent cohorts to have had completed their childbearing by 2022. This cohort makes an interesting case for the current study, because amongst the women in this cohort high childlessness rates (18%) co-occur with relatively high fertility rates (1.9) (Dormon, 2013), as well as high female labour force participation rates (Organisation for Economic Co-operation and Development, 2018). However, compared to most European countries, the UK has had less generous work and family reconciliation policies, opting out of providing state support for this matter until 1997 (Sigle, 2016). Even the family-work policies introduced in the UK since 1997 have focused almost entirely on women's entitlement, and made childbearing more attractive mainly amongst lower-income families. With limited parental leave, a strongly gendered division of domestic chores and family care, and a lack of affordable childcare, the UK still is amongst the least generous and pro-natalist countries for working parents compared to European countries (Chzhen et al., 2019; Frejka et al., 2008; McMunn et al., 2020). As a result, childlessness is disproportionally high amongst highly educated and employed women, while fertility is disproportionally high amongst lower-educated women with lower earnings (Berrington, 2017). Since the 1970s, the UK has experienced increases in divorce and cohabitation and decreases in marriage and fertility, together with increased ages at first marriage and childbearing, as well as women's participation in education and employment (Office for National Statistics, 2018b; Roantree and Vira, 2018; Sanders, 2018).²

²For a more detailed description of social and economic change across the 1970 and previous British cohorts, refer to for example Elliott and Shepherd (2006); Ferri et al. (2003).

3.2 Childlessness as a Life Course Process

Although some individuals make an active decision not to have children or are biologically unable to have children (Berrington, 2017), permanent childlessness is most often a process outcome of “a sequence of socially defined events and roles that the individual enacts over time” (Abbott, 2005; Giele and Elder Jr, 1998, p. 22). Throughout life, individuals follow normative paths of events or transitions that are in line with age- and sequence-appropriate behaviour. An example of a standard pathway would be to go into education, then into employment, followed by cohabitation, then marriage and childbearing hereafter (Kok, 2007). Individuals’ life course pathways are shaped not only by ethical and cultural norms, but also by institutions and welfare states (e.g. Mayer, 2009). Within these constraints, individuals have the agency to make their own choices and shape their life courses (Elder Jr, 1998). The sequence of these decisions and actions in different interlinked life domains, such as partnering, education and career, may potentially lead an individual to have children, or to remain childless by choice or postponement (Keizer et al., 2009).

While all principles of the life course perspective may to some extent apply to childlessness, two aforementioned paradigms are particularly relevant for the current study: *life-span development* and *life course multidimensionality*. The first of these tenets addresses the “developmental impact of a succession of life transitions” (Elder Jr, 1998, 3), i.e. that past experiences shape current and future events (Elder Jr et al., 2003; Kok, 2007). This temporal and sequential interdependence of events contributes to the accumulation of (dis)advantage over the life course (Elder Jr et al., 2003), and is therefore important to guide thinking about socio-economic inequalities in relation to childlessness across the life course. The second relevant paradigm of *life course multidimensionality* suggests that individuals participate in different social spheres at the same time, and that (their roles in) these different life domains are interdependent (Kok, 2007). An example of such multidimensionality is the interdependence between familial roles and occupational careers (e.g. Heinz, 2003). I use the tenet of life course multidimensionality to address the simultaneous interdependence of life domains and to place potential interaction effects between SWB and EWB in their associations with childlessness in the context of life course theory.

The upcoming sections first elaborate on the potentially bidirectional associations of childlessness with SWB and EWB across the life course, and then discuss in more detail the potential mechanisms by which SWB and EWB might interact in their relationships with childlessness.

3.2.1 Childlessness and Subjective Well-being

Previous research has suggested that the relationship between childlessness and SWB is mutual (Mastekaasa, 1992; Plotnick, 2009). An individual's SWB may play a role in determining their childbearing outcomes during the period leading up to permanent childlessness: generally, low-SWB individuals are more likely to remain involuntarily or circumstantially childless than high-SWB individuals (Bures et al., 2009; Cetre et al., 2016). One reason for this is that lower SWB may lead to conceiving issues and perhaps even infertility (Rooney and Domar, 2018). Further, selection and marriage market theories assert that individuals with lower SWB are less likely to attract a mating partner in the marriage market and when they do, they are more likely to get divorced (Mastekaasa, 1992).

In later stages of the life course, when childlessness may have transferred from being a temporary to a permanent state, childlessness may in turn affect SWB. However, reported results have been rather mixed and inconsistent, mainly because of differences in research designs as well as (the extent to which researchers account for) circumstances and contextual factors – including the operationalisation of SWB, the definition and reason for childlessness and the life course stage (Kohler and Mencarini, 2016; Nomaguchi and Milkie, 2020; Umberson et al., 2010). Besides, childlessness and parenthood both come with a 'mixed bag' of emotions and feelings as well as demands and rewards (Musick et al., 2016), and the 'balance sheet' of this mixed bag depends on several characteristics, such as partnership status, gender, social status and employment (for a review, see Nomaguchi and Milkie, 2020). In the context of the current study, one might expect voluntarily childless adults and parents to have similar levels of life satisfaction (e.g. Schoon et al., 2012; Stegen et al., 2020), while those with relinquished parenthood intentions may be less satisfied with life (White and McQuillan, 2006). Particularly involuntarily childless adults, and women especially (Lechner et al., 2007), face substantial deficits in their SWB due to intense emotions and feelings of anxiety, grief, depression, exclusion, isolation and disrupted identities (e.g. Koert and Daniluk, 2017). Nevertheless, coping and adaptation may have a positive effect on SWB for these individuals throughout their life course (Hadley and Hanley, 2011). Men, on the other hand, most often remain circumstantially childless because of low SES and celibacy (e.g. Köppen et al., 2017), which has been said to particularly negatively affect their SWB (Keizer and Ivanova, 2017; Kohler et al., 2005). Often this is not the case for women, however: women who remain childless for reasons other than infertility, and whom are often highly educated and non-partnered (e.g. Raab and Struffolino, 2020), tend to have some of the highest levels of SWB (e.g. Keizer and Ivanova, 2017). Research suggests that this is most likely the case because these women have more freedom and independence (Agrillo and Nelini, 2008) and need not face the burdens of traditional gender roles in housework and childcare (Myrskylä and Margolis, 2014).

3.2.2 Childlessness and Economic Well-being

Previous literature on the association between voluntary and circumstantial childlessness and EWB has found evidence for a positive relationship amongst women (Budig and England, 2001; Correll et al., 2007) and negative relationship amongst men (Killewald, 2013), often referred to as the so-called ‘motherhood wage penalty’ and ‘fatherhood wage premium’ (e.g. Keizer and Ivanova, 2017; Mari, 2019; Van Winkle and Fasang, 2020). In the stages leading up to permanent childlessness, EWB may affect one’s childbearing intentions and behaviours. From the supply side of labour, high-EWB women may be more likely to remain voluntarily or circumstantially childless than low-EWB women because the former tend to postpone childbearing given that they often face constraints that diminish their intention to have children. Such constraints may include dilemmas about high opportunity costs of having children, combining work and family, struggling to find a partner in largely hypergamous marriage markets, and wanting to wait until job tenure has been achieved (e.g. Keizer et al., 2008; Miettinen et al., 2015; Tanturri et al., 2015). While this educational gradient has recently been decreasing or even reversing in some European countries (e.g. Andersson et al., 2009; Kreyenfeld and Konietzka, 2017a), it has increased over time in the UK (Berrington, 2017). On the contrary, low-EWB men are generally more likely to remain circumstantially childless than high-EWB men (e.g. Barthold et al., 2012; Berrington, 2017; Keizer et al., 2008; Köppen et al., 2017; Koropeckyj-Cox and Call, 2007). Oftentimes, the former struggle to find a partner as a consequence of their diminished prospects to care and provide for their family, and remain childless as a consequence (e.g. Jalovaara and Fasang, 2017; Keizer et al., 2008; Raab and Struffolino, 2020; Tanturri and Mencarini, 2008; Wagner et al., 2019). For both women and men, though, low-EWB individuals may be more likely to remain involuntarily childless because of health issues due to financial hardship, and/or diminished opportunities to seek infertility treatment (Farley Ordovensky Staniec and Webb, 2007).

Having permanently remained without children may in turn also affect one’s EWB. Previous research has concluded that this effect is positive for women for two reasons (e.g. Koropeckyj-Cox and Call, 2007; Mika and Czaplicki, 2017). First, from the supply side of labour, childless women may be more likely to remain on the labour market because their work is not interrupted by childbearing (Gangl and Ziefle, 2009). This allows them to accumulate EWB over time in higher-status jobs compared to mothers who leave the labour market to bear and raise children, and possibly return to then mobilise into mother-friendly jobs (Gangl and Ziefle, 2009). Second, from the demand side of labour, working mothers may be discriminated against as being less committed and capable than working non-mothers (Correll et al., 2007), although not all researchers find evidence for such discrimination (Gangl and Ziefle, 2009). Contrastingly, the effect of childlessness on EWB is thought to be negative for men for two reasons (e.g. Dykstra and Keizer, 2009). First, childless men may be less likely to succeed in their career because

of lacking the ‘male breadwinner motivation’, which inclines fathers to increase their EWB to care for their family (Dykstra and Keizer, 2009; Keizer et al., 2009). Second, from the demand side of labour, employers tend to discriminate against childless men because they perceive fathers as being more capable and committed than equally qualified childless men with the same marital status (Killewald, 2013).

3.2.3 Childlessness and the Interaction Between Subjective and Economic Well-being

The life course paradigm of *multidimensionality* addresses the simultaneous influence of life domains on each other (Elder Jr, 1994). On the one hand, one may expect that EWB moderates the association between childlessness and SWB. Previous research has concluded, for example, that childless individuals with higher wealth and family income have less concerns and higher SWB than their poorer counterparts (McQuillan et al., 2012; Zhang and Hayward, 2001). The authors of these works suggest that this moderation may be the result of a protection effect against loneliness and depression and/or a buffer in times of stress. On the other hand, there is, to the best of my knowledge, no literature on the potential moderation of SWB on the relationship between childlessness and EWB. However, one may expect that high-SWB individuals remain childless for other reasons than being selected out of relationships (Mastekaasa, 1992) or into infertility (Rooney and Domar, 2018). One of these reasons may potentially be to focus on one’s professional career (Merz and Liefbroer, 2012). If this is the case, one may expect that amongst these high-SWB women, the positive effect of childlessness on EWB may be more positive than amongst their low-SWB counterparts. Contrastingly, amongst high-SWB men the negative effect of childlessness on EWB may be less negative than amongst low-SWB men.

In sum, one might expect that voluntarily childless adults and parents have similar levels of SWB, while non-voluntarily childless adults are satisfied with life to a smaller extent. The latter may be the case particularly for involuntarily childless women and circumstantially childless men. Given the likely selection of unhappier individuals into non-voluntary childlessness together with the negative consequences of infertility (especially for women) and celibacy (especially for men), these differentials are likely to increase throughout the life course. Similarly, one might expect EWB (dis)advantage to accumulate throughout the life course as well. Hereby, voluntarily and circumstantially childless women should have a consistent advantage compared to involuntarily childless women and particularly mothers. On the contrary, fathers are expected to have an advantage over childless men, especially so compared to circumstantially childless men but less so compared to voluntarily childless men. EWB and SWB are expected to positively influence each other, as well as each other’s relationship with childlessness. These expectations altogether are visualised in Figure 3.1.

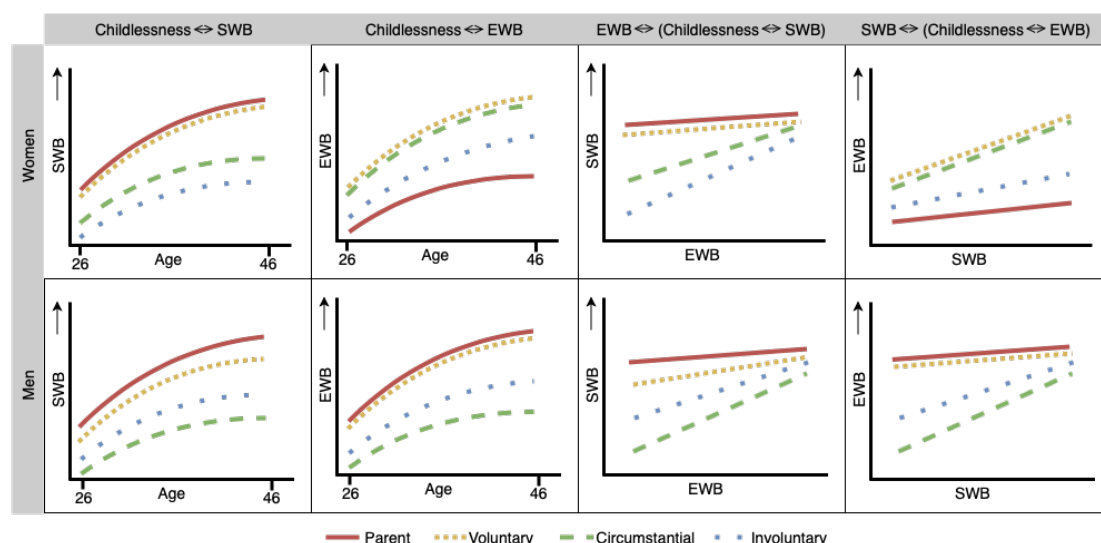


Figure 3.1: Expectations of SWB and EWB life course trajectories and interactions

3.3 Data

To demonstrate the proposed Bayesian HGCM approach, I use the 1970 British Cohort Study (BCS70) data. This is a longitudinal survey conducted by the Centre for Longitudinal Studies (CLS). Over 17,000 respondents, all born in one week of April 1970 in Great Britain, have been interviewed at ages 5, 10, 16, 21, 26, 30, 34, 38, 42 and 46. The survey contains information about life satisfaction, income, employment, education, health and family situation. The BCS70 is particularly suitable for this study because the survey follows respondents for a longer time span; interviews respondents from a fixed cohort and therefore needs no distinguishing between age and cohort effects; has a relatively large sample size (of eventually childless individuals) compared to similar surveys; has well-timed sweeps that capture a wide range of childbearing ages; and contains information on SWB and EWB in the majority of its sweeps.

I consider the quadrennial sweeps between ages 26 and 46 (University of London and Centre for Longitudinal Studies, 2016a,b, 2019a,b, 2020a,b). This age range is the longest age span for which all surveys contain the variables of interest. To conclude permanent childlessness, I only consider those individuals who have been observed in at least one sweep in their forties. Permanent childlessness is based on respondents' parental status at age 46 (or age 42 if they were not interviewed at age 46), because this is the most recently available sweep in the BCS data. While the fertile period will have ended by this age for most women, men may not have completed fertility by age 46. As a result, permanent childlessness may be overestimated amongst men in particular. While studies focusing explicitly on later-life consequences of childlessness consider mature and old-aged individuals (e.g. Cwikel et al., 2006; Hagestad and Call, 2007; Koropecj-Cox and Call, 2007; Tanturri et al., 2008; Vikström et al., 2011;

Zhang and Hayward, 2001), the majority of related studies examining ‘permanent childlessness’ and SEWB consider age cutoffs close to age 46. To illustrate, Miettinen et al. (2015) consider women aged 40–44 and men aged 45–49; Dykstra and Keizer (2009); Keizer et al. (2009) focus on men aged 40–59; Tanturri (2012) examines childlessness amongst women and men aged 30–49; Hadley and Hanley (2011) consider individuals aged over 33; Hansen et al. (2009) use a sample of adults aged 40–80; Barthold et al. (2012); Bures et al. (2009) focus on men and women aged at least 50/51; and Kneale and Joshi (2008, p. 1936) use the 1958 National Child Development Study of individuals followed up to age 46 to “estimate a full fertility schedule for the later 1970 (BCS70) cohort”, which was only observed up to age 34 at the time of their analysis. Further, given that only a very small share of British men will actually have children after age 46 in practice (Office for National Statistics, 2016),³ this age cut-off should not be problematic for the current study. Additionally, I do not consider the sample at age 21 because this is a subsample of only 1,647 respondents with a limited number of relevant variables. I also remove the sample at age 16 because it misses accurate information on all variables of interest. As 21.7% of women and 10.6% of men in the sample had already had a child by age 26, and previous research has shown that those who have children earlier in life are often socio-economically disadvantaged and become increasingly so over time because of early parenthood (Johansen et al., 2020), I include time-varying covariates for the timing and quantum of children (see next section). Although male childlessness may be underestimated given that attrition is more common amongst socially disadvantaged men, I use multiple imputation which has been shown to be effective in limiting attrition bias in the BSC70 data (Mostafa and Wiggins, 2014).

3.3.1 Operationalisation

The two dependent variables are SWB and EWB. SWB is operationalised from an ordinal scale from zero (complete dissatisfaction) to ten (complete satisfaction) of how satisfied respondents are with how life has turned out so far. I model SWB as a continuous variable because this simplifies interpretation and significantly improves model convergence and computational feasibility. Research has shown that results are robust to treating ordinal variables with at least five categories as continuous variables (e.g. Norman, 2010). EWB is represented by the continuous $\log(1 + x)$ of a respondent’s monthly gross pay and is computed from the period for and amount of gross pay. Although one’s EWB may depend on household income, particularly for unemployed mothers in single-income couples, I operationalise EWB from individual income because this more accurately reflects particularly women’s labour market interruptions following childbirth, and household income was not available consistently throughout the sweeps. If earnings data for a respondent who is out of the labour force are missing, these are set to zero; if some

³Of all live births in 2016, the year those born in the 1970 cohort had turned 46, only 3% were born to fathers aged over 46 at birth.

earnings are reported, these are kept intact. I correct the wages for inflation to accurately compare them throughout the time period considered (Office for National Statistics, 2018a).

The independent variable of interest reflects eventual parental status. Its value is ‘parent’ for those who report having had at least one child ever up to age 46 (or up to age 42 if the respondent was not interviewed at age 46). If a respondent reports never having had any children to this question, their reason for childlessness is deducted from a question asking for the most important reason the respondent has not had any children, which is asked only in the 2012 sweep during which respondents were aged 42.

The literature on childlessness often distinguishes three sets of reasons for childlessness (see e.g. references on pp. 586 in) Buhr and Huinink, 2017). The first group is comprised of the ‘voluntarily childless’, i.e. those who have an active intention to remain childless. Generally, women who remain childless lack motherly instinct or interest in children (Park, 2005); have concerns about societal issues such as politics and climate change (Stegen et al., 2020); reject the perceived advantages of parenthood (Kelly, 2009); have more secular and liberal values (e.g. Burkimsher and Zeman, 2017); reject traditional gender roles and prefer to follow their own autonomous paths (Stegen et al., 2020); have higher expectations of and desires for freedom, independence and experiences (Park, 2005), but lower agreeableness and extraversion (Avison and Furnham, 2015). Voluntarily childless individuals, and men in particular, also often feel that having children will negatively affect their financial situation (Park, 2005). While some childless people perceive their choice as an act of individual agency, the majority of permanently childless individuals report having remained without children despite having non-negative fertility intentions (e.g. Berrington, 2017; Kelly, 2009; Köppen et al., 2017; Rotkirch and Miettinen, 2017). Some of these individuals remain childless ‘involuntarily’ because of biological and/or medical reasons that hamper their ability to conceive or carry a pregnancy to live birth, such as infertility or other health problems (e.g. Berrington, 2017). Many others, yet, end up childless ‘by circumstance’ because they felt like “the necessary prerequisites for parenthood are not met at a given point in time” (Buhr and Huinink, 2017, p. 586). In other words, their childbearing intentions and outcomes are strongly dependent on their short-term and long-term circumstances and resources (e.g. Kuhnt et al., 2017; Stegen et al., 2020; Tanturri et al., 2015). As such, childbearing is often postponed perpetually to a time when circumstances will be more fortunate and resources will be more readily available, for example in terms of higher job security, stable partnerships or lower opportunity costs (Huber et al., 2010; Mynarska et al., 2015).

In distinguishing reasons for childlessness, the boundary between personal choice and circumstances can sometimes be blurred (Tanturri and Mencarini, 2008) and ex-post rationalisation can (unintentionally) be used to justify and gain control over outcomes resulting from one’s circumstances (Jeffries and Konnert, 2002; Kelly, 2009). Nevertheless, the aforementioned three-way distinction of involuntary, voluntary and circumstantial childlessness has provided functional (Tretjakova et al., 2020) and hence has

been widely applied in other studies (see e.g. (references in) [Buhr and Huinink, 2017](#)), and will therefore also be followed in the current analyses. Table 3.A.1 in Appendix 3.A gives an overview of the distinction between childlessness types based on respondents' answers given to the question 'What is the most important reason that you have not had any children?' Accordingly, I classify involuntarily childless individuals as those who reported being childless because of physical limitations, i.e. their own or partner's infertility problems, other health reasons or having (a partner who has) been sterilised, vasectomised or hysterectomised. Those who report actively not having wanted or prioritised children (from an early stage), e.g. because of not wanting to compromise their romantic relationship or having focused on their career, are categorised as voluntarily childless by choice. Circumstantially childless individuals are those who did not necessarily have negative childbearing intentions but have ended up childless because of difficult financial and/or housing situations, a partner who does not want (more) children, not having met the right person, not having got round to fulfilling their desire for children or having been in a homosexual relationship. If respondents have not disclosed their main reason for having remained childless or gave an indecisive answer, they are classified as 'unknown/indecisively childless'. I do not delete this group from the sample because i) this group might consist of a select sample of people who remained childless for no clear reason or do not want to report so, and ii) because I want to maximise the sample size of eventually childless individuals.

I further control for several covariates that may influence the relationship between permanent childlessness and SEWB, namely marital status, cohabitation, education, economic activity, health status and the timing and quantum of childbearing. Marital status is the respondent's legal marital status at the time of the interview and has categories i) single/never married, ii) (re)married/cohabiting, iii) divorced/separated/widowed. As respondents' marital status does not exhaustively indicate their relationship status, I also include an indicator for whether a respondent is cohabiting as a couple or not. Education is captured by a dichotomous indicator according to the highest academic or vocational qualification (NVQ) ever obtained throughout the sweeps, namely a higher education degree (NVQ levels of 4 and higher) or lower education degree (NVQ levels of 3 and lower). The categories of cohort members' current economic activity for which I have data on earnings are: i) full-time paid employment, ii) part-time paid employment and iii) out of the labour force (i.e. sick/disabled, in full-time education, retired, on a training scheme, looking after the home/family or unemployed). I remove full-time and part-time self-employed individuals (1,039 females and 1,728 males), because I have no information on earnings for them, and they tend to unreliably report income regardless ([Micklewright and Schnepf, 2010](#)). Health is a self-reported measure of general health, which I dichotomise because its response categories vary throughout sweeps and I am interested in the effect of good (i.e. excellent or (very) good) versus fair (i.e. fair or (very) poor) health. Respondents' number of children at the time of the interview as well as an indicator for whether at least

one child has arrived since the previous sweep are also controlled for to take into account the timing and quantum of childbearing by parental respondents. The number of children is categorised into i) none, ii) one child, iii) two children and iv) three or more children in order to consider the potential non-linearity of its effect on SEWB (i.e. the effect of having a child on a respondent may be different depending on the child's birth order).

The final sample includes 23,812 observations nested in 4,968 women and 18,963 observations nested in 2,230 men. On average, these women and men have been observed during 4.8 respectively 4.5 out of six sweeps. Up to age 46, 18.4% of women and 24.7% of men have remained childless (see Table 3.1). These numbers correspond to those found previously (e.g. Sanders, 2018). Of these childless women and men, 6.6% respectively 2.2% has had at least one miscarriage, and 7.5% respectively 3.9% has had a terminated pregnancy. Stillbirths have hardly occurred amongst the respondents in the sample (<1%). At age 46, 70% of respondents had some biological child(ren) and no non-biological children; 9% had both biological and non-biological children; 3% had some non-biological child(ren) and no biological children; and 18% neither had biological nor non-biological children.

3.4 Methodology

As aforementioned, modelling the dynamic interplay between childlessness and SEWB over the life course requires incorporating a number of substantive features (e.g. time-varying factors, multiple life domains, childlessness reason heterogeneity). The review of commonly used methods in the introductory section of this chapter showed that these methods are often able to partially satisfy (some of) these requirements, while a methodology that incorporates all of these features simultaneously has been lacking in the methodological toolkit of applied sociological and life course researchers. I propose using an approach involving multivariate multiple HGCMs to take into account the relevant substantive and conceptual features, and facilitate their modelling by applying Bayesian inference from statistics to sociology. As such, I am able to conceptualise childlessness as a heterogeneous process and examine how interrelated social and economic differentials behave across the life course. Hence, I can assess whether and how socio-economic (dis)advantage accumulates via childlessness and other relevant factors. The proposed approach allows for doing so by i) assessing CSEAD amongst individuals observed repeatedly throughout time via examining the correlation between intercept and linear time slope in a HGCM; ii) modelling childlessness as a permanent rather than temporary process via constructing prospective life course trajectories by eventual parental status at age 46; iii) acknowledging the heterogeneity within the group of childless individuals via distinguishing between voluntary, involuntary and circumstantial childlessness; iv) incorporating the interdependence between life domains via estimating multivariate models

Table 3.1: Descriptive statistics

Variable	Women				Men			
	Mean	St. Dev	Min	Max	Mean	St. Dev	Min	Max
Year	2006.294	6.727	1996.000	2016.000	2006.611	6.669	1996.000	2016.000
Age	36.294	6.727	26.000	46.000	36.611	6.669	26.000	46.000
SWB: Life satisfaction	7.387	1.919	0.000	10.000	7.228	1.869	0.000	10.000
EWB: log(1 + inflation-corrected monthly gross pay)	5.879	3.077	0.000	12.041	7.259	2.468	0.000	12.041
Child arrived since last wave	0.198	0.399			0.211	0.408		
Cohabitation								
Cohabiting	0.728	0.445			0.711	0.453		
Non-cohabiting	0.272	0.445			0.289	0.453		
Economic activity								
Full-time paid employee	0.503	0.500			0.879	0.327		
Out of the labour force	0.219	0.414			0.105	0.307		
Part-time paid employee	0.278	0.448			0.016	0.127		
Education								
NVQ3-	0.574	0.494			0.573	0.495		
NVQ4+	0.426	0.494			0.427	0.495		
Eventual parental status								
Parent	0.816	0.387			0.753	0.431		
Circumstantially childless	0.047	0.213			0.072	0.259		
Involuntarily childless	0.029	0.168			0.019	0.135		
Unknown childless	0.053	0.225			0.091	0.288		
Voluntarily childless	0.054	0.226			0.064	0.245		
Health status								
Fair	0.159	0.366			0.148	0.355		
Good	0.841	0.366			0.852	0.355		
Marital status								
(Re)married	0.550	0.497			0.524	0.499		
Divorced/separated/widowed	0.127	0.333			0.086	0.281		
Single and never married	0.323	0.468			0.389	0.488		
Number of natural children								
No children	0.329	0.470			0.433	0.495		
One child	0.199	0.399			0.194	0.395		
Two children	0.321	0.467			0.261	0.439		
Three or more children	0.150	0.357			0.112	0.315		
Number of observations		23,812				18,963		
Number of individuals		4,968				4,230		
Average number of sweeps per person		4.793				4.483		

with at least two dependent variables; v) assessing what factors (besides permanent childlessness) may drive (changes in) socio-economic differentials between childless adults and parents via controlling for marital status, education, employment and health and examining their composition across groups with different childbearing outcomes; and vi) estimating a model able to converge whilst acknowledging the aforementioned complexities on data with a small sample size relative to the number of model parameters via a Bayesian approach.

I apply Bayesian inference from statistics to sociology in order to facilitate the modelling of the substantive and conceptual features an accurate model of CSEAD and childlessness requires. Bayesian inference has several advantages over frequentist approaches, particularly in this case of hierarchical analysis (Lynch and Bartlett, 2019). As Bayesian statistics are not widely applied in social science disciplines, and sociology particularly, (Lynch and Bartlett, 2019), this work also demonstrates these advantages to a broader audience. First, the model complexity is relatively high due to random effects of time across

individuals, non-linear time polynomials and interactions (e.g. between eventual parental status and time polynomials). With the current BCS70 sample size and sample sizes of most surveys more generally, the model fails to converge in a frequentist setting. As Bayesian methods do not rely on asymptotic properties, they are better suited for these kinds of situations with high model complexity and relatively small sample sizes (McNeish, 2016). Second, Bayesian modelling is more intuitive and suitable for hierarchical modelling because of the possibility to specify a hierarchical prior (i.e. priors can be put on the prior parameter(s) indefinitely). Due to this structure, one can obtain posterior distributions for the parameter of childlessness for every single individual in the sample, and thus more accurate predictions of SWB and EWB for groups of parents and childless individuals. Additionally, the hierarchical prior specification allows flexibility by including previous knowledge and desired complexity (O'Hagan and Forster, 2004). Although I currently estimate two-level models, these could easily be extended to take further clustering into account, for example for a cross-country comparative analysis. Third, the hierarchical structure of Bayes' theorem allows for incorporating dependencies between parameters across levels (Raudenbush and Bryk, 2002). This is particularly useful as the models include cross-level interactions between time polynomials and an indicator for eventual childlessness to measure socio-economic differentials between eventually childless adults and eventual parents throughout the life course. Fourth, Bayesian analysis allows for the formal comparison of non-nested models (Raftery, 1995), and so I am able to compare all estimated models to identify which time-varying factors (best) explain the (development of) SWB and EWB differentials. Fifth, Bayesian approaches allow researchers to incorporate subjective prior beliefs or evidence for the parameters in the prior distribution. While this work follows recommendations from the literature (e.g. Lemoine, 2019) to set weakly informative priors (see section 3.4.3) as not to force the results in a certain direction, including some prior information may be desirable for reasons of identifiability of parameters as well as accumulation of scientific knowledge (Lynch and Bartlett, 2019).

3.4.1 Bayesian Multivariate Multiple Hierarchical Growth Curve Model

HGCMs take into account the hierarchical structure of longitudinal data, i.e. that repeated observations of the same individual are not independent but rather depend on some measure of time (e.g. sweep or age) (Steele, 2008). In the explanation of the HGCM that follows, scalars are denoted as single letters (e.g. x), vectors are denoted as underlined letters (e.g. $\underline{x}$ or $\underline{X}$) and matrices are denoted as bold capital letters (e.g. $\mathbf{X}$). Suppose the number of groups (i.e. individuals) is denoted by I and the sample size of group i (i.e. the number of observations for individual i) is denoted by N_i . Then the total sample size equals $N = \sum_i^I N_i$. Let the number of dependent variables be L (in this case, the dependent variables are SWB and EWB so $L = 2$) and the number of level-1 and level-2 independent variables be K_1 and K_2 , respectively. Then the

level-1 model for group i is defined as

$$\underline{Y}_i = \mathbf{X}_i \underline{\beta}_i + \underline{e}_i \quad (3.1)$$

where $\underline{Y}_i$ and $\underline{e}_i$ are column vectors of length $N_i L$ representing vectorised versions of the dependent variables respectively residuals for all observations N_i of individual i . Further, $\underline{\beta}_i$ is a vector of length $K_1 L$ describing the regression coefficients for the independent variables $\mathbf{X}_i = \mathbf{I}_L \otimes \tilde{\mathbf{X}}_i$, which is a $(N_i L \times K_1 L)$ matrix of independent variables where $\mathbf{I}_L$ is the $(L \times L)$ identity matrix and $\tilde{\mathbf{X}}_i$ is the $(N_i \times K_1)$ matrix of K_1 independent variables for cohort member i . Note that there may also be control variables contained in $\tilde{\mathbf{X}}_i$ for which the coefficient does not vary across individuals; for these variables $\underline{X}_k$, $\beta_{ikl} = \beta_{kl} \forall i = 1, \dots, N$. Additionally, residuals $\underline{e}_i \sim \mathcal{N}(\underline{0}, \underline{\Sigma}_i)$ where $\underline{0}$ is a $N_i L$ -length column vector of zeros and $\underline{\Sigma}_i = \tilde{\Sigma} \otimes \mathbf{I}_{N_i}$ is a $(N_i L \times N_i L)$ residual variance-covariance matrix for group i , where $\mathbf{I}_{N_i}$ is the $(N_i \times N_i)$ identity matrix and $\tilde{\Sigma}$ is the $(L \times L)$ residual matrix between dependent variables under the assumption of equivalence in groups. Here, $\tilde{\Sigma}$ is restricted to a diagonal matrix to substantially reduce computation time. The level-2 model for group i is specified as

$$\underline{\beta}_i = \mathbf{W}_i \underline{\gamma} + \underline{r}_i \quad (3.2)$$

where $\mathbf{W}_i = \mathbf{I}_{K_1 L} \otimes \tilde{\mathbf{w}}_i$ contains the group-level explanatory variables, where $\mathbf{I}_{K_1 L}$ is the $(K_1 L \times K_1 L)$ identity matrix and $\tilde{\mathbf{w}}_i$ a row vector of length K_2 . Further, $\underline{\gamma}$ is a column vector of length $K_1 K_2 L$ that contains the parameters for $\mathbf{W}_i$. Residuals $\underline{r}_i \sim \mathcal{N}(\underline{0}, \mathbf{U})$ where $\underline{0}$ is a $K_1 L$ -length vector of zeros and $\mathbf{U}$ the $(K_1 L \times K_1 L)$ residual variance-covariance matrix. Note that $(e_j, r_j) \perp (e_l, r_l) \forall j \neq l$ (Snijders and Berkhof, 2008). The complete-data likelihood function for the model as specified in Equations 3.1 and 3.2 is denoted as

$$\mathcal{L}(\underline{\beta}, \underline{\gamma}, \tilde{\Sigma}, \mathbf{U} | \mathbf{Y}, \mathbf{X}, \mathbf{W}) = \prod_{i=1}^I \frac{1}{(2\pi)^{\frac{1}{2}} |\underline{\Delta}_i|^{\frac{1}{2}}} \exp((\underline{Y}_i - \underline{G}_i)' \underline{\Delta}_i (\underline{Y}_i - \underline{G}_i)) \quad (3.3)$$

where $\underline{G}_i = \mathbf{X}_i \mathbf{W}_i \underline{\gamma}$ is a column vector of length $N_i L$ and $\underline{\Delta}_i = \mathbf{X}_i \mathbf{U} \mathbf{X}_i' + \underline{\Sigma}_i$ is a $(N_i L \times N_i L)$ matrix. Given the complete-data likelihood function and priors, the joint posterior distribution can be denoted as

$$\Pr(\underline{\beta}, \underline{\gamma}, \tilde{\Sigma}, \mathbf{U} | \mathbf{Y}, \mathbf{X}, \mathbf{W}) \propto \mathcal{L}(\underline{\beta}, \underline{\gamma}, \tilde{\Sigma}, \mathbf{U} | \mathbf{Y}, \mathbf{X}, \mathbf{W}) \Pr(\underline{\beta}) \Pr(\underline{\gamma}) \Pr(\tilde{\Sigma}) \Pr(\mathbf{U}) \quad (3.4)$$

The full marginal conditional posterior distribution for a particular parameter, for example $\underline{\gamma}$, can then be obtained by integrating out the other parameters $\underline{\beta}$, $\tilde{\Sigma}$ and $\mathbf{U}$ from the above joint posterior distribution.

$$\Pr(\underline{\gamma} | \underline{\beta}, \tilde{\Sigma}, \mathbf{U}, \mathbf{Y}, \mathbf{X}, \mathbf{W}) = \int \int \int \Pr(\underline{\beta}, \underline{\gamma}, \tilde{\Sigma}, \mathbf{U} | \mathbf{Y}, \mathbf{X}, \mathbf{W}) d\underline{\beta} d\tilde{\Sigma} d\mathbf{U} \quad (3.5)$$

If posterior results cannot be obtained using analytical integration, numerical or Monte Carlo methods can be used to approximate the integrals (see section 3.4.3).

3.4.2 Analytical Strategy

To answer the substantive research questions, I estimate a Bayesian multivariate multiple HGCM with two dependent variables: SWB and EWB. Although the distributions of EWB and SWB are very slightly right respectively left skewed, I specify Gaussian distributions for both dependent variables. Various tests showed that specifying skewed Normal distributions substantially increased computation time without notably improving or changing the results compared to specifying Gaussian distributions. The level-2 variables include categorical variables indicating eventual parental status and the highest obtained education, which are time-invariant for each individual. Descriptive preliminary analyses showed that SWB and EWB trajectories are of cubic shape across the life course. Therefore, level-1 includes first, second and third-order orthogonal (i.e. statistically independent) polynomials of time, i.e. a respondent's age at the time of interview minus the grand minimum age. I allow the intercept and parameter for the first-order (i.e. linear) time polynomial to vary across individuals, as is standard practice in hierarchical longitudinal models (Field et al., 2012) and allows me to examine CAD from the correlation between intercept and linear time slope. A positive such correlation indicates that those starting at higher levels of the dependent variable will also experience a steeper growth therein over time, resulting in increasing differences across individuals and therefore a diverging pattern (i.e. cumulative (dis)advantage), while negative or non-substantial correlations indicate convergence respectively stable differentials over time. As I aim to examine how SWB and EWB moderate the influence of eventual childlessness on the other, I allow for interactions between the indicator for eventual childlessness and one dependent variable in the models estimating the other dependent variable. On top of the described baseline model M1, I include time-varying control variables for the timing and quantum of children (M2), SWB if predicting EWB, or EWB if predicting SWB (M3), marital status and cohabitation (M4), education (M5), economic activity (M6) and health status (M7). I estimate separate models for each independent variable as well as one model containing all independent variables (M8), such that I can examine which factors (best) explain SWB and EWB compared to childlessness. The models are estimated separately for women and men –instead of simultaneously by including interactions with a gender dummy variable– to assess gender differences while limiting computational cost and model complexity.

3.4.3 Missing Data, Priors and Model Implementation

In this particular application, I use multiple imputation by chained equations to deal with missing values in both numerical and categorical data, taking the hierarchical structure of longitudinal data into account. By incorporating in the standard errors the between-data uncertainty resulting from imputation, accurate and unbiased estimates will be produced (White et al., 2011). Manual inspection of the data have shown that there is no identifiable pattern (non-randomness) in the missingness, and that the vast majority of observations has either no missingness at all or missingness in only one variable (see also Figures 3.B.1a and 3.B.1b in Appendix 3.B). Although White et al. (2011) recommend setting the number of imputations equal to the percentage of incomplete observations, I use four imputations to optimise the trade-off between computational cost and robust results in this specific setting (as shown from additional analyses).

As aforementioned, one of the advantages of taking a Bayesian approach is the possibility of incorporating prior beliefs about the distributions of parameters (Lynch and Bartlett, 2019). The larger the size of the data, the smaller the influence of the prior distribution on the posterior distribution will be (Lemoine, 2019). While noninformative priors are not always completely noninformative and might suffer from similar problems as frequentist methods, highly informative priors might make learning from the data challenging (*ibid.*). Therefore, I follow recommendations from the literature (e.g. Lemoine, 2019) and set weakly informative priors on all parameters in the model. Doing so also improves sampling efficiency and convergence while minimising the influence of the prior on the posterior distribution (Bürkner, 2018). However, note that when applying the approach to other settings, one might choose to use a different prior specification depending on the particular application of the model and the information that is available a priori.⁴

For the intercept and parameters of the fixed effects, I set $\mathcal{N}(7, 2)$ respectively $\mathcal{N}(0, 10)$ priors. Normal priors are a common choice for the coefficients in hierarchical models (Stan Development Team, 2019). The value of 7 for the mean of the prior distributions for the intercepts is based on the distributions of SWB and EWB; the mean value of the prior distributions for fixed effects parameters are usually set to zero. The variances of these distributions are chosen at relatively large values such that the influence of the prior is minimal (Gelman and Hill, 2006). As the interpretation of the intercept is more intuitive when all explanatory variables are centered, I set priors on the intercepts of the centered data matrix. For the standard deviations of the group-level effects (i.e. the intercept and orthogonal time polynomials) as well as the residual standard deviation, I set half Cauchy priors (location of zero and scale of two). These priors have been recommended as weakly informative priors for usage for standard deviations in the case of hierarchical models because of shown sharp inference capabilities (Gelman, 2006). Finally, I

⁴For a practical guide, refer to <https://github.com/stan-dev/stan/wiki/Prior-Choice-Recommendations> or <https://www.fao.org/3/y1958e/y1958e06.htm> for example.

set Lewandowski, Kurowicka and Joe (LKJ) priors (Lewandowski et al., 2009) with parameter equal to one (i.e. a priori all correlations are equally likely) for the Cholesky factors of the correlation matrices between the group-level effects (i.e. intercept and linear time slope). These priors behave similarly as Beta priors and have been chosen because they improve numerical stability and efficiency (Bürkner, 2018).⁵ The results of sensitivity analyses in Appendix 3.E.1 and 3.E.2 show that in this application, my findings are robust to using uninformative respectively (highly) informative priors, mainly due to the sample size being large and the influence of the prior thus being relatively small.

I obtain parameter estimates by drawing samples from the full conditional posterior distributions and pooling these. Sampling is executed using R package *brms*, relying on Stan software using the No-U-Turn Sampler (NUTS), which is a type of Hamiltonian Monte Carlo (HMC). This sampler has been chosen because it automates the tuning of the algorithm parameters such as the accuracy and leads to faster convergence and a reduction of correlation in the Markov chains (Hoffman and Gelman, 2014). For each model estimated, I run 12 chains (three chains for each of the four imputed data sets) with 2,000 iterations each in parallel. The first 50% of the iterations (burn-in draws) are used to gauge the sampler and are removed before pooling the results, which is in line with recommendations by Kruschke (2014) of several hundred to thousand steps of burn-in. To reduce correlation amongst the draws, I keep only every 10th (i.e. thinning rate) observation, leaving $3 \cdot 4 \cdot 2,000 \cdot 0.50 \cdot 0.10 = 1,200$ posterior samples per model. Although a larger number of chains and iterations generally improves the chances of convergence, researchers should seek a specification optimising the trade-off between achieving convergence and limiting computational cost. While the current specification does so for this particular application, this set-up needs not necessarily generalise to other applications. I assess the model fits by means of two information criteria, as is common practice for Bayesian hierarchical modelling where the computation of Bayes factors is challenging (Rouder et al., 2013). Specifically, I compare models using the Widely Applicable Information Criterion (WAIC), which is an improvement of the Deviation Information Criterion (DIC), and the Leave-One-Out (cross-validation) Information Criterion (LOOIC), which serves the same purpose as the Akaike Information Criterion (AIC) used in frequentist statistics (see Gelman et al. (2014)).

3.5 Results

Before elaborating on the substantive results, I discuss some model diagnostics. Table 3.2 shows the results for the fully controlled model M8; Tables 3.C.1 and 3.C.2 in Appendix 3.C show the results for all models M1 to M8. Careful inspection of convergence diagnostics, including the potential scale reduction

⁵See also https://mc-stan.org/docs/2_28/stan-users-guide/multivariate-hierarchical-priors.html#fn5 for more information on common multivariate hierarchical priors (Stan Development Team, 2019).

factor on split chains (Bürkner, 2018; Gelman and Rubin, 1992) as shown in Appendix 3.D, as well as posterior density and trace plots,⁶ shows that all chains have converged ($\hat{R} < 1.1$) for each parameter in each of the models, including the log posterior density up to a normalised constant (lp_). The information criteria in the latter tables show that the models with all control variables (M8) have the best fit, followed by the models controlling for economic activity (predicting EWB) and partnership status (predicting SWB). The standard deviations of the intercepts and orthogonal time polynomials indicate that both SWB and EWB at baseline as well as their change throughout time vary across respondents, supporting the choice for random intercepts and random effects for the first-order time polynomial. The remainder of this section discusses findings from the proposed approach with a focus on socio-economic trajectories, differentials and CAD across the life course by eventual parental status.

3.5.1 Socio-economic Differentials between Parents and Childless Adults throughout the Life Course

Some of the outputs the proposed approach produces are the predicted prospective SWB and EWB life course trajectories of (groups of) eventually childless individuals and eventual parents, as shown in Figures 3.2 respectively 3.3 for total model M8. Both SWB and EWB trajectories behave according to shapes observed in previous research (e.g. Guvenen et al., 2016; Switek and Easterlin, 2018), and the temporary dip in EWB around the late thirties might be explained by the Great Recession of 2008. The trajectories show that parents, and mothers in particular, report the highest levels of SWB throughout their life course (around 7.5 on the life satisfaction scale), followed by voluntarily (7.0-7.5), indecisively/involuntarily (6.25-7.25) and circumstantially childless (6.0-6.5) men and women. In terms of gender differences, voluntarily childless women and fathers report particularly high SWB compared to voluntarily childless men respectively mothers, while involuntarily childless women and circumstantially childless men suffer particularly relative to their counterparts of the opposite sex. Further, circumstantially and voluntarily childless women earn most (about 6.5-7.5 on the $\log(1+x)$ scale), while mothers earn least (5.0-6.0). Contrastingly, fathers have the highest earnings (7.0-8.0), while childless men have lower earnings that are similar across the sets of reasons for childlessness (5.5-7.0). By assessing the correlation between the intercept and linear time slope from the uncontrolled models, as shown in Tables 3.C.1 and 3.C.2, one can assess whether socio-economic (dis)advantage accumulates throughout the life course. This correlation is non-substantial for female SWB, but positive for EWB and male SWB, implying that the female SWB differentials are stable throughout the life course while the EWB and male SWB differentials increase

⁶These posterior density and trace plots have been excluded here for conciseness (given that 40 models have been estimated in total, each with 12 chains and between 8,485 and 9,977 parameters including the random effects), but are available from the author upon request.

over time. In other words, social (dis)advantage accumulates amongst males but not females, while economic (dis)advantage accumulates amongst both males and females.

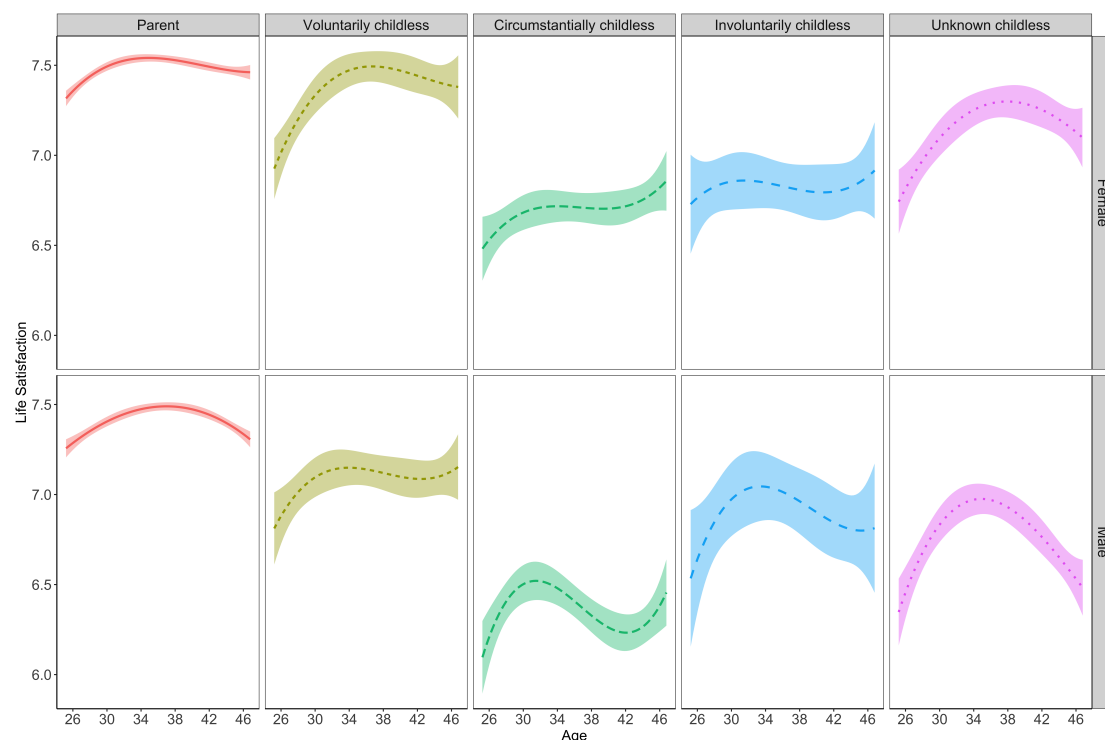


Figure 3.2: Predicted SWB trajectories for women and men by eventual parental status from total model M8

3.5.2 Explanations for Socio-economic (Dis)advantage and its Accumulation throughout Life

By combining a number of different results from the models, it is possible to examine what factors contribute to the observed SWB and EWB differentials and their development over time, and to what extent and by which mechanisms they do so. Figures 3.4 and 3.5 show the marginal effect of eventual parental status on SWB respectively EWB throughout models M1 to M8 for women and men, which together with the model fits in Tables 3.C.1 and 3.C.2 serves purpose to identify the factors that influence the observed differentials and the relative extent to which they do so. The regression coefficients in Table 3.2 show how these factors contribute to lower or higher SEWB. To obtain some additional substantive insights regarding the composition of childless adults and parents across these factors (e.g. which groups are most (un)likely married or full-time employed), I estimate additional Bayesian (multinomial) logistic regression models, predicting each of the control variables from the interaction between eventual parental status and gender. I use the same set-up as for the hierarchical models, running 12 chains (three chains for each of four imputed data sets) with 2,000 iterations each, with a burn-in percentage of 50% and

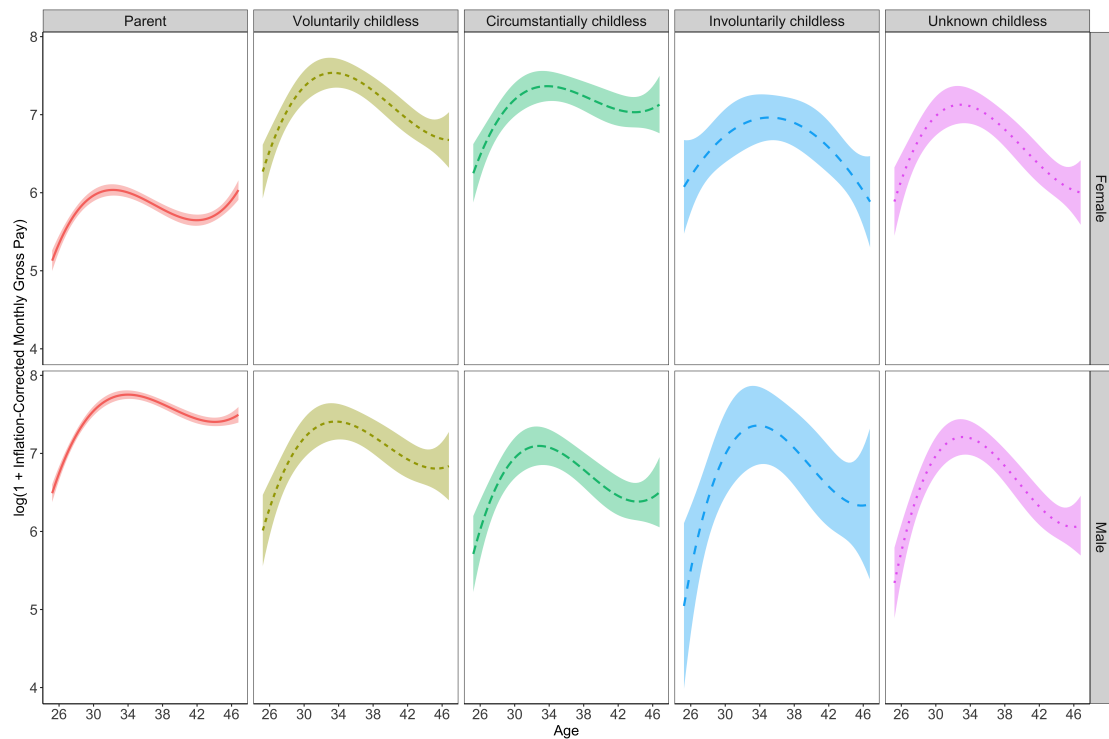


Figure 3.3: Predicted EWB trajectories for women and men by eventual parental status from total model M8

thinning rate of 10%, resulting in 1,200 posterior samples per model. On each of the parameters, I set $\mathcal{N}(0,5)$ priors with a variance relatively large compared to the parameter estimates for minimal influence on the posterior while providing convergence acceleration. The predicted probabilities are shown in Figure 3.6; the regression coefficients in Table 3.F.1 in Appendix 3.F. Careful inspection of convergence diagnostics (see potential scale reduction factor on split chains (Bürkner, 2018; Gelman and Rubin, 1992) in Appendix 3.D) shows that all chains have converged ($\hat{R} < 1.1$) for each parameter in each of these multinomial models. In the next sections, I summarise the findings combined from these results, first for SWB and then for EWB.

3.5.2.1 Social (dis)advantage by eventual parental status: Life course accumulation and explanations

The marginal effects and model fits show that cohabitation and marital status explain most of the observed SWB differentials. Table 3.2 and Figure 3.6 show that cohabitation and marriage increase SWB, and parents, who have the highest SWB, are married and cohabiting most likely, while the least satisfied circumstantially childless are most often non-cohabiting and/or most often single. Controlling for child quantum and timing further increases parents', and particularly mothers', SWB advantage (Figure 3.4): although the recent arrival of a child increases SWB, SWB also decreases on average with the number of

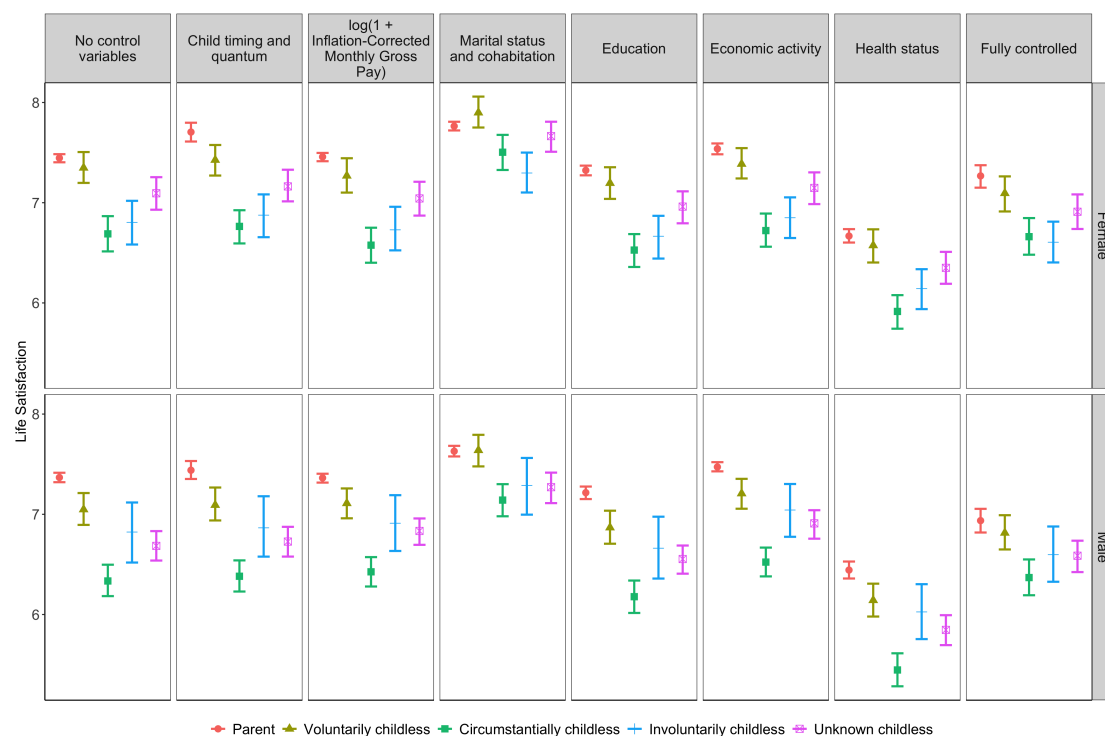


Figure 3.4: Marginal effect of eventual childlessness on SWB for women and men throughout models

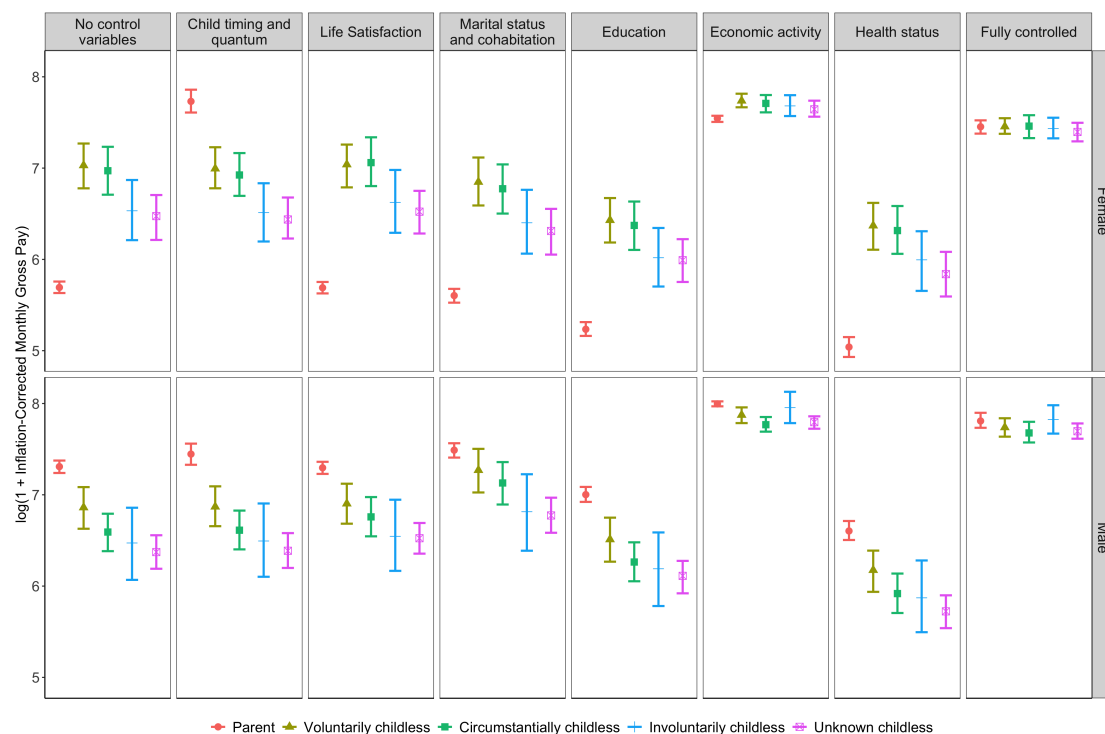


Figure 3.5: Marginal effect of eventual childlessness on EWB for women and men throughout models

children (Table 3.2). The marginal effects further show that controlling for health (or, to a smaller extent, education) lowers the SWB levels across the groups, but does not change the gradient, indicating that good health and being highly educated positively affect SWB similarly across all groups. According to the regression coefficients in Table 3.2 and predicted probabilities in Figure 3.6, marital status and cohabitation also explain why childless men have substantially lower SWB than childless women: cohabitation and marriage, which increase SWB, is less common amongst the former than the latter. Additionally, childless women are more likely to be highly educated than childless men, which might also explain why the former are more satisfied with life than the latter, given that higher education increases SWB.

Interestingly, although female SWB (dis)advantage does not accumulate in the uncontrolled model (Table 3.C.1), it does in the model controlling for child timing and quantum, and male SWB (dis)advantage also accumulates more strongly in this model (Table 3.C.2). In other words, the growth in parents' SWB is decelerated because they have children, and would be steeper had they (had) fewer children. The accumulation of male SWB (dis)advantage is less strong, on the other hand, when controlling for marital status and cohabitation or economic activity. Two joint observations from Table 3.2 and Figure 3.6 contribute to increasing social inequalities across the groups of childless men and fathers throughout the life course. First, fathers, followed by involuntarily, unknowingly and voluntarily and then circumstantially childless men, are most likely married and thus happiest. Second, fathers, followed by voluntarily childless men and then unknowingly, circumstantially and involuntarily childless men, are most likely to be full-time employed. Finally, male SWB (dis)advantage no longer accumulates when taking into account that fathers and voluntarily childless men are healthiest and thus happiest, while involuntarily childless men are less likely to have good health.

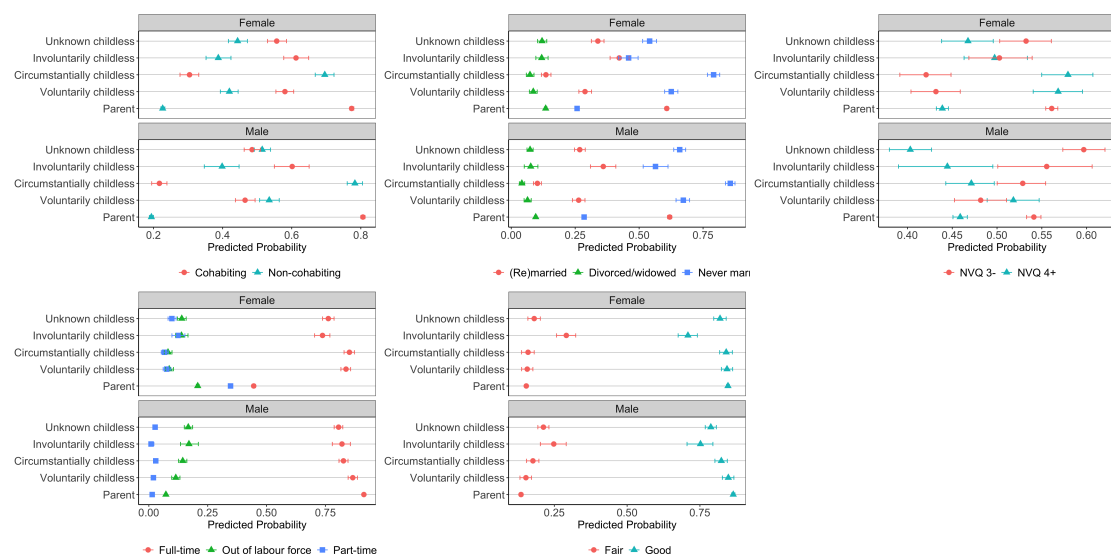


Figure 3.6: Predicted probabilities from Bayesian (multinomial) logistic regression models estimating each control variable from the interaction between the eventual childlessness indicator and gender

3.5.2.2 Economic (dis)advantage by eventual parental status: Life course accumulation and explanations

According to the regression coefficients in Table 3.2 and predicted probabilities in Figure 3.6, the observed EWB differentials are largely explained by economic activity differences across the groups: those who earn most (i.e. voluntarily childless men and women, circumstantially childless women and fathers) also have the highest probability of working full-time compared to their peers, and full-time employment increases EWB compared to working part-time or being out of the labour force. The reversal of the marginal effect amongst women when controlling for child timing and quantum (Figure 3.5) indicates that mothers would actually earn more than childless women had they (had) fewer children. Reducing or completely foregoing employment, mainly as a result of childbearing, therefore seems to play a crucial role in the economic differences observed amongst women. For men, on the other hand, marital status and cohabitation differences, rather than parental status differences, play a role in explaining the observed EWB differentials. That is, married men have an EWB advantage over single men, and fathers are most likely to be married while circumstantially childless men are most likely to remain single (Table 3.2 and Figure 3.6). The marginal effects show that when controlling for these differences, the earnings differential between fathers, voluntarily and circumstantially childless men disappear (Figure 3.5). Besides compositional differences across the groups between women and men in terms of economic activity and marital status, educational differences may also explain, though to a much smaller extent, why mothers earn least and fathers earn most. Although higher education increases EWB for both women and men (Table 3.2), mothers are less likely than fathers to be highly educated (Figure 3.6). Additionally, the earnings advantage of circumstantially childless women over circumstantially childless men can be explained not only by the fact that the former are more often married and cohabiting than the latter, but also that the former are more likely highly educated than the latter.

Table 3.C.1 shows that the accumulation of female EWB (dis)advantage would have been even stronger had mothers had none or fewer children, indicating that having children hampers economic growth amongst females. On the contrary, if the economic activity distribution would be the same across all groups of childless women and mothers, then the economic differences between them would actually decrease (i.e. converge) throughout the life course. For men, the economic differentials would neither grow nor decline throughout life if this were the case (Table 3.C.2). Seemingly, women's incentive to decrease working hours and men's incentive to increase them upon having children explains the largest part of increasing economic differences across the groups of parents and childless adults throughout the life course. Similarly, although to a smaller extent, the accumulation of male economic (dis)advantage would occur to a smaller extent if there were no marital status, cohabitation, health or education differences

between fathers and childless men.

3.5.3 Influence of Socio-economic Domains on one another and their Relationships with Eventual Parental Status

Finally, the model results are able to shed insight into how the social and economic life domains influence one another and their relationship with childlessness. Figures 3.7 and 3.8 show the marginal effects of the interactions of EWB respectively SWB with eventual parental status on SWB respectively EWB from the total models (M8). SWB and EWB positively affect one another for both women and men. Further, EWB positively moderates the association between eventual parental status and SWB: the SWB gap between the groups decreases at higher levels of EWB and so SWB levels converge. Higher EWB makes the biggest difference for circumstantially and involuntarily childless women as well as fathers and non-involuntarily childless men, and the least for mothers and involuntarily childless men. Contrastingly, there does not seem to be a clear moderating effect of SWB on the association between eventual parental status and EWB. That is, a diverging pattern for the female EWB differentials across the full range of SWB is merely visible for life satisfaction values of at least seven. On the other hand, a converging pattern amongst men is merely visible for fathers and voluntarily childless men, and the disadvantage of undesirably childless men increases with SWB.

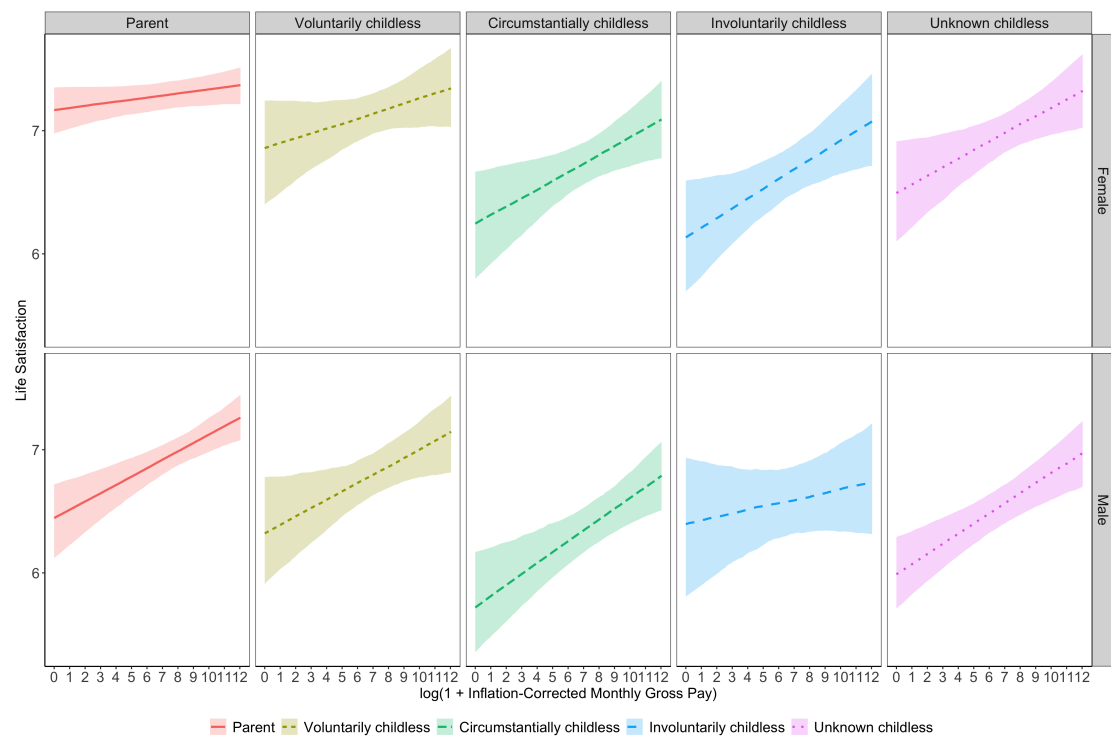


Figure 3.7: Marginal effect of EWB on SWB by eventual parental status for women and men from total model M8

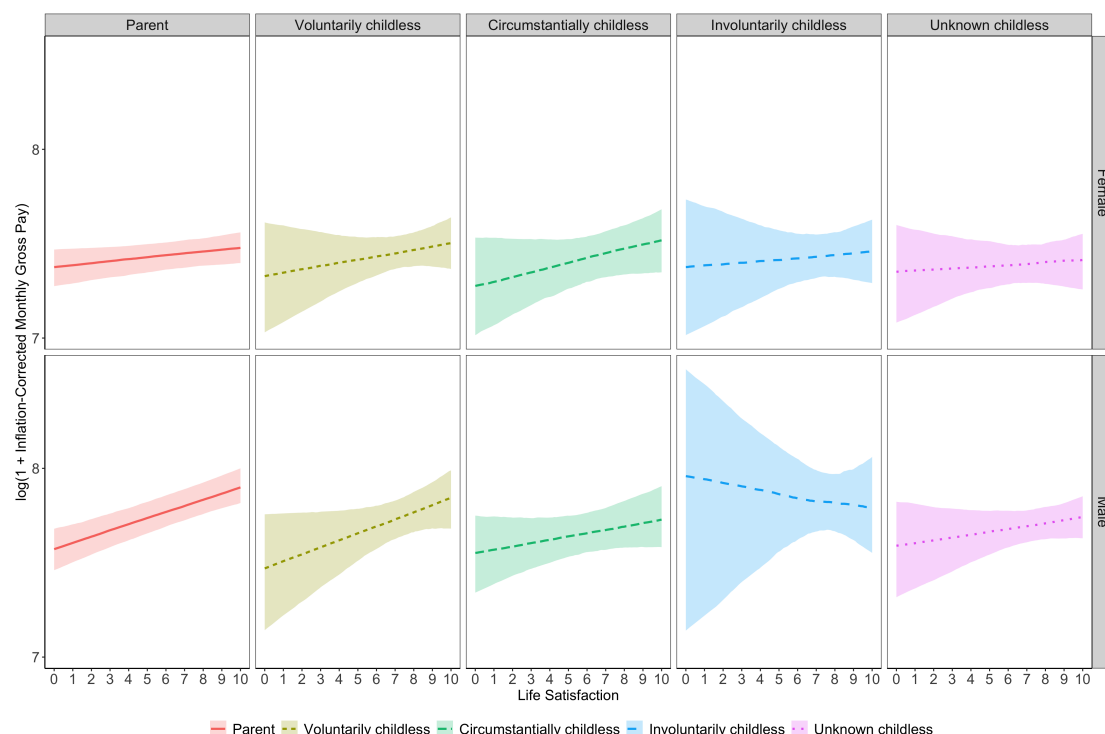


Figure 3.8: Marginal effect of SWB on EWB by eventual parental status for women and men from total model M8

3.6 Conclusion and Discussion

Research to date has examined the relationship between childlessness and socio-economic well-being (SEWB) quite extensively. However, a holistic overview of this relationship across the life course has been lacking due to methodological limitations in considering the substantive and conceptual complexities of this association. I have overcome these limitations by applying Bayesian inference in conjunction with HGCMs from statistics to sociology. As such, I have demonstrated the advantages of the Bayesian approach to a wider audience from disciplines in which Bayesian statistics have rarely been applied. Another methodological benefit of this work is that I have suggested a modelling approach that could be applied or extended to other studies of CAD, beyond the relationship between childlessness and CSEAD, where similar substantive challenges arise. From an applied perspective, the proposed approach facilitated the incorporation and modelling of such conceptual features, which has in turn allowed me to provide a holistic overview of the complex and potentially bidirectional relationship between childlessness and SEWB across the life course, and how this results in the growth of socio-economic inequalities between childless adults and parents throughout life. As such, I acknowledged the relationship between SEWB and the heterogeneous and unclearly marked process of childlessness as a dynamic interplay over long periods of the life course. I have also incorporated the interdependence between experiences in the

social and economic life domains, and examined the role of partnerships, employment, education and health on eventual parental status and (the accumulation of (dis)advantage in) SEWB. As a result, the methodological innovation of transferring Bayesian HGCMs from statistics to sociology and questions of CAD, and CSEAD in relation to childlessness more specifically, has merited a number of important substantive insights and contributions.

Whilst previous studies on the topic of childlessness and SEWB have generally defined parental status as a binary factor (i.e. parents versus childless), and sometimes at an age where childlessness might not yet have been definitive, my analysis has shown it is crucial to acknowledge childlessness as a complex life course process, having a number of different reasons and associated consequences. For example, parents and voluntarily childless adults generally fare best socially and economically, while circumstantially and involuntarily childless adults fare worst in these domains, except for mothers and circumstantially childless women who are worst respectively best off economically. Although these economic differentials are in line with expectations and findings from the literature (Aassve et al., 2006; Gangl and Ziefle, 2009; Jalovaara and Fasang, 2020; Keizer et al., 2009; Killewald, 2013; McQuillan et al., 2012), there has been ongoing debate in the literature whether parents should be more or less satisfied with life than their childless counterparts. This lack of consensus mainly stems from differences in research designs in terms of the life course stage, the reason for childlessness and the consideration of other relevant factors such as marital status (Kohler and Mencarini, 2016). By employing the methodological approach suggested, I have been able to connect these different views into one holistic framework where they complement rather than contradict each other. For example, it seems that parents, although they might feel more burden, role conflict and stress (Twenge et al., 2003), are more satisfied with life overall (as also concluded by e.g. Myrskylä and Margolis, 2014). This is the case to a similar extent as for voluntarily childless individuals who might benefit from their freedom and independence (Agrillo and Nelini, 2008). Contrastingly, those who have not actively chosen childlessness might experience negative consequences like stigma, loneliness, social exclusion and lower senses of meaning and belonging (McQuillan et al., 2003; Turnbull et al., 2016). These findings highlight that the group of childless individuals is indeed heterogeneous, and that the reason for childlessness is strongly interdependent with experiences in other life domains. The proposed approach acknowledges and incorporates this complexity and therefore provides a more accurate and comprehensive overview of childlessness and well-being than has previously been achieved with other methods and frameworks.

Moreover, my findings have shown that the observed (gender differences in) social and economic differentials are driven mainly by differences in partnerships and education respectively economic activity, rather than differences in childbearing behaviour per se. The roles of partnerships and working hours, or

‘human capital’ more broadly, in explaining (gender differences in) life satisfaction and earnings differentials have been acknowledged in previous research as well (e.g. Correll et al., 2007; Gangl and Ziefle, 2009; Jalovaara and Fasang, 2020; Keizer et al., 2008, 2009, 2010; Killewald, 2013; Umberson et al., 2010; Van Winkle and Fasang, 2020), although the role of education has been (unjustifiably) overlooked in most studies focusing on life satisfaction (with few exceptions, e.g. Hansen et al., 2009; Myrskylä and Margolis, 2014). In line with findings from other (life course) studies, parenthood life satisfaction gaps as well as motherhood wage gaps are largest amongst those who have a larger number of children (Doren, 2019; Kahn et al., 2014; Myrskylä and Margolis, 2014; Van Winkle and Fasang, 2020). In addition, my results clearly show that earnings and life satisfaction positively influence one another, which corresponds to findings of related studies (e.g. Comolli et al., 2021; Frech and Damaske, 2019). Life satisfaction differentials across the groups of parents and childless individuals are smaller at higher levels of earnings, potentially because of a buffer effect in times of stress, loneliness or depression (McQuillan et al., 2012; Zhang and Hayward, 2001). These findings therefore provide evidence for the life course paradigm of *multidimensionality* (Elder Jr, 1994), and emphasise how neglecting to simultaneously consider life experiences in multiple domains may lead to biased conclusions (Heinz, 2003; Kohler et al., 2005). The approach proposed in this study enables researchers to examine trajectories in multiple life domains synchronously by means of estimating a multivariate model and incorporating (time-varying) covariates.

Furthermore, I have shown that social (dis)advantage accumulates throughout the life course amongst men mainly via marital status differences between the groups of childless adults and parents, while economic (dis)advantage accumulates amongst both women and men mainly via economic activity differences between the groups. These results provide support for the hypothesis of the “developmental impact of a succession of life transitions” (Elder Jr, 1998, p. 3), i.e. that past experiences shape current and future events (Elder Jr et al., 2003; Kok, 2007), and are in line with findings from related life course studies of CSEAD (Comolli et al., 2021; Frech and Damaske, 2019). Earlier on, highly earning women may more likely select themselves into voluntary or circumstantial childlessness and low-earning men into circumstantial or involuntary childlessness (e.g. Keizer et al., 2008). This selection could happen potentially via higher opportunity cost of having children; marriage postponement because of longer time spent in education; difficulty of finding a mating partner in largely hypergamous marriage markets; and/or health issues caused by financial hardship (Becker, 1981; Kreyenfeld and Konietzka, 2017b). These already highly earning groups of women and men may then gain a further economic advantage throughout life because they are highly educated and more often partnered (in the case of fathers, a selection effect in line with findings from Frech and Damaske (e.g. 2019); Mari (e.g. 2019); Van Winkle and Fasang (e.g. 2020)). That is, these women might not interrupt their career for childbearing (Gangl and Ziefle, 2009);

these men might have more motivation to be breadwinners for their family (Keizer et al., 2009); and these women and men might be perceived as more committed employees (Correll et al., 2007; Killewald, 2013). Recent life course studies have concluded in a similar fashion that unadjusted parenthood wage gaps tend to grow throughout life, but that motherhood wage penalties adjusted for human capital tend to diminish or even disappear over time (Kahn et al., 2014; Van Winkle and Fasang, 2020). These studies also indicated that motherhood wage penalties persisted for mothers with at least three children, while fatherhood wage premiums hardly existed at any point during the life course (*ibid.*). On the other hand, Comolli et al. (2021) found evidence for a cumulative risk of low rather than high financial well-being (FWB) for childless women. However, their measure of FWB was based on the overall financial situation (i.e. depending also on women's partners' earnings instead of merely their own). Further, given that this risk was mainly due to weak labour market attachment, their finding might be particularly applicable to women who adjusted their careers to an expectation to have children, but eventually never had them. As such, findings from related research are in line with those presented in the current study, and suggest that (the growth of) economic parenthood differentials largely depend(s) on human capital and labour market participation differences between parents and childless adults.

In a similar fashion, happier individuals may be more likely to become parents (Cetre et al., 2016) while unhappier individuals may be selected into undesired childlessness, potentially through difficulty finding and maintaining a stable relationship (Mastekaasa, 1992) or because of health issues (Rooney and Domar, 2018). These (dis)advantages may grow further throughout the life course later on as (past) childbearing behaviour in turn influences SEWB. Previous studies have found that life satisfaction advantages for parents should only last during a few years around the birth of the first child (Myrskylä and Margolis, 2014). While I have found that mothers' SWB advantage does not increase throughout life, fathers' social advantage compared to men who will remain undesirably childless does. This gender difference might stem from fathers generally having less caring responsibilities and sleep deprivation than mothers (McDonnell et al., 2019; Myrskylä and Margolis, 2014), while undesirably childless men particularly suffer from being single, lower educated and unhealthier compared to childless women (e.g. Keizer and Ivanova, 2017; Kohler et al., 2005). Altogether, the findings with respect to CSEAD highlight the importance of the ability of the proposed approach to consider the potentially bidirectional relationship between childlessness and SEWB across the life course (i.e. before, during and after the transition from temporary to permanent childlessness) to understand how socio-economic inequalities between the groups of childless adults and parents develop across the life course.

This study has some methodological limitations that need to be considered. First, only observed variables were used to model concepts such as SWB and EWB in order to limit model complexity and keep focus on the main purpose of the proposed approach, i.e. examining CAD through childbearing outcomes

that might not be clearly marked; might not be definitive at the time of measurement; may have different reasons; and may associate with multiple life domains simultaneously and contemporaneously. The approach could be extended to include latent variables as to capture developmental trajectories, taking measurement error into account, as done by [Zhu et al. \(2020\)](#) for example. Second, missing data could be dealt with directly at the same time as estimating the model parameters by means of formulating a joint model of missingness and analysis ([Best and Mason, 2013](#)). Although the currently used multiple imputation strategy proved accurate and computationally feasible in this application, the direct imputation method might outperform the multiple imputation approach for data that contain non-random missingness, or in terms of computational time when the number of imputations would increase substantially.

Additionally, some of the operationalisation choices made require more discussion. First, I have distinguished different types of childlessness based on respondents' main reason given for their childlessness. Such responses may suffer from ex-post rationalisation whereby fertility ideals and outcomes are aligned retrospectively to mitigate hardship stemming from childlessness ([Berrington, 2017](#)). Additionally, these reasons may lack some level of detail, for example when it comes to the particular rationale behind 'not having wanted children'. This challenges the distinction of these reasons into the three-way classification of childlessness types often used in the relevant literature (e.g. [Buhr and Huinink, 2017](#)). Future research might benefit from collecting larger-scale longitudinal data on specific (reasons for) fertility intentions and outcomes, and examine CSEAD across more detailed reasons for childlessness, also when it comes to their alignment to earlier-life fertility intentions. Second, the operationalisation of EWB does not include income from other sources (e.g. child benefits, partner's income), which may bias (the comparison of childless adults and parents') earnings. Information about household or other sources of income was not sufficiently available in the data, and having an individual measure of income more accurately reflects labour market interruptions following childbirth. Follow-up studies could perhaps use the proposed approach with other measures of EWB to better understand the investigated relationships across different specifications of EWB. Third, by defining childlessness from a biological rather than residential perspective, I might have overlooked parents of non-biological children and their socio-economic investments in them. Nevertheless, biological childlessness should be a more accurate measure than residential childlessness for the purposes of this study, because the results on SWB and EWB would otherwise be downwardly biased given that residential parents are often more socio-economically advantaged relative to non-residential parents, particularly when it comes to men ([Poole et al., 2016](#)). Fourth, I have removed self-employed individuals from the sample because there was no information on earnings for them, which might bias the produced estimates of childlessness and its relationship with SWB and particularly EWB. For instance, while job security might increase one's intentions to have children (e.g. [Jalovaara and Miettinen, 2013](#); [Miettinen and Szalma, 2014](#)), unfortunate prospects may just as well lead some women to

‘give up’ on their career and become full-time mothers instead (Keizer et al., 2008). In the BCS70 data, relative shares of childlessness across economic activities vary substantially by gender and the nature of self-employment, and these differences may or may not cancel each other out. Future related research may want to focus more on this seemingly selective group of self-employed individuals.

Notwithstanding these limitations, I have shown that socio-economic inequalities exist between parents and those who have remained childless for different reasons. More and more people remain childless nowadays, and clearly not always by personal choice. While some people choose childlessness, others might be selected into remaining childless, for example because of earnings prospects, health issues or struggling to find a mating partner. These childbearing behaviours might in turn lead to particular interdependent socio-economic outcomes, such as loneliness or the opportunity to remain on the labour market. As a result, socio-economic inequalities between eventually childless adults and eventual parents grow further throughout the life course. Indeed, the (accumulation of) socio-economic differentials across the groups is driven to a large extent by differences between the groups in partnerships and economic activity, rather than parental status in itself. As childlessness rates have substantially increased over the past decades and may continue to do so in the near future, it is essential that employers, policy makers and institutions focus on reducing socio-economic inequalities between childless adults and parents, and men and women more generally (e.g. Mills et al., 2008). To a certain extent, socio-economic developments in terms of gender equality, family-work policies and marriage rates since the 1970s may have contributed to reinforcing or diminishing these inequalities. Further action should be taken to prevent socio-economic inequalities between childless adults and parents from continuing to grow further, for example via support for those struggling to combine work with family, and for those with lower levels of physical and mental health.

In conclusion, this research not only shows the capabilities and benefits of the proposed approach, but also its potential to be applied to other contexts. Using the approach applied in this study, I have been able to provide a comprehensive overview of the relationship between childlessness and SEWB throughout the life course. Most commonly used methods have not enabled researchers to do so because of methodological limitations in incorporating and modelling various substantive complexities of the problem at hand. These complexities mainly stem from the observations that childlessness is often a product of a complex life course process which is not clearly marked; might not be definitive at the time of measurement; may have different reasons; and may associate with multiple life domains simultaneously and contemporaneously. In this study, I have demonstrated how these limitations can be overcome using the proposed approach. Although the focus of the current study has been on childlessness and SEWB, this approach could be extended to other life course topics where researchers aim to examine CAD through a bidirectional association between prosperousness in multiple life domains and a definitive life course

process, whereby processual pathways into and reasons for this permanent status are heterogeneous and the transition from temporary to permanent status is an unclearly marked absence of some event that becomes definitive only once the event can no longer take place. For example, the approach could be used to study CAD in the interdependent life domains of physical, financial and/or marital well-being for those who have continuously participated in the labour market and those who have not (and for different reasons so), thereby incorporating the role of relevant factors such as human capital, time spent as a couple and physical activity. As the current study demonstrates, examining CAD throughout the life course is methodologically and conceptually complex. Yet, I have been able to suggest and apply an approach that enables researchers to understand and model this complexity to provide meaningful insights that may have important (policy) implications for reducing inequalities within society.

Table 3.2: Pooled coefficients for the female and male Bayesian HGCMs estimating EWB (log(1+inflation-corrected monthly gross pay)) and SWB (life satisfaction) from total models M6

Variable	Women		Men	
	SWB	EWB	SWB	EWB
Intercept	6.240*	7.264*	5.744*	7.533*
	(5.797; 6.667)	(7.002; 7.522)	(5.364; 6.176)	(7.328; 7.737)
SWB		0.024		0.018
		(-0.009; 0.061)		(-0.011; 0.047)
EWB	0.070*		0.087*	
	(0.018; 0.125)		(0.037; 0.132)	
poly(Time, 1)	6.916	20.500*	-4.686	16.827*
	(-2.408; 15.246)	(13.208; 27.700)	(-12.879; 3.476)	(10.184; 23.191)
poly(Time, 2)	-4.151	-12.638*	5.726	-9.728*
	(-12.736; 4.379)	(-20.155; -5.368)	(-13.609; 2.370)	(-17.592; -0.524)
poly(Time, 3)	7.248	6.861	11.186*	8.434*
	(-1.480; 15.809)	(-0.035; 13.906)	(3.050; 18.984)	(1.645; 16.202)
Eventual parental status (ref: Circumstantially childless)				
Involuntarily childless	-0.093	0.094	0.659*	0.354
	(-0.635; 0.477)	(-0.365; 0.526)	(0.025; 1.235)	(-0.441; 1.037)
Involuntarily childless*SWB		-0.015		-0.028
		(-0.071; 0.041)		(-0.116; 0.080)
Involuntarily childless*EWB	0.008		-0.058	
	(-0.069; 0.083)		(-0.133; 0.025)	
Involuntarily childless*poly(Time, 1)	-10.103	-0.731	-3.872	-2.811
	(-24.069; 4.282)	(-12.524; 11.958)	(-18.603; 11.599)	(-16.076; 8.967)
Involuntarily childless*poly(Time, 2)	6.260	-1.248	2.660	-3.432
	(-7.665; 20.873)	(-14.606; 11.599)	(-13.276; 17.969)	(-17.352; 10.913)
Involuntarily childless*poly(Time, 3)	4.180	1.391	-5.245	1.904
	(-10.788; 19.395)	(-10.118; 12.521)	(-20.598; 10.729)	(-10.644; 14.984)
Parent	0.915*	0.096	0.689*	0.019
	(0.533; 1.309)	(-0.176; 0.348)	(0.342; 1.031)	(-0.198; 0.246)
Parent*SWB		-0.014		0.015
		(-0.051; 0.022)		(-0.016; 0.044)
Parent*EWB	-0.053*		-0.019	
	(-0.105; -0.005)		(-0.061; 0.025)	
Parent*poly(Time, 1)	10.444*	4.333	9.150*	4.760
	(0.479; 21.384)	(-3.748; 11.852)	(0.596; 18.329)	(-2.228; 12.078)
Parent*poly(Time, 2)	2.310	2.250	5.949	-4.392
	(-7.074; 11.506)	(-6.044; 10.218)	(-3.042; 15.157)	(-13.806; 3.547)
Parent*poly(Time, 3)	-4.572	0.822	-12.329*	0.655
	(-13.323; 4.690)	(-6.352; 8.147)	(-21.236; -3.763)	(-7.943; 8.759)
Unknown childless	0.257	0.078	0.260	0.034
	(-0.234; 0.776)	(-0.288; 0.446)	(-0.109; 0.606)	(-0.305; 0.337)
Unknown childless*SWB		-0.018		-0.002
		(-0.069; 0.032)		(-0.047; 0.043)
Unknown childless*EWB	-0.002		-0.006	
	(-0.069; 0.063)		(-0.053; 0.044)	
Unknown childless*poly(Time, 1)	1.383	-6.586	-1.293	-2.949
	(-11.211; 14.605)	(-17.274; 3.980)	(-13.518; 10.635)	(-13.222; 6.387)
Unknown childless*poly(Time, 2)	-1.516	0.818	-5.357	-2.025
	(-14.658; 12.282)	(-10.298; 11.774)	(-18.052; 7.244)	(-15.641; 12.466)
Unknown childless*poly(Time, 3)	1.498	1.796	-2.467	-2.432
	(-11.470; 14.024)	(-8.710; 13.235)	(-15.130; 10.251)	(-11.448; 6.275)
Voluntarily childless	0.602*	0.051	0.580*	-0.082
	(0.053; 1.162)	(-0.316; 0.389)	(0.179; 0.994)	(-0.475; 0.305)
Voluntarily childless*SWB		-0.007		0.019
		(-0.055; 0.044)		(-0.032; 0.074)
Voluntarily childless*EWB	-0.028		-0.020	
	(-0.103; 0.050)		(-0.071; 0.032)	
Voluntarily childless*poly(Time, 1)	-2.272	0.955	5.882	-1.717
	(-15.013; 9.937)	(-9.225; 11.135)	(-6.332; 17.903)	(-11.407; 7.896)
Voluntarily childless*poly(Time, 2)	-9.576	-6.093	3.225	0.541
	(-23.165; 4.189)	(-16.756; 4.756)	(-10.413; 17.178)	(-9.605; 10.417)
Voluntarily childless*poly(Time, 3)	-0.840	7.481	-9.404	-3.548
	(-14.578; 11.640)	(-4.098; 19.040)	(-21.672; 3.524)	(-13.497; 6.719)
Child arrived since last wave (ref: No child arrived)	0.218*	0.049	0.153*	-0.006
	(0.129; 0.315)	(-0.002; 0.105)	(0.077; 0.235)	(-0.053; 0.040)
Number of children (ref: No children)				
One child	-0.273*	-0.176*	-0.236*	-0.018
	(-0.374; -0.164)	(-0.247; -0.108)	(-0.340; -0.128)	(-0.088; 0.052)
Two children	-0.295*	-0.238*	-0.259*	0.060
	(-0.406; -0.176)	(-0.308; -0.173)	(-0.379; -0.143)	(-0.013; 0.132)
Three or more children	-0.483*	-0.369*	-0.306*	-0.010
	(-0.615; -0.342)	(-0.446; -0.293)	(-0.450; -0.169)	(-0.103; 0.077)
Marital status (ref: (Re)married)				
Divorced/separated/widowed	-0.355*	0.024	-0.374*	-0.056
	(-0.438; -0.267)	(-0.035; 0.084)	(-0.489; -0.265)	(-0.122; 0.014)
Single and never married	-0.288*	-0.005	-0.176*	-0.118*
	(-0.359; -0.213)	(-0.050; 0.041)	(-0.251; -0.098)	(-0.168; -0.072)
Non-cohabiting (ref: Cohabiting)	-0.785*	-0.044	-0.736*	-0.015
	(-0.848; -0.716)	(-0.114; 0.011)	(-0.810; -0.655)	(-0.069; 0.036)
Higher educated NVQ4+ (ref: Lower educated NVQ3-)	0.132*	0.341*	0.135*	0.300*
	(0.069; 0.200)	(0.298; 0.378)	(0.065; 0.202)	(0.263; 0.336)
Economic activity (ref: Full-time paid employee)				
Out of the labour force	-0.085	-7.108*	-0.277	-7.458*
	(-0.253; 0.089)	(-7.159; -7.056)	(-0.564; 0.026)	(-7.514; -7.397)
Part-time paid employee	-0.058	-0.697*	-0.183	-0.869*
	(-0.128; 0.011)	(-0.743; -0.657)	(-0.426; 0.042)	(-1.069; -0.700)
Good health (ref: Fair health)	0.825*	0.110*	0.916*	0.081*
	(0.753; 0.894)	(0.063; 0.154)	(0.835; 0.990)	(0.029; 0.131)
cor(Intercept, poly(Time, 1))	-0.090	-0.964*	0.140	0.234
	(-0.240; 0.049)	(-0.999; -0.875)	(-0.610; 0.882)	(-0.952; 0.984)
sd(Intercept)	0.859*	0.334*	0.820*	0.359*
	(0.825; 0.894)	(0.303; 0.364)	(0.775; 0.864)	(0.310; 0.397)
sd(poly(Time, 1))	34.968*	11.317*	19.877*	2.778*
	(6.400; 45.032)	(7.381; 14.992)	(0.258; 38.331)	(0.137; 7.395)
LOOIC	93230.488	73742.339	72941.389	55236.382
WAIC	93114.322	74843.041	72873.544	57731.059

References

- Aassve, A., Burgess, S., Propper, C., and Dickson, M. (2006). Employment, family union and childbearing decisions in Great Britain. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 169(4):781–804.
- Abbott, A. (2005). Process and Temporality in Sociology: The Idea of Outcome in U.S. Sociology. In Steinmetz, G., editor, *The Politics of Method in the Human Sciences: Positivism and Its Epistemological Others*, pages 393–426. Durham, NC: Duke University Press.
- Agrillo, C. and Nelini, C. (2008). Childfree by choice: A review. *Journal of Cultural Geography*, 25(3):347–363.
- Allison, P. D. (2009). *Fixed effects regression models*. Sage Publications.
- Altman, D. G. and Royston, P. (2006). The cost of dichotomising continuous variables. *BMJ*, 332(7549):1080–1080.
- Andersson, G., Rønsen, M., Knudsen, L. B., Lappegård, T., Neyer, G., Skrede, K., Teschner, K., and Vikat, A. (2009). Cohort fertility patterns in the Nordic countries. *Demographic Research*, 20:313–352.
- Avison, M. and Furnham, A. (2015). Personality and voluntary childlessness. *Journal of Population Research*, 32(1):45–67.
- Barthold, J. A., Myrskylä, M., and Jones, O. R. (2012). Childlessness drives the sex difference in the association between income and reproductive success of modern Europeans. *Evolution and Human Behavior*, 33(6):628–638.
- Becker, G. S. (1981). *A treatise on the family*. Cambridge, MA: Harvard University Press.
- Berrington, A. (2017). Childlessness in the UK. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 57–76. Springer.
- Best, N. and Mason, A. (2013). Bayesian methods for missing data: Part 1 key concepts. [PowerPoint slides]. Retrieved from: https://www.bayes-pharma.org/Abstracts2013/slides/NickyBest_MissingData.pdf.
- Bijlsma, M. J. and Wilson, B. (2020). Modelling the socio-economic determinants of fertility: a mediation analysis using the parametric g-formula. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 183(2):493–513.
- Botosaru, I. and Gutierrez, F. H. (2018). Difference-in-differences when the treatment status is observed in only one period. *Journal of Applied Econometrics*, 33(1):73–90.
- Budig, M. J. and England, P. (2001). The wage penalty for motherhood. *American Sociological Review*, 66(2):204–225.
- Buhr, P. and Huinink, J. (2017). Why childless men and women give up on having children. *European Journal of Population*, 33(4):585–606.
- Bures, R. M., Koropecjy-Cox, T., and Loree, M. (2009). Childlessness, parenthood, and depressive symptoms among middle-aged and older adults. *Journal of Family Issues*, 30(5):670–687.
- Burkimsher, M. and Zeman, K. (2017). Childlessness in Switzerland and Austria. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 115–137. Springer.
- Bürkner, P. (2018). Package "brms": Bayesian Regression Models using 'Stan'. [R package]. Retrieved from: <https://cran.r-project.org/web/packages/brms/brms.pdf>.
- Cetre, S., Clark, A. E., and Senik, C. (2016). Happy people have children: Choice and self-selection into parenthood. *European Journal of Population*, 32(3):445–473.
- Chzhen, Y., Gromada, A., and Rees, G. (2019). Are the world's richest countries family friendly? Policy in the OECD and EU. Technical report, Unicef. Retrieved from: https://www.unicef-irc.org/publications/pdf/Family-Friendly-Policies-Research_UNICEF_%202019.pdf.
- Comolli, C., Bernardi, L., and Voorpostel, M. (2021). Joint family and work trajectories and multidimensional wellbeing. *European Journal of Population*, 37:643–696.
- Correll, S. J., Benard, S., and Paik, I. (2007). Getting a job: Is there a motherhood penalty? *American Journal of Sociology*, 112(5):1297–1338.
- Cwikel, J., Gramotnev, H., and Lee, C. (2006). Never-married childless women in Australia: Health and social circumstances in older age. *Social Science & Medicine*, 62(8):1991–2001.
- Doren, C. (2019). Which mothers pay a higher price? Education differences in motherhood wage penalties by parity and fertility timing. *Sociological Science*, 6:684–709.

- Dormon, O. (2013). Cohort Fertility 2012: Childbearing by the year of birth of mothers including trends in average family size, the age at which women give birth, and childlessness. Technical report, Office for National Statistics.
- Dykstra, P. A. and Keizer, R. (2009). The wellbeing of childless men and fathers in mid-life. *Ageing & Society*, 29(8):1227–1242.
- Elder Jr, G. H. (1994). Time, human agency, and social change: Perspectives on the life course. *Social Psychology Quarterly*, 57(1):4–15.
- Elder Jr, G. H. (1998). The life course as developmental theory. *Child Development*, 69(1):1–12.
- Elder Jr, G. H., Johnson, M. K., and Crosnoe, R. (2003). The emergence and development of life course theory. In Mortimer, J. and Shanahan, M., editors, *Handbook of the Life Course*, pages 3–19. Springer.
- Elliott, J. and Shepherd, P. (2006). Cohort profile: 1970 British birth cohort (BCS70). *International Journal of Epidemiology*, 35(4):836–843.
- Farley Ordovensky Staniec, J. and Webb, N. J. (2007). Utilization of infertility services: how much does money matter? *Health Services Research*, 42(3p1):971–989.
- Ferri, E., Bynner, J., and Wadsworth, M. (2003). *Changing Britain, changing lives: Three generations at the turn of the century*. Institute of Education, University of London London.
- Field, A., Miles, J., and Field, Z. (2012). *Discovering statistics using R*. Los Angeles, CA: Sage Publications.
- Frech, A. and Damaske, S. (2019). Men’s income trajectories and physical and mental health at midlife. *American Journal of Sociology*, 124(5):1372–1412.
- Frejka, T., Sobotka, T., Hoem, J., and Toulemon, L. (2008). Childbearing trends and policies in Europe: Summary and general conclusions. *Demographic Research*, 19:5–13.
- Gangl, M. and Ziefle, A. (2009). Motherhood, labor force behavior, and women’s careers: An empirical assessment of the wage penalty for motherhood in Britain, Germany, and the United States. *Demography*, 46(2):341–369.
- Gauthier, J.-A., Widmer, E. D., Bucher, P., and Notredame, C. (2010). Multichannel sequence analysis applied to social science data. *Sociological Methodology*, 40(1):1–38.
- Gelman, A. (2006). Prior distributions for variance parameters in hierarchical models. *Bayesian Analysis*, 1(3):515–534.
- Gelman, A. and Hill, J. (2006). *Data analysis using regression and multilevel/hierarchical models*. Cambridge, United Kingdom: Cambridge University Press.
- Gelman, A., Hwang, J., and Vehtari, A. (2014). Understanding predictive information criteria for Bayesian models. *Statistics and Computing*, 24(6):997–1016.
- Gelman, A. and Rubin, D. B. (1992). Inference from iterative simulation using multiple sequences. *Statistical Science*, 7(4):457–472.
- Giele, J. and Elder Jr, G. (1998). *Methods of life course research: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications.
- Guvenen, F., Karahan, F., Ozkan, S., and Song, J. (2016). What do data on millions of US workers reveal about life-cycle earnings dynamics? Technical report, Technical report No. 710, Federal Reserve Bank of New York Staff Report.
- Hadley, R. and Hanley, T. (2011). Involuntarily childless men and the desire for fatherhood. *Journal of Reproductive and Infant Psychology*, 29(1):56–68.
- Hagestad, G. O. and Call, V. R. (2007). Pathways to childlessness: A life course perspective. *Journal of Family Issues*, 28(10):1338–1361.
- Hansen, T., Slagsvold, B., and Moum, T. (2009). Childlessness and psychological well-being in midlife and old age: An examination of parental status effects across a range of outcomes. *Social Indicators Research*, 94(2):343–362.
- Heinz, W. R. (2003). From work trajectories to negotiated careers. In Mortimer, J. and Shanahan, M., editors, *Handbook of the Life Course*, pages 185–204. Springer.
- Hoekstra, T. and Twisk, J. W. (2015). The analysis of individual health trajectories across the life course: Latent class growth models versus mixed models. In Burton-Jeangros, C., Cullati, S., Sacker, A., and Blane, D., editors, *A life course perspective on health trajectories and transitions*, pages 179–195. Springer, Cham.
- Hoffman, M. D. and Gelman, A. (2014). The No-U-Turn sampler: adaptively setting path lengths in Hamiltonian Monte Carlo. *Journal of Machine Learning Research*, 15(1):1593–1623.
- Huber, S., Bookstein, F. L., and Fieder, M. (2010). Socioeconomic status, education, and reproduction in modern women: An evolutionary perspective. *American Journal of Human Biology*, 22(5):578–587.

- Jalovaara, M. and Fasang, A. E. (2017). From never partnered to serial cohabitators: Union trajectories to childlessness. *Demographic Research*, 36:1703–1720.
- Jalovaara, M. and Fasang, A. E. (2020). Family life courses, gender, and mid-life earnings. *European Sociological Review*, 36(2):159–178.
- Jalovaara, M. and Miettinen, A. (2013). Does his paycheck also matter? The socioeconomic resources of co-residential partners and entry into parenthood in Finland. *Demographic Research*, 28:881–916.
- Jeffries, S. and Konnert, C. (2002). Regret and psychological well-being among voluntarily and involuntarily childless women and mothers. *The International Journal of Ageing and Human Development*, 54(2):89–106.
- Johansen, E. R., Nielsen, H. S., and Verner, M. (2020). Long-term consequences of early parenthood. *Journal of Marriage and Family*, 82(4):1286–1303.
- Kahn, J. R., García-Manglano, J., and Bianchi, S. M. (2014). The motherhood penalty at midlife: Long-term effects of children on women's careers. *Journal of Marriage and Family*, 76(1):56–72.
- Keizer, R., Dykstra, P. A., and Jansen, M. D. (2008). Pathways into childlessness: Evidence of gendered life course dynamics. *Journal of Biosocial Science*, 40(6):863–878.
- Keizer, R., Dykstra, P. A., and Poortman, A.-R. (2009). Life outcomes of childless men and fathers. *European Sociological Review*, 26(1):1–15.
- Keizer, R., Dykstra, P. A., and Poortman, A.-R. (2010). The transition to parenthood and well-being: the impact of partner status and work hour transitions. *Journal of Family Psychology*, 24(4):429–438.
- Keizer, R. and Ivanova, K. (2017). What's a (childless) man without a woman? The differential importance of couple dynamics for the wellbeing of childless men and women in the Netherlands. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 313–330. Springer.
- Kelly, M. (2009). Women's voluntary childlessness: A radical rejection of motherhood? *Women's Studies Quarterly*, 37(2):157–172.
- Killewald, A. (2013). A reconsideration of the fatherhood premium: Marriage, coresidence, biology, and fathers' wages. *American Sociological Review*, 78(1):96–116.
- Kneale, D. and Joshi, H. (2008). Postponement and childlessness: Evidence from two British cohorts. *Demographic Research*, 19:1935–1968.
- Koert, E. and Daniluk, J. C. (2017). When time runs out: reconciling permanent childlessness after delayed childbearing. *Journal of Reproductive and Infant Psychology*, 35(4):342–352.
- Kohler, H., Behrman, J., and Skytthe, A. (2005). Partner + children = happiness? The effects of partnerships and fertility on well-being. *Population and Development Review*, 31(3):407–445.
- Kohler, H.-P. and Mencarini, L. (2016). The parenthood happiness puzzle: An introduction to special issue. *European Journal of Population*, 32(3):327–338.
- Kok, J. (2007). Principles and prospects of the life course paradigm. *Annales de Démographie Historique*, 1(113):203–230.
- Köppen, K., Mazuy, M., and Toulemon, L. (2017). Childlessness in France. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 77–95. Springer.
- Koropecjy-Cox, T. and Call, V. R. (2007). Characteristics of older childless persons and parents: Cross-national comparisons. *Journal of Family Issues*, 28(10):1362–1414.
- Kreyenfeld, M. and Konietzka, D. (2017a). Childlessness in East and West Germany: Long-Term Trends and Social Disparities. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 97–114. Springer.
- Kreyenfeld, M. and Konietzka, D. (2017b). *Childlessness in Europe: Contexts, Causes, and Consequences*. Springer.
- Kruschke, J. (2014). *Doing Bayesian data analysis: A tutorial with R, JAGS, and Stan*. Academic Press.
- Kuhnt, A.-K., Kreyenfeld, M., and Trappe, H. (2017). Fertility ideals of women and men across the life course. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 235–251. Springer.
- Lechner, L., Bolman, C., and van Dalen, A. (2007). Definite involuntary childlessness: associations between coping, social support and psychological distress. *Human Reproduction*, 22(1):288–294.
- Lemoine, N. P. (2019). Moving beyond noninformative priors: Why and how to choose weakly informative priors in Bayesian analyses. *Oikos*, 128(7):912–928.
- Lewandowski, D., Kurowicka, D., and Joe, H. (2009). Generating random correlation matrices based on vines and extended onion method. *Journal of Multivariate Analysis*, 100(9):1989–2001.

- Lynch, S. M. and Bartlett, B. (2019). Bayesian Statistics in Sociology: Past, Present, and Future. *Annual Review of Sociology*, 45.
- Mari, G. (2019). Is there a fatherhood wage premium? A reassessment in societies with strong male-breadwinner legacies. *Journal of Marriage and Family*, 81(5):1033–1052.
- Mastekaasa, A. (1992). Marriage and psychological well-being: Some evidence on selection into marriage. *Journal of Marriage and the Family*, 54(4):901–911.
- Mayer, K. U. (2009). New directions in life course research. *Annual Review of Sociology*, 35:413–433.
- McDonnell, C., Luke, N., and Short, S. E. (2019). Happy moms, happier dads: Gendered caregiving and parents' affect. *Journal of Family Issues*, 40(17):2553–2581.
- McMunn, A., Bird, L., Webb, E., and Sacker, A. (2020). Gender divisions of paid and unpaid work in contemporary UK couples. *Work, Employment and Society*, 34(2):155–173.
- McNeish, D. (2016). On using Bayesian methods to address small sample problems. *Structural Equation Modeling: A Multidisciplinary Journal*, 23(5):750–773.
- McQuillan, J., Greil, A. L., Shreffler, K. M., Wonch-Hill, P. A., Gentzler, K. C., and Hathcoat, J. D. (2012). Does the reason matter? Variations in childlessness concerns among US women. *Journal of Marriage and Family*, 74(5):1166–1181.
- McQuillan, J., Greil, A. L., White, L., and Jacob, M. C. (2003). Frustrated fertility: Infertility and psychological distress among women. *Journal of Marriage and Family*, 65(4):1007–1018.
- Merz, E.-M. and Liefbroer, A. C. (2012). The attitude toward voluntary childlessness in Europe: Cultural and institutional explanations. *Journal of Marriage and Family*, 74(3):587–600.
- Micklewright, J. and Schnepf, S. V. (2010). How reliable are income data collected with a single question? *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 173(2):409–429.
- Miettinen, A., Rotkirch, A., Szalma, I., Donno, A., and Tanturri, M.-L. (2015). Increasing childlessness in Europe: Time trends and country differences. *Families and Societies: Working Paper Series*, 33.
- Miettinen, A. and Szalma, I. (2014). Childlessness intentions and ideals in Europe. *Finnish Yearbook of Population Research*, 49:31–55.
- Mika, T. and Czaplicki, C. (2017). Fertility and women's old-age income in Germany. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 331–349. Springer.
- Mills, M., Mencarini, L., Tanturri, M. L., and Begall, K. (2008). Gender equity and fertility intentions in Italy and the Netherlands. *Demographic Research*, 18:1–26.
- Mostafa, T. and Wiggins, D. (2014). Handling attrition and non-response in the 1970 British Cohort Study. Technical report, Institute of Education, University of London.
- Musick, K., Meier, A., and Flood, S. (2016). How parents fare: Mothers' and fathers' subjective well-being in time with children. *American Sociological Review*, 81(5):1069–1095.
- Mynarska, M., Matysiak, A., Rybińska, A., Tocchioni, V., and Vignoli, D. (2015). Diverse paths into childlessness over the life course. *Advances in Life Course Research*, 25:35–48.
- Myrskylä, M. and Margolis, R. (2014). Happiness: Before and after the kids. *Demography*, 51(5):1843–1866.
- Nagin, D. S. (2010). Group-based trajectory modeling: An overview. *Handbook of Quantitative Criminology*, pages 53–67.
- Nomaguchi, K. and Milkie, M. A. (2020). Parenthood and well-being: A decade in review. *Journal of Marriage and Family*, 82(1):198–223.
- Norman, G. (2010). Likert scales, levels of measurement and the “laws” of statistics. *Advances in Health Sciences Education*, 15(5):625–632.
- Office for National Statistics (2016). Births by parents' characteristics in England and Wales statistical bulletins. Retrieved from: <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/bulletins/birthsbyparentscharacteristicsinenglandandwales/2016/pdf>.
- Office for National Statistics (2018a). Consumer price inflation time series (mm23). [Computer file]. Retrieved from: <https://www.ons.gov.uk/generator?format=xls&uri=/economy/inflationandpriceindices/timeseries/czbh/mm23&series=&fromYear=1948&toYear=2018&frequency=years>.
- Office for National Statistics (2018b). Divorces in England and Wales: 2018. Statistical bulletin, Office for National Statistics. Retrieved from: <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/divorce/bulletins/divorcesinenglandandwales/2018/pdf>.

- O'Hagan, A. and Forster, J. (2004). *Kendall's advanced theory of statistics, volume 2B: Bayesian inference*. Hodder Education.
- Organisation for Economic Co-operation and Development (2018). Employment: Labour force participation rate, by sex and age group. [Computer file]. Retrieved from: <https://stats.oecd.org/index.aspx?queryid=54741#>.
- Park, K. (2005). Choosing childlessness: Weber's typology of action and motives of the voluntarily childless. *Sociological Inquiry*, 75(3):372–402.
- Plotnick, R. D. (2009). Childlessness and the economic well-being of older Americans. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 64(6):767–776.
- Poole, E., Speight, S., O'Brien, M., Connolly, S., and Aldrich, M. (2016). Who are non-resident fathers? A British socio-demographic profile. *Journal of Social Policy*, 45(2):223–250.
- Raab, M. and Struffolino, E. (2020). The heterogeneity of partnership trajectories to childlessness in Germany. *European Journal of Population*, 36(1):53–70.
- Raftery, A. E. (1995). Bayesian model selection in social research. *Sociological Methodology*, 25:111–163.
- Raudenbush, S. W. and Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*, volume 1. Thousand Oaks, CA: Sage Publications.
- Ritschard, G. and Studer, M. (2018). Sequence analysis: where are we, where are we going? In Ritschard, G. and Studer, M., editors, *Sequence analysis and related approaches*, pages 1–11. Springer, Cham.
- Roantree, B. and Vira, K. (2018). The rise and rise of women's employment in the UK. IFS Briefing Note BN234, Institute for Fiscal Studies. Retrieved from: <https://www.ifs.org.uk/uploads/BN234.pdf>.
- Rooney, K. L. and Domar, A. D. (2018). The relationship between stress and infertility. *Dialogues in Clinical Neuroscience*, 20(1):41.
- Rossignon, F., Studer, M., Gauthier, J.-A., and Le Goff, J.-M. (2018). Sequence history analysis (SHA): Estimating the effect of past trajectories on an upcoming event. In Ritschard, G. and Studer, M., editors, *Sequence Analysis and Related Approaches*, pages 83–100. Springer, Cham.
- Rotkirch, A. and Miettinen, A. (2017). Childlessness in Finland. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 139–158. Springer.
- Rouder, J., Richard, D., and Pratte, M. (2013). Hierarchical bayesian models. [Powerpoint slides]. Retrieved from: <http://pcl.missouri.edu/sites/default/files/p5.pdf>.
- Sanders, S. (2018). Childbearing for women born in different years, England and Wales: 2018. Technical report, Office for National Statistics.
- Schoon, I., Chen, M., Kneale, D., and Jager, J. (2012). Becoming adults in Britain: lifestyles and wellbeing in times of social change. *Longitudinal and Life Course Studies*, 3(2):173–189.
- Sigle, W. (2016). Fertility and population change in the United Kingdom. In Rindfuss, R. and Choe, M., editors, *Low Fertility, Institutions, and their Policies*, pages 77–98. Springer.
- Snijders, T. A. and Berkhof, J. (2008). Diagnostic checks for multilevel models. In de Leeuw, J. and Meijer, E., editors, *Handbook of multilevel analysis*, pages 141–175. Springer.
- Sobotka, T. (2017). Childlessness in Europe: Reconstructing long-term trends among women born in 1900–1972. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 17–53. Springer.
- Stan Development Team (2019). Stan user's guide version 2.28. Retrieved from: https://mc-stan.org/docs/2_28/stan-users-guide/index.html.
- Steele, F. (2008). Multilevel models for longitudinal data. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 171(1):5–19.
- Stegen, H., Switsers, L., and De Donder, L. (2020). Life stories of voluntarily childless older people: A retrospective view on their reasons and experiences. *Journal of Family Issues*, 42(7):1536–1558.
- Studer, M., Struffolino, E., and Fasang, A. E. (2018). Estimating the relationship between time-varying covariates and trajectories: The sequence analysis multistate model procedure. *Sociological Methodology*, 48(1):103–135.
- Switek, M. and Easterlin, R. A. (2018). Life transitions and life satisfaction during young adulthood. *Journal of Happiness Studies*, 19(1):297–314.
- Tanturri, M. (2012). The determinants of childlessness among men and women in later adult life in Italy: do they differ? PAA 2012 Annual Meeting. New Orleans – 11–13 April 2012. Retrieved from: <https://paa2013.princeton.edu/papers/131642>.

- Tanturri, M., de Santis, G., and Seghieri, C. (2008). Economic well-being in old age in Italy: does having children make a difference? *Genus*, 64:75–99.
- Tanturri, M. L. and Mencarini, L. (2008). Childless or childfree? Paths to voluntary childlessness in Italy. *Population and Development Review*, 34(1):51–77.
- Tanturri, M. L., Mills, M., Rotkirch, A., Sobotka, T., Takács, J., Miettinen, A., Faludi, C., Kantsa, V., and Nasiri, D. (2015). State-of-the-art report: Childlessness in Europe. *Families and Societies*, 32:1–53.
- Tretjakova, V., Gedvilaitė-Kordušienė, M., and Rapolienė, G. (2020). Women's pathways to childlessness in Lithuania. *Social Sciences Bulletin*, 2:7–21.
- Turnbull, B., Graham, M. L., and Taket, A. R. (2016). Social exclusion of Australian childless women in their reproductive years. *Social Inclusion*, 4(1):102–115.
- Twenge, J. M., Campbell, W. K., and Foster, C. A. (2003). Parenthood and marital satisfaction: A meta-analytic review. *Journal of Marriage and Family*, 65(3):574–583.
- Umberson, D., Pudrovska, T., and Reczek, C. (2010). Parenthood, childlessness, and well-being: A life course perspective. *Journal of Marriage and Family*, 72(3):612–629.
- University of London, I. and Centre for Longitudinal Studies (2016a). 1970 British Cohort Study: Forty-Two-Year Follow-Up, 2012. [data collection]. 5th Edition. UK Data Service. SN: 7473, <http://doi.org/10.5255/UKDA-SN-7473-2>.
- University of London, I. and Centre for Longitudinal Studies (2016b). 1970 British Cohort Study: Twenty-Nine-Year Follow-Up, 1999–2000. [data collection]. 4th Edition. Joint Centre for Longitudinal Research, [original data producer(s)]. Joint Centre for Longitudinal Research. SN: 5558, <http://doi.org/10.5255/UKDA-SN-5558-3>.
- University of London, I. and Centre for Longitudinal Studies (2019a). 1970 British Cohort Study: Forty-Six-Year Follow-Up, 2016–2018. [data collection]. 5th Edition. UK Data Service. SN: 8547, <http://doi.org/10.5255/UKDA-SN-8547-1>.
- University of London, I. and Centre for Longitudinal Studies (2019b). 1970 British Cohort Study: Thirty-Eight-Year Follow-Up, 2008–2009. [data collection]. 5th Edition. UK Data Service. SN: 6557, <http://doi.org/10.5255/UKDA-SN-6557-4>.
- University of London, I. and Centre for Longitudinal Studies (2020a). 1970 British Cohort Study: Thirty-Four-Year Follow-Up, 2004–2005. [data collection]. 5th Edition. UK Data Service. SN: 5585, <http://doi.org/10.5255/UKDA-SN-5585-4>.
- University of London, I. and Centre for Longitudinal Studies (2020b). 1970 British Cohort Study: Twenty-Six-Year Follow-Up, 1996. [data collection]. 5th Edition. UK Data Service. SN: 3833, <http://doi.org/10.5255/UKDA-SN-3833-3>.
- Van Winkle, Z. and Fasang, A. E. (2020). Parenthood wage gaps across the life course: A comparison by gender and race. *Journal of Marriage and Family*, 82(5):1515–1533.
- Vikström, J., Bladh, M., Hammar, M., Marcusson, J., Wressle, E., and Sydsjö, G. (2011). The influences of childlessness on the psychological well-being and social network of the oldest old. *BMC Geriatrics*, 11(1):78.
- Wagner, M., Huinink, J., and Liefbroer, A. C. (2019). Running out of time? Understanding the consequences of the biological clock for the dynamics of fertility intentions and union formation. *Demographic Research*, 40:1–26.
- White, I. R., Royston, P., and Wood, A. M. (2011). Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine*, 30(4):377–399.
- White, L. K. and McQuillan, J. (2006). No longer intending: The relationship between relinquished fertility intentions and distress. *Journal of Marriage and Family*, 68(2):478–490.
- Willson, A. E., Shuey, K. M., and Elder, Jr, G. H. (2007). Cumulative advantage processes as mechanisms of inequality in life course health. *American Journal of Sociology*, 112(6):1886–1924.
- Wu, L. L. (2003). Event history models for life course analysis. In Mortimer, J. and Shanahan, M., editors, *Handbook of the Life Course*, pages 477–502. Springer.
- Zhang, Z. and Hayward, M. D. (2001). Childlessness and the psychological well-being of older persons. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 56(5):S311–S320.
- Zhu, Y., Steele, F., and Moustaki, I. (2020). A multilevel structural equation model for the interrelationships between multiple latent dimensions of childhood socio-economic circumstances, partnership transitions and mid-life health. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 183(3):1029–1050.

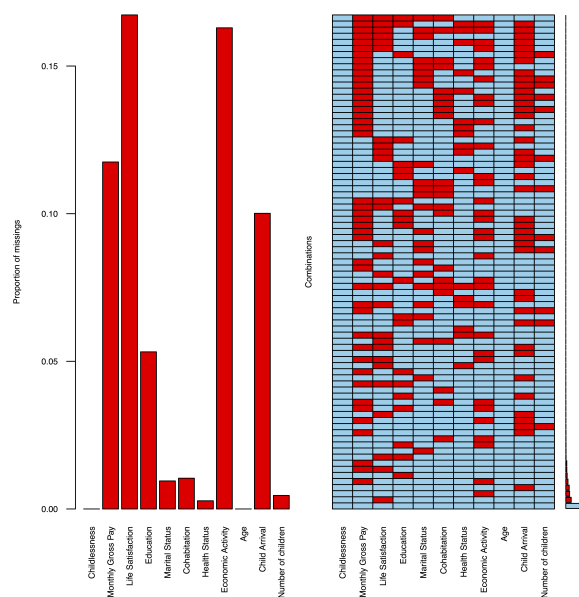
Appendices

Appendix 3.A Distinction of Childlessness Types

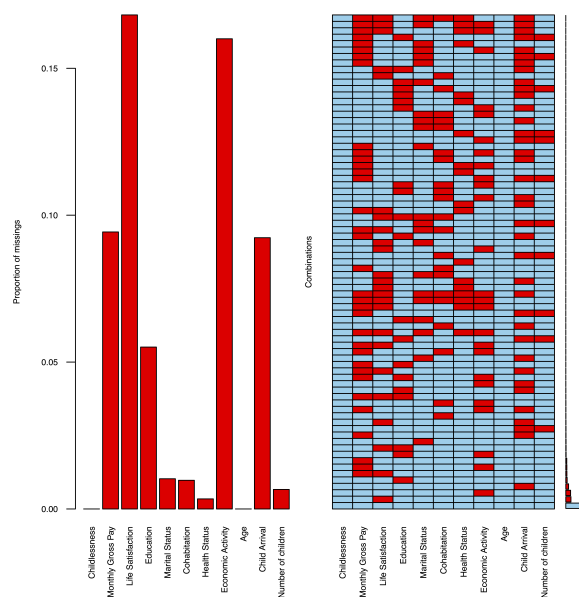
Table 3.A.1: Childlessness types based on respondents' answer to the question 'What is the most important reason that you have not had any children?' (asked in the 2012 sweep at age 42)

Childlessness type	Reason
Involuntary	Infertility problem (partner)
	Infertility problem (personal)
	Other health reason
	Part. sterilised/vasectomy/hysterectomy
Voluntary	I have not wanted to have children
	Partner and I have not wanted children
	Won't compromise relationship with part
	I have been focused on my career
Circumstantial	My financial sit. made it difficult
	My housing situation made it difficult
	My spouse/partner doesn't want children
	Partner has children doesn't want more
	Not met right person to have child with
	Wanted children but not got round to it
	Homosexual relationship
Unknown	Don't know
	Don't want to answer
	Not applicable (for those who are still childless)
	No particular reason
	Other reason

Appendix 3.B Missingness Plots



(a) Aggregation plots for missingness proportions and patterns in female data



(b) Aggregation plots for missingness proportions and patterns in male data

Figure 3.B.1: Aggregation plots for missingness proportions and patterns in (a) female and (b) male data

Appendix 3.C Bayesian Hierarchical Regression Results for Models 1 to 6

Table 3.C.1: Pooled coefficients for the female Bayesian HGCMs estimating EWB (log(1+inflation-corrected monthly gross pay)) and SWB (life satisfaction)

Coefficient	No control variables	Child quantum and timing	Other dependent variable	Marital status and cohabitation	Education	Economic activity	Health status	Fully controlled
SWB								
Intercept	6.684* (6.512; 6.857)	6.682* (6.511; 6.847)	5.923* (5.503; 6.351)	7.503* (7.325; 7.678)	6.522* (6.353; 6.681)	6.716* (6.554; 6.883)	5.905* (5.734; 6.070)	6.240* (5.797; 6.667)
EWB			0.108* (0.053; 0.161)					0.070* (0.018; 0.125)
poly(Time, 1)	9.720* (1.106; 18.517)	12.976* (3.858; 21.679)	9.216* (0.564; 17.746)	2.212 (-6.725; 11.340)	9.934* (1.033; 18.692)	10.487* (1.887; 19.118)	12.351* (3.055; 21.114)	6.916 (-2.408; 15.246)
poly(Time, 2)	-7.466 (-16.198; 1.173)	-6.992 (-15.625; 1.471)	-4.160 (-12.801; 4.679)	-5.436 (-13.671; 3.279)	-7.311 (-15.849; 1.386)	-6.339 (-15.199; 3.018)	-8.603 (-17.390; 3.376)	-4.151 (-12.736; 4.379)
poly(Time, 3)	5.840 (-2.494; 13.900)	5.223 (-3.349; 13.643)	4.401 (-4.022; 12.776)	4.934 (-3.296; 13.453)	5.863 (-2.305; 14.274)	9.728* (-2.485; 13.913)	5.350 (1.217; 18.018)	7.248 (-1.480; 15.809)
Eventual parental status (ref: Circumstantially childless)								
Involuntarily childless	0.118 (-0.160; 0.408)	0.120 (-0.137; 0.372)	0.118 (-0.516; 0.703)	-0.201 (-0.475; 0.056)	0.140 (-0.135; 0.407)	0.134 (-0.140; 0.392)	0.238 (-0.015; 0.493)	-0.093 (-0.635; 0.477)
Involuntarily childless*EWB			0.008 (-0.071; 0.089)					0.008 (-0.069; 0.083)
Involuntarily childless*poly(Time, 1)	-7.841 (-22.462; 7.122)	-8.819 (-24.433; 6.212)	-7.097 (-22.457; 7.302)	-10.171 (-25.749; 4.241)	-7.571 (-23.953; 8.502)	-7.320 (-22.028; 8.479)	-7.175 (-22.588; 7.424)	-10.103 (-24.069; 4.282)
Involuntarily childless*poly(Time, 2)	5.715 (-9.411; 21.212)	5.448 (-10.176; 21.001)	7.468 (-7.977; 22.100)	4.252 (-11.034; 19.076)	6.126 (-9.991; 21.425)	6.123 (-8.469; 21.583)	5.665 (-9.261; 20.535)	6.260 (-7.665; 20.873)
Involuntarily childless*poly(Time, 3)	3.264 (-11.870; 18.158)	3.715 (-10.890; 17.744)	3.248 (-12.181; 18.102)	4.209 (-10.632; 18.589)	2.873 (-12.111; 18.147)	3.234 (-10.927; 17.901)	2.990 (-12.511; 18.151)	4.180 (-10.788; 19.395)
Parent	0.759* (0.577; 0.929)	0.937* (0.752; 1.130)	1.316* (0.906; 1.738)	0.262* (0.086; 0.442)	0.797* (0.644; 0.970)	0.818* (0.645; 1.001)	0.757* (0.592; 0.923)	0.915* (0.533; 1.309)
Parent*EWB			-0.072* (-0.126; -0.018)					-0.053* (-0.105; -0.005)
Parent*poly(Time, 1)	-3.641 (-12.779; 4.854)	8.381 (-1.512; 18.181)	-3.682 (-12.693; 5.419)	-2.281 (-11.577; 7.298)	-3.644 (-13.295; 5.339)	-4.141 (-13.788; 5.438)	-2.665 (-12.229; 7.050)	10.444* (0.479; 21.384)
Parent*poly(Time, 2)	-1.045 (-10.337; 8.149)	1.733 (-7.225; 11.553)	-3.428 (-12.921; 6.002)	4.473 (-4.773; 13.520)	-1.104 (-10.281; 8.023)	-1.836 (-12.061; 7.915)	-0.990 (-10.480; 8.269)	2.310 (-7.074; 11.506)
Parent*poly(Time, 3)	-2.397 (-10.825; 6.333)	-4.534 (-13.681; 4.732)	-2.065 (-10.739; 6.820)	-3.397 (-12.267; 5.754)	-2.444 (-11.486; 6.077)	-2.905 (-12.348; 5.747)	-2.380 (-11.323; 6.257)	-4.572 (-13.323; 4.690)
Unknown childless	0.399* (0.167; 0.630)	0.401* (0.171; 0.646)	0.490 (-0.074; 1.055)	0.159 (-0.062; 0.399)	0.428* (0.192; 0.669)	0.419* (0.160; 0.656)	0.433* (0.209; 0.654)	0.257 (-0.234; 0.776)
Unknown childless*EWB			-0.005 (-0.074; 0.066)					-0.002 (-0.069; 0.063)
Unknown childless*poly(Time, 1)	4.822 (-8.574; 18.488)	2.913 (-10.306; 16.559)	6.457 (-7.131; 20.040)	1.795 (-11.024; 15.019)	4.767 (-8.467; 19.058)	5.311 (-8.624; 19.120)	4.515 (-8.325; 18.153)	1.383 (-11.211; 14.605)
Unknown childless*poly(Time, 2)	-4.659 (-18.058; 8.146)	-4.801 (-17.659; 8.894)	-2.798 (-15.289; 10.574)	-4.038 (-16.917; 8.265)	-4.110 (-18.234; 9.411)	-3.923 (-17.413; 9.649)	-3.278 (-15.873; 10.228)	-1.516 (-14.658; 12.282)
Unknown childless*poly(Time, 3)	-4.096 (-17.049; 8.652)	-3.401 (-16.916; 9.388)	-4.666 (-18.416; 8.472)	0.151 (-13.228; 12.980)	-3.820 (-17.614; 8.831)	-3.889 (-17.378; 8.505)	-2.019 (-15.538; 11.072)	1.498 (-11.470; 14.024)
Voluntarily childless	0.657* (0.434; 0.877)	0.662* (0.426; 0.892)	0.873* (0.276; 1.478)	0.399* (0.180; 0.631)	0.667* (0.434; 0.901)	0.661* (0.439; 0.888)	0.660* (0.438; 0.880)	0.602* (0.053; 1.162)
Voluntarily childless*EWB			-0.031 (-0.108; 0.044)					-0.028 (-0.103; 0.050)
Voluntarily childless*poly(Time, 1)	4.218 (-9.106; 19.069)	2.398 (-10.720; 15.497)	5.397 (-7.705; 18.505)	-1.627 (-15.262; 11.433)	4.570 (-9.845; 18.171)	5.323 (-7.542; 18.834)	4.918 (-8.978; 18.107)	-2.272 (-15.013; 9.937)
Voluntarily childless*poly(Time, 2)	-11.109 (-24.589; 1.569)	-11.565 (-25.116; 1.666)	-10.454 (-24.220; 4.590)	-8.126 (-21.178; 5.566)	-11.262 (-23.786; 2.040)	-10.486 (-25.238; 3.461)	-12.180 (-26.511; 2.489)	-9.576 (-23.165; 4.189)
Voluntarily childless*poly(Time, 3)	-1.651 (-14.482; 10.971)	-1.248 (-14.491; 11.836)	-2.025 (-14.772; 10.892)	-1.472 (-13.886; 11.353)	-1.906 (-14.976; 10.320)	-1.649 (-14.497; 11.769)	-1.086 (-15.019; 11.287)	-0.840 (-14.578; 11.640)
Child arrived since last wave (ref: No child arrived)		0.346* (0.248; 0.446)						0.218* (0.129; 0.315)
Number of children (ref: No children)								
One child		-0.287* (-0.396; -0.190)						-0.273* (-0.374; -0.164)
Two children		-0.248* (-0.358; -0.141)						-0.295* (-0.406; -0.176)
Three or more children		-0.576* (-0.711; -0.436)						-0.483* (-0.615; -0.342)
Marital status (ref: (Re)married)								
Divorced/separated/widowed				-0.368* (-0.459; -0.284)				-0.355* (-0.438; -0.267)
Single and never married				-0.267* (-0.344; -0.189)				-0.288* (-0.359; -0.213)
Non-cohabiting (ref: Cohabiting)				-0.826* (-0.890; -0.762)				-0.785* (-0.848; -0.716)
Higher educated NVQ4+ (ref: Lower educated NVQ3-)					0.289* (0.217; 0.363)			0.132* (0.069; 0.200)
Economic activity (ref: Full-time paid employee)								
Out of the labour force						-0.320* (-0.408; -0.238)		-0.085 (-0.253; 0.089)
Part-time paid employee						-0.062 (-0.127; 0.000)		-0.058 (-0.128; 0.011)
Good health (ref: Fair health)							0.929* (0.854; 0.995)	0.825* (0.753; 0.894)
cor(Intercept, poly(Time, 1))	0.076 (-0.020; 0.179)	0.105* (0.006; 0.213)	0.070 (-0.029; 0.169)	-0.023 (-0.139; 0.093)	0.085 (-0.014; 0.194)	0.073 (-0.025; 0.174)	-0.028 (-0.132; 0.086)	-0.090 (-0.240; 0.049)
sd(Intercept)	1.056* (1.020; 1.092)	1.041* (1.005; 1.079)	1.028* (0.992; 1.065)	0.956* (0.923; 0.991)	1.046* (1.012; 1.083)	1.035* (1.002; 1.073)	0.972* (0.935; 1.012)	0.859* (0.825; 0.894)
sd(poly(Time, 1))	46.485* (37.821; 54.616)	45.384* (36.600; 54.314)	46.245* (37.375; 54.453)	40.116* (30.180; 49.560)	46.468* (37.343; 54.724)	46.840* (38.239; 54.519)	42.689* (32.952; 51.431)	34.968* (6.400; 45.032)
LOOIC	94955.320	94829.334	94922.231	93929.884	94914.597	94933.644	94380.584	93230.488
WAIC	94755.535	94640.465	94732.086	93785.374	94718.392	94745.222	94219.014	93114.322

Table 3.C.1: (continued) Pooled coefficients for the female Bayesian HGCMs estimating EWB (log(1+inflation-corrected monthly gross pay)) and SWB (life satisfaction)

Coefficient	No control variables	Child quantum and timing	Other dependent variable	Marital status and cohabitation	Education	Economic activity	Health status	Fully controlled
EWB								
Intercept	6.975* (6.710; 7.235)	7.001* (6.769; 7.235)	6.175* (5.504; 6.867)	6.775* (6.504; 7.040)	6.375* (6.103; 6.634)	7.695* (7.596; 7.788)	6.322* (6.065; 6.585)	7.264* (7.002; 7.522)
SWB			0.120* (0.029; 0.214)					0.024 (-0.009; 0.061)
poly(Time, 1)	3.198 (-7.609; 13.884)	27.652* (16.662; 39.008)	2.410 (-7.982; 13.240)	6.550 (-4.613; 18.307)	4.095 (-7.023; 15.946)	19.896* (12.838; 27.203)	5.269 (-5.882; 16.487)	20.500* (13.208; 27.700)
poly(Time, 2)	-32.247* (-42.530; -21.528)	-42.611* (-52.573; -32.680)	-30.926* (-40.845; -21.361)	-32.502* (-42.148; -22.637)	-31.992* (-41.980; -21.265)	-11.902* (-19.406; -4.379)	-32.610* (-42.682; -22.506)	-12.638* (-20.155; -5.368)
poly(Time, 3)	17.599* (8.051; 27.128)	18.610* (8.774; 28.940)	17.130* (7.203; 27.136)	17.682* (7.848; 27.440)	17.973* (8.312; 27.634)	6.271 (-0.581; 13.203)	20.818* (11.741; 30.370)	6.861 (-0.035; 13.906)
Eventual parental status (ref: Circumstantially childless)								
Involuntarily childless	-0.431 (-0.865; 0.004)	-0.412 (-0.833; 0.009)	-0.676 (-1.830; 0.477)	-0.369 (-0.800; 0.068)	-0.347 (-0.766; 0.033)	-0.026 (-0.184; 0.141)	-0.328 (-0.718; 0.083)	0.094 (-0.365; 0.526)
Involuntarily childless*SWB			0.033 (-0.118; 0.185)					-0.015 (-0.071; 0.041)
Involuntarily childless*poly(Time, 1)	-3.238 (-19.412; 14.572)	-9.734 (-28.377; 7.972)	-3.100 (-21.858; 13.829)	-3.089 (-20.083; 14.932)	-3.769 (-22.164; 13.848)	0.177 (-12.215; 12.625)	-3.535 (-21.626; 13.408)	-0.731 (-12.524; 11.958)
Involuntarily childless*poly(Time, 2)	-8.096 (-24.212; 8.264)	-5.220 (-22.754; 12.274)	-8.748 (-25.340; 7.388)	-8.340 (-24.355; 8.802)	-8.525 (-25.083; 7.677)	-0.718 (-13.471; 12.314)	-8.189 (-24.239; 8.978)	-1.248 (-14.606; 11.599)
Involuntarily childless*poly(Time, 3)	-2.506 (-18.199; 12.362)	-2.573 (-19.642; 12.750)	-2.427 (-20.511; 14.726)	-2.264 (-18.187; 14.950)	-2.232 (-18.725; 13.871)	1.609 (-10.336; 13.934)	-2.459 (-19.566; 14.509)	1.391 (-10.118; 12.521)
Parent	-1.284* (-1.546; -1.009)	0.759* (0.494; 1.020)	-1.115* (-1.903; -0.403)	-1.178* (-1.452; -0.906)	-1.142* (-1.399; -0.881)	-0.161* (-0.249; -0.065)	-1.286* (-1.559; -1.027)	0.096 (-0.176; 0.348)
Parent*SWB			-0.035 (-0.133; 0.066)					-0.014 (-0.051; 0.022)
Parent*poly(Time, 1)	7.965 (-3.717; 19.878)	67.306* (55.607; 79.663)	8.273 (-3.761; 19.738)	9.931 (-2.427; 22.119)	7.754 (-4.446; 19.485)	-4.616 (-12.411; 2.542)	9.072 (-4.125; 20.924)	4.333 (-3.748; 11.852)
Parent*poly(Time, 2)	10.038 (-1.314; 21.069)	-20.383* (-30.873; -9.443)	9.464 (-1.097; 20.331)	8.289 (-2.222; 18.822)	9.826 (-1.833; 20.439)	3.010 (-5.599; 11.027)	9.565 (-1.356; 20.519)	2.250 (-6.044; 10.218)
Parent*poly(Time, 3)	12.609* (2.517; 23.361)	12.919* (2.793; 22.934)	12.810* (1.626; 23.413)	12.832* (2.901; 23.585)	12.528* (2.237; 22.772)	1.382 (-5.646; 8.653)	12.779* (2.283; 23.382)	0.822 (-6.352; 8.147)
Unknown childless	-0.493* (-0.871; -0.136)	-0.471* (-0.806; -0.156)	-0.886 (-1.846; 0.084)	-0.455* (-0.799; -0.088)	-0.374* (-0.728; -0.034)	-0.058 (-0.173; 0.048)	-0.472* (-0.822; -0.118)	0.078 (-0.288; 0.446)
Unknown childless*SWB			0.048 (-0.075; 0.181)					-0.018 (-0.069; 0.032)
Unknown childless*poly(Time, 1)	-10.208 (-26.117; 5.432)	-19.794* (-36.940; -2.441)	-10.828 (-26.764; 4.747)	-9.724 (-26.672; 5.537)	-10.366 (-27.065; 6.343)	-5.110 (-15.754; 5.455)	-10.705 (-28.584; 5.567)	-6.586 (-17.274; 3.980)
Unknown childless*poly(Time, 2)	-13.615 (-29.317; 1.799)	-9.148 (-25.188; 6.457)	-12.622 (-28.500; 2.896)	-12.993 (-27.865; 2.499)	-13.354 (-28.064; 1.642)	0.100 (-11.083; 11.165)	-12.846 (-27.717; 2.271)	0.818 (-10.298; 11.774)
Unknown childless*poly(Time, 3)	2.786 (-12.708; 17.760)	2.819 (-12.356; 17.548)	2.796 (-12.946; 16.997)	2.400 (-12.046; 17.371)	2.761 (-12.832; 18.543)	1.249 (-9.852; 11.487)	3.909 (-11.049; 17.914)	1.796 (-8.710; 13.235)
Voluntarily childless	0.058 (-0.324; 0.428)	0.076 (-0.261; 0.400)	0.093 (-0.917; 1.133)	0.063 (-0.278; 0.443)	0.063 (-0.273; 0.405)	0.030 (-0.092; 0.159)	0.049 (-0.331; 0.410)	0.051 (-0.316; 0.389)
Voluntarily childless*SWB			-0.016 (-0.162; 0.116)					-0.007 (-0.055; 0.044)
Voluntarily childless*poly(Time, 1)	-1.635 (-17.181; 14.850)	-10.646 (-27.522; 6.242)	-1.858 (-18.475; 14.922)	-0.653 (-16.892; 16.775)	-1.517 (-18.510; 14.721)	2.554 (-8.267; 12.909)	-1.057 (-17.547; 15.198)	0.955 (-9.225; 11.135)
Voluntarily childless*poly(Time, 2)	-12.637 (-27.636; 3.168)	-7.939 (-22.173; 7.184)	-12.653 (-28.036; 2.022)	-12.585 (-29.093; 3.126)	-13.711 (-28.280; 0.619)	-6.114 (-17.031; 4.909)	-14.005 (-28.662; 0.616)	-6.093 (-16.756; 4.756)
Voluntarily childless*poly(Time, 3)	4.241 (-10.398; 19.276)	3.839 (-11.110; 18.611)	3.925 (-10.147; 18.317)	4.394 (-10.094; 19.236)	4.160 (-11.218; 19.904)	8.097 (-2.221; 19.008)	4.358 (-10.505; 18.947)	7.481 (-4.098; 19.040)
Child arrived since last wave (ref: No child arrived)		-0.418* (-0.521; -0.317)						0.049 (-0.002; 0.105)
Number of children (ref: No children)								
One child		-1.937* (-2.082; -1.791)						-0.176* (-0.247; -0.108)
Two children		-2.372* (-2.526; -2.230)						-0.238* (-0.308; -0.173)
Three or more children		-3.357* (-3.556; -3.170)						-0.369* (-0.446; -0.293)
Marital status (ref: (Re)married)								
Divorced/separated/widowed				0.209* (0.064; 0.354)				0.024 (-0.035; 0.084)
Single and never married				0.354* (0.241; 0.472)				-0.005 (-0.050; 0.041)
Non-cohabiting (ref: Cohabiting)				-0.148* (-0.257; -0.036)				-0.044 (-0.114; 0.011)
Higher educated NVQ4+ (ref: Lower educated NVQ3-)					1.068* (0.960; 1.179)			0.341* (0.298; 0.378)
Economic activity (ref: Full-time paid employee)								
Out of the labour force						-7.226* (-7.277; -7.179)		-7.108* (-7.159; -7.056)
Part-time paid employee						-0.773* (-0.816; -0.734)		-0.697* (-0.743; -0.657)
Good health (ref: Fair health)							0.782* (0.675; 0.886)	0.110* (0.063; 0.154)
cor(Intercept, poly(Time, 1))	0.280* (0.229; 0.331)	0.549* (0.493; 0.604)	0.281* (0.232; 0.334)	0.289* (0.237; 0.344)	0.286* (0.232; 0.341)	-0.949* (-0.999; -0.818)	0.259* (0.205; 0.310)	-0.964* (-0.999; -0.875)
sd(Intercept)	1.687* (1.635; 1.742)	1.537* (1.489; 1.590)	1.652* (1.601; 1.707)	1.697* (1.641; 1.752)	1.604* (1.550; 1.654)	0.378* (0.350; 0.408)	1.614* (1.562; 1.669)	0.334* (0.303; 0.364)
sd(poly(Time, 1))	152.023* (144.549; 159.489)	132.970* (125.351; 140.776)	151.505* (144.038; 159.022)	150.731* (143.151; 158.059)	151.763* (144.475; 159.797)	9.502* (5.814; 13.220)	149.294* (141.669; 156.821)	11.317* (7.381; 14.992)
LOOIC	113619.138	111577.196	113654.411	113594.352	113466.738	74655.917	113579.282	73742.339
WAIC	113080.489	111169.246	113125.496	113046.929	112947.789	76144.992	113076.971	74843.041

Table 3.C.2: Pooled coefficients for the male Bayesian HGCMs estimating EWB (log(1+inflation-corrected monthly gross pay)) and SWB (life satisfaction)

Coefficient	No control variables	Child quantum and timing	Other dependent variable	Marital status and cohabitation	Education	Economic activity	Health status	Fully controlled
SWB								
Intercept	6.341* (6.193; 6.500)	6.341* (6.187; 6.502)	5.420* (5.077; 5.733)	7.157* (6.995; 7.318)	6.184* (6.022; 6.347)	6.526* (6.382; 6.670)	5.449* (5.284; 5.616)	5.744* (5.364; 6.176)
EWB			0.140* (0.099; 0.187)					0.087* (0.037; 0.132)
poly(Time, 1)	-0.864 (-8.819; 7.700)	-0.158 (-8.505; 7.787)	-1.918 (-9.434; 5.848)	-9.837* (-18.228; -1.577)	-0.740 (-9.194; 7.288)	0.767 (-7.589; 9.130)	2.674 (-5.588; 10.300)	-4.686 (-12.879; 3.476)
poly(Time, 2)	-12.697* (-20.727; -4.004)	-12.073* (-20.245; -4.087)	-5.983 (-14.111; 2.321)	-9.496* (-18.558; -0.979)	-12.321* (-20.478; -4.167)	-7.187 (-15.390; 0.645)	-13.379* (-21.925; -4.612)	-5.726 (-13.609; 2.370)
poly(Time, 3)	12.250* (3.933; 20.599)	12.405* (4.124; 20.677)	8.633* (0.522; 17.170)	11.051* (2.795; 18.948)	12.267* (4.237; 20.347)	9.224* (0.971; 17.201)	15.015* (6.716; 22.989)	11.186* (3.050; 18.984)
Eventual parental status (ref: Circumstantially childless)								
Involuntarily childless	0.485* (0.153; 0.798)	0.482* (0.170; 0.812)	0.565 (-0.109; 1.234)	0.149 (-0.163; 0.453)	0.486* (0.147; 0.821)	0.522* (0.244; 0.830)	0.581* (0.298; 0.896)	0.659* (0.025; 1.235)
Involuntarily childless*EWB			-0.011 (-0.099; 0.079)					-0.058 (-0.133; 0.025)
Involuntarily childless*poly(Time, 1)	-0.285 (-8.865; 16.518)	-0.663 (-16.303; 16.032)	0.192 (-15.219; 15.991)	-3.189 (-18.577; 13.543)	-0.634 (-16.172; 16.025)	-0.260 (-17.424; 15.728)	-1.097 (-17.828; 13.988)	-3.872 (-18.603; 11.599)
Involuntarily childless*poly(Time, 2)	-1.746 (-17.623; 14.180)	-1.526 (-17.696; 14.002)	-0.927 (-17.082; 14.494)	2.791 (-13.756; 18.201)	-1.501 (-17.676; 14.038)	-1.104 (-16.590; 15.406)	-0.725 (-17.150; 14.291)	2.660 (-13.276; 17.969)
Involuntarily childless*poly(Time, 3)	-4.633 (-20.413; 10.801)	-4.938 (-20.295; 12.022)	-5.208 (-20.058; 11.284)	-5.253 (-20.543; 10.647)	-5.017 (-20.561; 11.039)	-5.319 (-21.293; 9.649)	-5.849 (-20.636; 11.071)	-5.245 (-20.598; 10.729)
Parent	1.023* (0.857; 1.181)	1.041* (0.858; 1.219)	0.929* (0.578; 1.291)	0.482* (0.328; 0.639)	1.028* (0.863; 1.190)	0.942* (0.792; 1.096)	0.989* (0.838; 1.141)	0.689* (0.342; 1.031)
Parent*EWB			0.000 (-0.049; 0.045)					-0.019 (-0.061; 0.025)
Parent*poly(Time, 1)	5.410 (-3.757; 14.193)	9.747* (0.397; 20.039)	3.029 (-6.099; 11.437)	2.176 (-6.659; 11.908)	5.623 (-3.516; 14.760)	4.018 (-5.083; 13.181)	5.101 (-3.572; 14.194)	9.150* (0.596; 18.329)
Parent*poly(Time, 2)	1.210 (-8.189; 10.237)	4.300 (-4.722; 13.111)	-0.159 (-9.658; 9.018)	7.184 (-1.923; 16.630)	0.925 (-8.306; 9.370)	-0.876 (-9.442; 8.154)	0.572 (-8.795; 9.589)	5.949 (-3.042; 15.157)
Parent*poly(Time, 3)	-12.242* (-21.389; -3.241)	-13.133* (-22.177; -4.126)	-11.980* (-21.074; -2.738)	-12.584* (-21.285; -3.487)	-12.327* (-21.279; -3.892)	-11.772* (-20.761; -2.989)	-10.899* (-20.200; -1.773)	-12.329* (-21.236; -3.763)
Unknown childless	0.351* (0.152; 0.556)	0.347* (0.149; 0.550)	0.223 (-0.191; 0.611)	0.132 (-0.065; 0.333)	0.374* (0.161; 0.582)	0.382* (0.179; 0.577)	0.400* (0.215; 0.590)	0.260 (-0.109; 0.606)
Unknown childless*EWB			0.025 (-0.029; 0.077)					-0.006 (-0.053; 0.044)
Unknown childless*poly(Time, 1)	0.228 (-12.263; 12.229)	-0.502 (-12.499; 11.959)	1.969 (-10.535; 14.602)	-2.783 (-15.607; 9.186)	0.523 (-12.833; 13.309)	1.727 (-10.390; 13.869)	1.024 (-10.992; 13.713)	-1.293 (-13.518; 10.635)
Unknown childless*poly(Time, 2)	-9.161 (-21.428; 1.899)	-9.513 (-22.454; 2.530)	-6.887 (-20.348; 6.875)	-9.497 (-21.766; 2.241)	-9.148 (-21.106; 3.341)	-7.763 (-19.404; 4.427)	-6.162 (-18.435; 6.041)	-3.357 (-18.052; 7.244)
Unknown childless*poly(Time, 3)	-4.333 (-17.365; 9.098)	-4.785 (-17.983; 8.380)	-6.021 (-18.993; 6.945)	-1.349 (-15.096; 11.371)	-4.293 (-17.296; 8.719)	-5.514 (-17.880; 7.740)	-4.368 (-16.845; 9.124)	-2.467 (-15.130; 10.251)
Voluntarily childless	0.704* (0.475; 0.913)	0.699* (0.473; 0.930)	0.683* (0.270; 1.096)	0.486* (0.263; 0.696)	0.678* (0.452; 0.909)	0.672* (0.459; 0.871)	0.684* (0.467; 0.894)	0.580* (0.179; 0.994)
Voluntarily childless*EWB			-0.002 (-0.056; 0.051)					-0.020 (-0.071; 0.032)
Voluntarily childless*poly(Time, 1)	8.671 (-3.801; 21.418)	8.117 (-4.318; 21.183)	7.523 (-4.937; 20.538)	7.338 (-5.845; 19.998)	8.978 (-4.274; 22.050)	7.478 (-5.460; 20.906)	8.626 (-3.988; 21.365)	5.882 (-6.332; 17.903)
Voluntarily childless*poly(Time, 2)	3.287 (-10.548; 16.575)	2.947 (-10.350; 16.207)	3.486 (-8.979; 16.216)	4.355 (-9.727; 16.949)	3.066 (-10.853; 16.604)	3.669 (-9.765; 16.985)	1.718 (-11.581; 15.146)	3.225 (-10.413; 17.178)
Voluntarily childless*poly(Time, 3)	-8.252 (-21.090; 4.568)	-8.672 (-22.486; 4.385)	-8.375 (-22.189; 3.792)	-8.852 (-21.582; 3.519)	-8.564 (-21.590; 4.313)	-8.680 (-21.553; 3.635)	-8.610 (-22.042; 4.336)	-9.404 (-21.672; 3.524)
Child arrived since last wave (Ref: No child arrived)		0.216* (0.127; 0.309)						0.153* (0.077; 0.235)
Number of children (ref: No children)								
One child		-0.091 (-0.200; 0.015)						-0.236* (-0.340; -0.128)
Two children		-0.080 (-0.203; 0.039)						-0.259* (-0.379; -0.143)
Three or more children		-0.246* (-0.393; -0.102)						-0.306* (-0.450; -0.169)
Marital status (ref: (Re)married)								
Divorced/separated/widowed				-0.424* (-0.536; -0.319)				-0.374* (-0.489; -0.265)
Single and never married				-0.182* (-0.262; -0.102)				-0.176* (-0.251; -0.098)
Non-cohabiting (ref: Cohabiting)				-0.808* (-0.883; -0.734)				-0.736* (-0.810; -0.655)
Higher educated NVQ4+ (ref: Lower educated NVQ3-)					0.349* (0.265; 0.431)			0.135* (0.065; 0.202)
Economic activity (ref: Full-time paid employee)								
Out of the labour force						-1.161* (-1.289; -1.040)		-0.277 (-0.564; 0.026)
Part-time paid employee						-0.367* (-0.605; -0.106)		-0.183 (-0.426; 0.042)
Good health (ref: Fair health)								
							1.084* (1.005; 1.165)	0.916* (0.835; 0.990)
cor(Intercept, poly(Time, 1))	0.235* (0.119; 0.366)	0.260* (0.146; 0.414)	0.193* (0.065; 0.347)	0.160* (0.010; 0.358)	0.235* (0.120; 0.379)	0.190* (0.068; 0.344)	0.132 (-0.019; 0.360)	0.140 (-0.610; 0.882)
sd(Intercept)	1.062* (1.022; 1.104)	1.062* (1.019; 1.102)	0.955* (0.911; 0.999)	0.975* (0.929; 1.017)	1.048* (1.009; 1.089)	0.969* (0.925; 1.009)	0.946* (0.905; 0.986)	0.820* (0.775; 0.864)
sd(poly(Time, 1))	39.137* (29.989; 47.413)	38.322* (28.438; 46.692)	37.000* (26.623; 45.648)	32.793* (18.624; 42.138)	38.825* (29.188; 47.033)	37.548* (27.511; 45.701)	32.945* (8.318; 43.425)	19.877* (0.258; 38.331)
LOOIC	74537.922	74516.910	74185.289	73852.562	74485.917	74219.076	73971.556	72941.389
WAIC	74392.227	74361.223	74049.625	73748.821	74342.273	74091.618	73862.265	72873.544

Table 3.C.2: (continued) Pooled coefficients for the male Bayesian HGCMs estimating EWB (log(1+inflation-corrected monthly gross pay)) and SWB (life satisfaction)

Coefficient	No control variables	Child quantum and timing	Other dependent variable	Marital status and cohabitation	Education	Economic activity	Health status	Fully controlled
EWB								
Intercept	6.602* (6.393; 6.802)	6.608* (6.399; 6.819)	5.471* (5.013; 5.919)	7.146* (6.909; 7.375)	6.273* (6.058; 6.481)	7.752* (7.671; 7.836)	5.921* (5.712; 6.141)	7.533* (7.328; 7.737)
SWB			0.178* (0.110; 0.248)					0.018 (-0.011; 0.047)
poly(Time, 1)	5.384 (-4.237; 14.881)	7.180 (-2.213; 17.332)	5.513 (-3.655; 14.753)	-1.336 (-10.836; 8.746)	5.838 (-4.255; 15.511)	18.299* (12.127; 24.216)	8.077 (-1.762; 17.556)	16.827* (10.184; 23.191)
poly(Time, 2)	-42.802* (-51.471; -32.474)	-42.951* (-52.545; -32.932)	-40.716* (-49.921; -32.028)	-40.554* (-49.623; -31.813)	-42.838* (-51.990; -33.568)	-9.616* (-17.647; -0.461)	-43.488* (-52.973; -33.743)	-9.728* (-17.592; -0.524)
poly(Time, 3)	24.203* (16.096; 33.133)	24.219* (15.512; 33.281)	22.594* (14.182; 31.633)	23.842* (14.796; 32.996)	24.465* (15.303; 33.559)	8.506* (1.734; 15.749)	26.530* (18.463; 34.513)	8.434* (1.645; 16.202)
Eventual parental status (ref: Circumstantially childless)								
Involuntarily childless	-0.116 (-0.552; 0.338)	-0.109 (-0.556; 0.353)	-0.016 (-0.998; 0.973)	-0.309 (-0.757; 0.138)	-0.078 (-0.507; 0.363)	0.192* (0.016; 0.382)	-0.034 (-0.458; 0.403)	0.354 (-0.441; 1.037)
Involuntarily childless*SWB			-0.025 (-0.157; 0.109)					-0.028 (-0.116; 0.080)
Involuntarily childless*poly(Time, 1)	-1.594 (-18.719; 16.351)	-1.866 (-18.665; 15.511)	-1.067 (-18.260; 15.890)	-3.093 (-20.924; 14.380)	-2.122 (-20.258; 16.134)	-1.320 (-14.458; 11.448)	-1.726 (-18.276; 15.041)	-2.811 (-16.076; 8.967)
Involuntarily childless*poly(Time, 2)	-6.053 (-22.100; 10.197)	-6.126 (-22.115; 10.050)	-5.964 (-22.725; 11.011)	-4.426 (-20.814; 12.124)	-5.416 (-21.762; 11.421)	-4.484 (-18.789; 9.998)	-5.199 (-21.533; 12.044)	-3.432 (-17.532; 0.913)
Involuntarily childless*poly(Time, 3)	3.995 (-13.258; 20.726)	4.406 (-11.396; 20.456)	5.433 (-10.601; 22.001)	3.750 (-12.817; 19.335)	3.969 (-12.091; 20.672)	1.803 (-11.437; 15.326)	4.285 (-12.125; 20.099)	1.904 (-10.644; 14.984)
Parent	0.696* (0.487; 0.918)	0.810* (0.585; 1.041)	0.548* (0.014; 1.075)	0.342* (0.122; 0.567)	0.720* (0.517; 0.931)	0.221* (0.142; 0.304)	0.672* (0.457; 0.874)	0.019 (-0.198; 0.246)
Parent*SWB			-0.003 (-0.075; 0.073)					0.015 (-0.016; 0.044)
Parent*poly(Time, 1)	15.406* (4.821; 25.408)	21.469* (9.953; 32.515)	14.567* (4.870; 24.533)	12.167* (1.820; 22.013)	15.889* (5.356; 26.825)	7.120* (0.112; 13.714)	15.321* (4.567; 25.922)	4.760 (-2.228; 12.078)
Parent*poly(Time, 2)	5.833 (-4.852; 15.180)	5.521 (-4.294; 15.926)	5.572 (-4.053; 15.612)	9.429 (-0.605; 18.793)	5.548 (-4.508; 15.158)	6.004 (-15.070; 1.969)	5.357 (-5.035; 15.331)	-4.392 (-13.806; 3.547)
Parent*poly(Time, 3)	-1.119 (-11.214; 8.557)	-1.826 (-11.278; 7.225)	0.700 (-9.163; 9.951)	-1.540 (-10.902; 7.900)	-1.137 (-10.786; 8.284)	-0.053 (-8.092; 7.229)	-0.144 (-9.532; 8.871)	0.655 (-7.943; 8.759)
Unknown childless	-0.205 (-0.487; 0.080)	-0.209 (-0.474; 0.075)	-0.714* (-1.406; -0.033)	-0.339* (-0.597; -0.062)	-0.142 (-0.405; 0.126)	0.029 (-0.076; 0.137)	-0.179 (-0.445; 0.070)	0.034 (-0.305; 0.337)
Unknown childless*SWB			0.069 (-0.028; 0.168)					-0.002 (-0.047; 0.043)
Unknown childless*poly(Time, 1)	-10.064 (-24.110; 3.979)	-11.356 (-25.045; 1.421)	-10.132 (-24.183; 4.715)	-11.891 (-25.343; 1.655)	-9.615 (-23.825; 3.772)	-2.716 (-12.083; 7.157)	-9.474 (-22.929; 5.249)	-2.949 (-13.222; 6.387)
Unknown childless*poly(Time, 2)	-13.687* (-27.845; -0.561)	-13.781* (-27.205; -0.509)	-11.451 (-24.634; 2.098)	-14.287* (-27.511; -1.170)	-13.871* (-26.723; -0.093)	-2.597 (-16.621; 12.529)	-11.962 (-25.448; 1.643)	-2.025 (-15.641; 12.466)
Unknown childless*poly(Time, 3)	4.299 (-7.142; 16.081)	4.675 (-7.209; 16.162)	4.703 (-7.209; 17.000)	5.831 (-6.901; 17.972)	5.103 (-7.046; 16.676)	-3.056 (-11.459; 6.114)	5.086 (-7.667; 17.001)	-2.432 (-11.448; 6.275)
Voluntarily childless	0.261 (-0.061; 0.557)	0.259 (-0.045; 0.544)	0.039 (-0.627; 0.722)	0.136 (-0.166; 0.435)	0.238 (-0.084; 0.539)	0.106 (-0.006; 0.214)	0.252 (-0.032; 0.555)	-0.082 (-0.475; 0.305)
Voluntarily childless*SWB			0.015 (-0.069; 0.103)					0.019 (-0.032; 0.074)
Voluntarily childless*poly(Time, 1)	5.505 (-9.145; 20.827)	4.497 (-9.408; 17.937)	4.031 (-10.628; 19.627)	4.887 (-9.642; 20.290)	5.387 (-8.925; 19.542)	-1.229 (-10.670; 8.591)	5.960 (-9.071; 20.669)	-1.717 (-11.407; 7.896)
Voluntarily childless*poly(Time, 2)	-4.246 (-18.034; 9.268)	-4.080 (-18.105; 9.795)	-4.365 (-17.246; 9.198)	-3.782 (-16.907; 9.797)	-4.271 (-17.564; 9.685)	0.400 (-10.346; 10.682)	-5.026 (-18.551; 8.601)	0.541 (-9.605; 10.417)
Voluntarily childless*poly(Time, 3)	2.106 (-11.108; 15.820)	1.731 (-11.525; 14.257)	3.003 (-10.216; 16.611)	1.359 (-11.490; 14.957)	1.728 (-11.373; 14.609)	1.306 (-14.487; 5.790)	1.306 (-11.773; 14.762)	-3.548 (-13.497; 6.719)
Child arrived since last wave (ref: No child arrived)		0.041 (-0.054; 0.146)						-0.006 (-0.053; 0.040)
Number of children (ref: No children)								
One child		-0.158* (-0.287; -0.028)						-0.018 (-0.088; 0.052)
Two children		-0.091 (-0.237; 0.040)						0.060 (-0.013; 0.132)
Three or more children		-0.440* (-0.623; -0.247)						-0.010 (-0.103; 0.077)
Marital status (ref: (Re)married)								
Divorced/separated/widowed				-0.186* (-0.319; -0.046)				-0.056 (-0.122; 0.014)
Single and never married				-0.229* (-0.328; -0.130)				-0.118* (-0.168; -0.072)
Non-cohabiting (ref: Cohabiting)				-0.428* (-0.522; -0.334)				-0.015 (-0.069; 0.036)
Higher educated NVQ4+ (ref: Lower educated NVQ3-)					0.698* (0.583; 0.813)			0.300* (0.263; 0.336)
Economic activity (ref: Full-time paid employee)								
Out of the labour force						-7.554* (-7.611; -7.499)		-7.458* (-7.514; -7.397)
Part-time paid employee						-0.894* (-1.076; -0.739)		-0.869* (-1.069; -0.700)
Good health (ref: Fair health)							0.832* (0.737; 0.928)	0.081* (0.029; 0.131)
cor(Intercept,poly(Time, 1))	0.441* (0.383; 0.496)	0.441* (0.385; 0.500)	0.438* (0.376; 0.498)	0.420* (0.361; 0.483)	0.399* (0.340; 0.456)	0.567 (-0.810; 0.994)	0.404* (0.342; 0.467)	0.234 (-0.952; 0.984)
sd(Intercept)	1.639* (1.588; 1.690)	1.628* (1.582; 1.680)	1.530* (1.477; 1.581)	1.581* (1.530; 1.631)	1.598* (1.550; 1.648)	0.407* (0.361; 0.443)	1.541* (1.492; 1.592)	0.359* (0.310; 0.397)
sd(poly(Time,1))	102.476* (95.734; 109.751)	103.078* (96.319; 110.014)	99.915* (93.144; 106.037)	100.354* (93.694; 107.263)	102.419* (95.579; 108.772)	4.251* (0.131; 10.090)	98.503* (91.713; 105.504)	2.778* (0.137; 7.395)
LOOIC	81845.936	81860.897	81768.467	81762.304	81833.872	56084.198	81765.999	55236.382
WAIC	81982.502	81964.862	81793.019	81860.780	81932.292	59768.892	81864.423	57731.059

Appendix 3.D Convergence Diagnostics

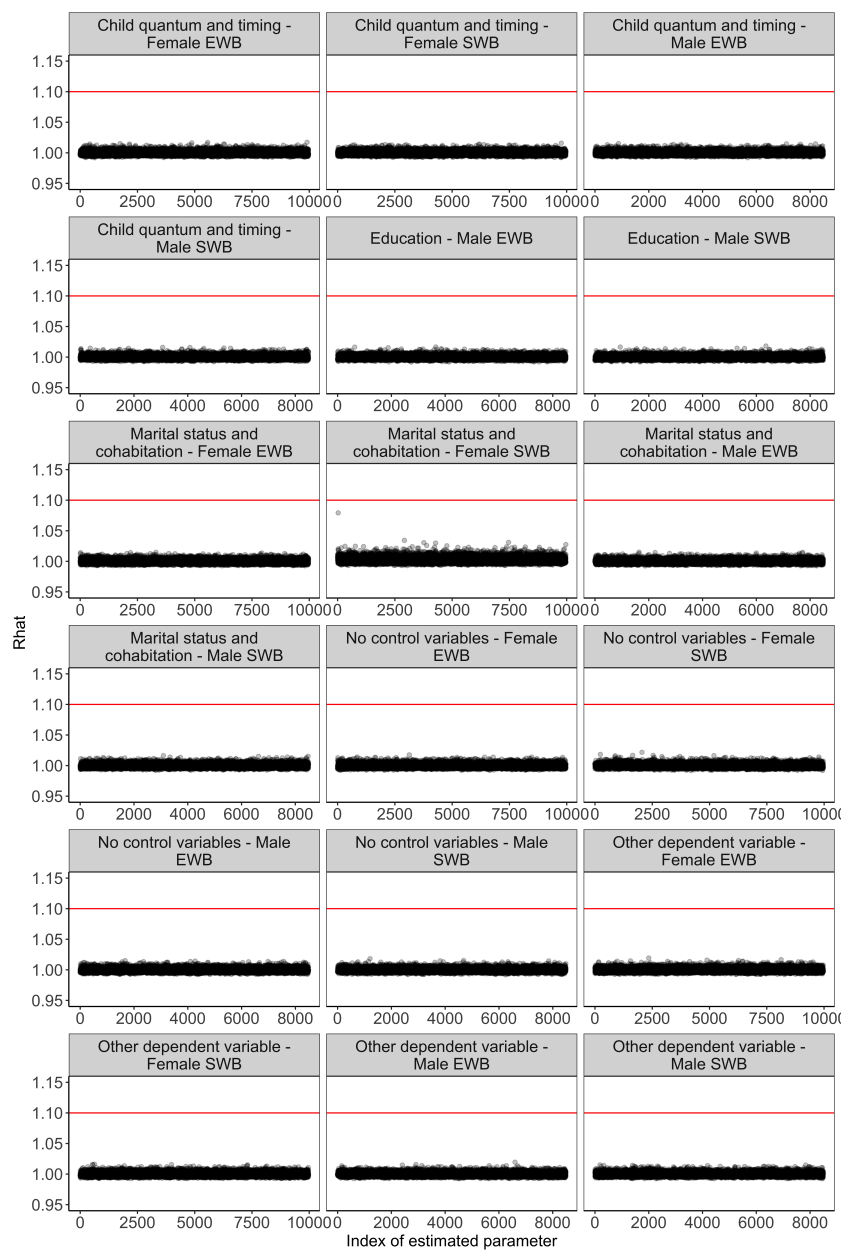


Figure 3.D.1: Average scale reduction factor on split chains ($\hat{R}$) per parameter (x-axis) per model (facets)

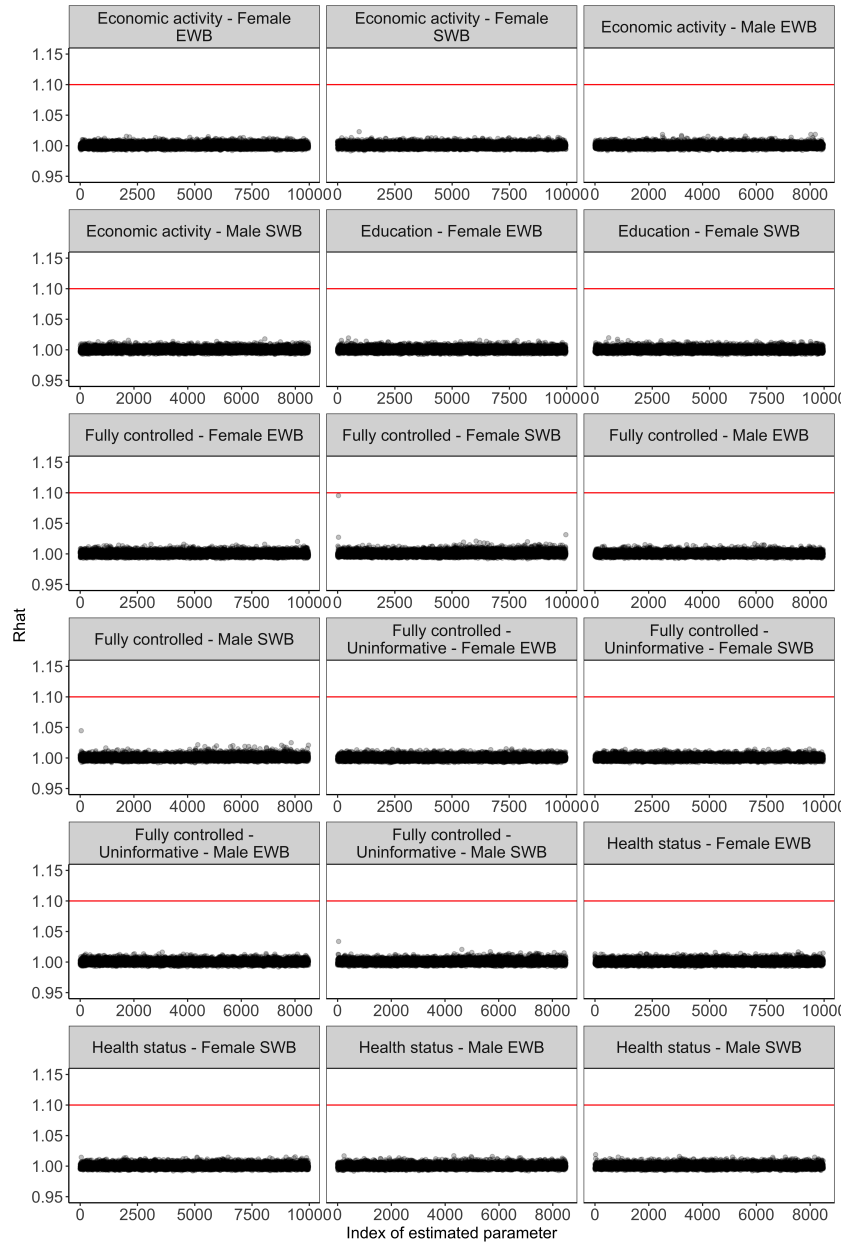


Figure 3.D.1: (continued) Average scale reduction factor on split chains ($\hat{R}$) per parameter (x-axis) per model (facets)

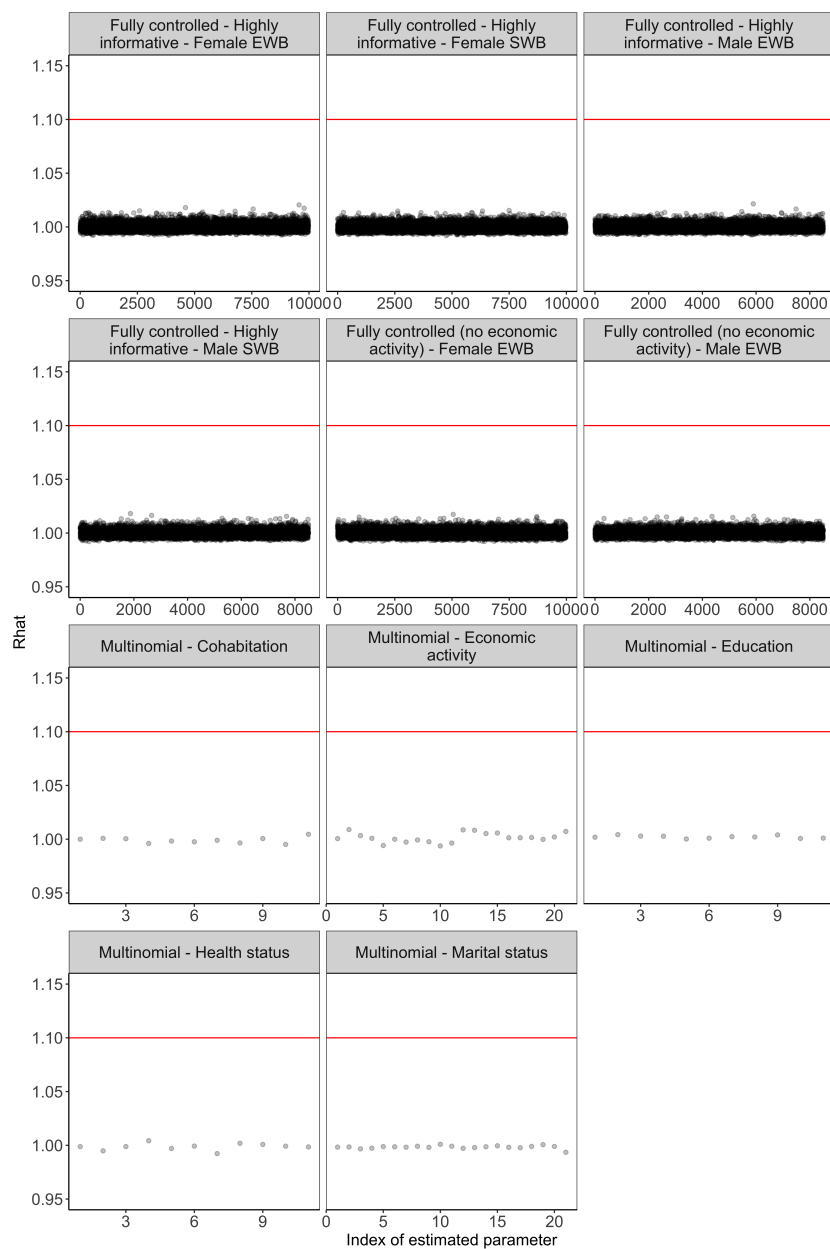


Figure 3.D.1: (continued) Average scale reduction factor on split chains ($\hat{R}$) per parameter (x-axis) per model (facets)

Appendix 3.E Sensitivity Analyses

3.E.1 Sensitivity Analysis – Uninformative Priors

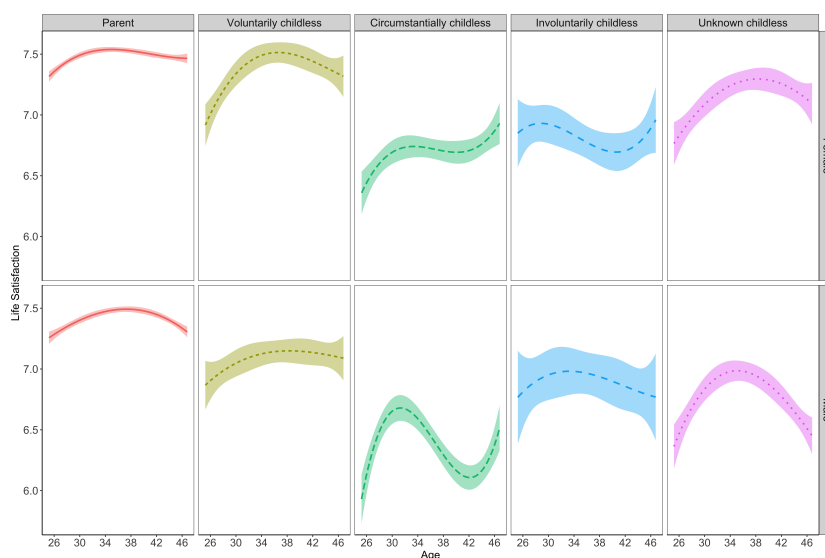


Figure 3.E.1: Predicted SWB trajectories for women and men by eventual parental status from total model M8 with uninformative priors

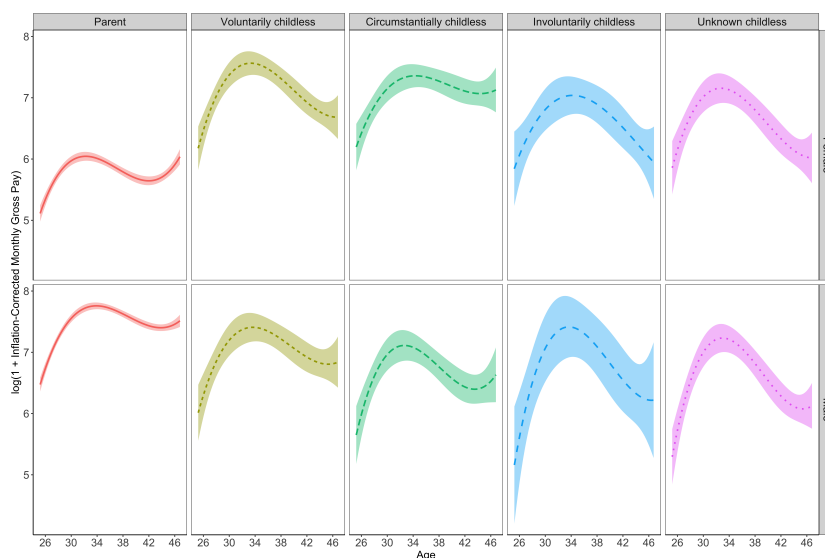


Figure 3.E.2: Predicted EWB trajectories for women and men by eventual parental status from total model M8 with uninformative priors

3.E.2 Sensitivity Analysis – Highly Informative Priors

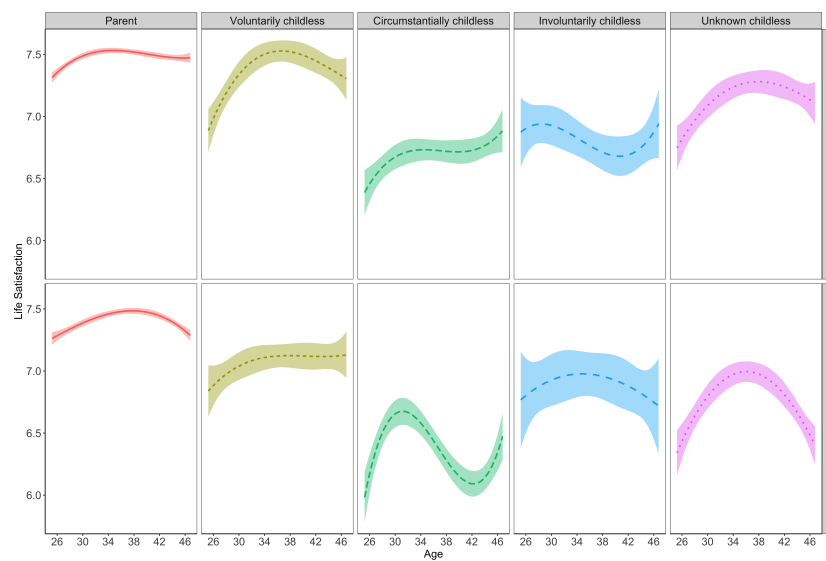


Figure 3.E.3: Predicted SWB trajectories for women and men by eventual parental status from total model M8 with highly informative priors

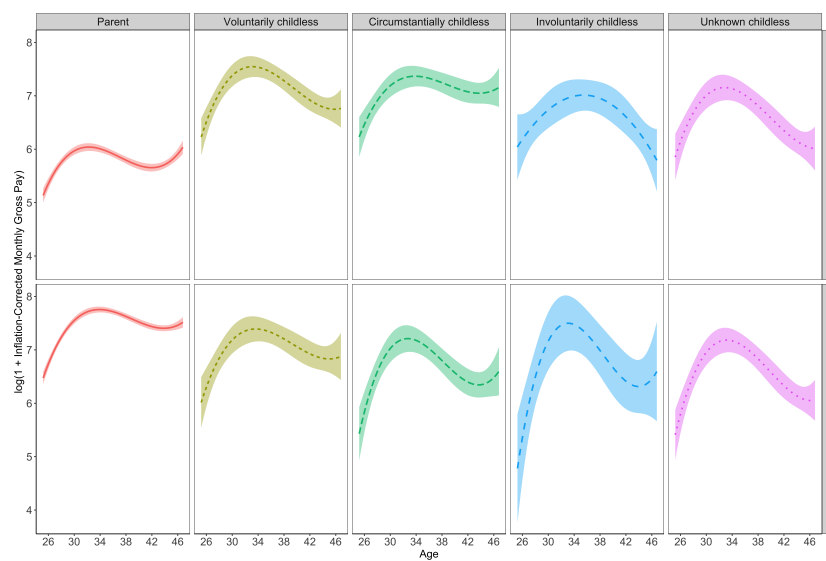


Figure 3.E.4: Predicted EWB trajectories for women and men by eventual parental status from total model M8 with highly informative priors

Appendix 3.F Bayesian Multinomial Regression Results

Table 3.F.1: Pooled coefficients from Bayesian (multinomial) logistic regression models estimating each control variable from the interaction between the eventual childlessness indicator (ref: Circumstantially childless) and gender (ref: Female)

	Cohabitation	Marital Status		Education	Economic Activity		Health Status
	Non-cohabiting	(Re)married	Single and never married	NVQ4+	Out of the labour force	Part-time paid employee	Good
Intercept	0.828* (0.700; 0.957)	0.618* (0.367; 0.879)	2.385* (2.172; 2.615)	0.320* (0.200; 0.435)	-2.353* (-2.581; -2.132)	-2.554* (-2.802; -2.322)	1.663* (1.502; 1.827)
Male	0.456* (0.284; 0.645)	0.290 (-0.108; 0.673)	0.653* (0.300; 0.985)	-0.435* (-0.603; -0.282)	0.604* (0.338; 0.867)	-0.796* (-1.189; -0.412)	-0.121 (-0.334; 0.097)
Involuntarily childless	-1.286* (-1.482; -1.101)	0.652* (0.281; 1.015)	-1.031* (-1.374; -0.695)	-0.331* (-0.516; -0.144)	0.677* (0.382; 0.997)	0.764* (0.424; 1.086)	-0.771* (-0.990; -0.535)
Involuntarily childless*Male	-0.410* (-0.735; -0.106)	0.005 (-0.608; 0.644)	0.010 (-0.554; 0.576)	0.222 (-0.089; 0.511)	-0.506* (-0.947; -0.075)	-2.049* (-3.565; -0.965)	0.342 (-0.027; 0.709)
Parent	-2.056* (-2.185; -1.922)	0.890* (0.632; 1.151)	-1.736* (-1.972; -1.516)	-0.566* (-0.685; -0.443)	1.590* (1.369; 1.828)	2.304* (2.066; 2.558)	0.044 (-0.123; 0.210)
Parent*Male	-0.653* (-0.842; -0.475)	0.070 (-0.319; 0.461)	-0.209 (-0.552; 0.148)	0.516* (0.357; 0.685)	-2.375* (-2.653; -2.090)	-3.118* (-3.561; -2.688)	0.267* (0.040; 0.477)
Unknown childless	-1.055* (-1.216; -0.893)	0.418* (0.114; 0.746)	-0.879* (-1.156; -0.593)	-0.450* (-0.620; -0.292)	0.655* (0.392; 0.930)	0.498* (0.194; 0.810)	-0.150 (-0.356; 0.057)
Unknown childless*Male	-0.170 (-0.400; 0.054)	-0.032 (-0.494; 0.451)	0.037 (-0.379; 0.477)	0.172 (-0.040; 0.406)	-0.478* (-0.819; -0.149)	-0.568* (-1.084; -0.015)	-0.081 (-0.358; 0.194)
Voluntarily childless	-1.152* (-1.317; -0.981)	0.594* (0.255; 0.931)	-0.397* (-0.697; -0.092)	-0.045 (-0.210; 0.125)	0.078 (-0.209; 0.378)	0.150 (-0.180; 0.499)	0.021 (-0.205; 0.232)
Voluntarily childless*Male	0.008 (-0.224; 0.239)	-0.076 (-0.568; 0.447)	-0.276 (-0.690; 0.200)	0.233* (0.009; 0.460)	-0.356 (-0.738; 0.013)	-0.622 (-1.283; 0.028)	0.155 (-0.137; 0.453)
LOOIC	46640.642		75204.129	58798.962		60809.062	36677.095
WAIC	46640.577		75204.011	58798.892		60808.928	36677.023

Chapter 4

The role of social network structure and composition in childlessness behaviours and patterns: Evidence from agent-based simulations in the Netherlands¹

Abstract

Quantitative reasoning and evidence for theories about the influence of social networks, as well as their structural and compositional characteristics, on changes in fertility-related patterns have been lacking due to substantive, data and methodological limitations. I present an agent-based simulation model (ABSM) with statistical and machine learning emulators to examine how macro-level childlessness patterns emerge from interactions amongst micro-level agents within endogenously formed meso-level social networks, and particularly the role of the structural and compositional social network characteristics therein. Calibrating the ABSM for the Dutch female birth cohorts between 1935 and 1965, I show that macro-level female childlessness patterns emerge from micro-level childbearing decisions via meso-level social network influences. Further, a baseline model without social influence cannot reproduce the steep increase in childlessness observed between the 1945 and 1955 birth cohorts, while the ABSM with social influence can. Additionally, these women's social networks were rather 'traditional', but deviation from social norms through increasingly 'individualistic' (i.e. sparse and heterogeneous) networks may have contributed to the observed growth in childlessness. The findings encourage data collection efforts, specifically regarding educational gradients in social influence and endogenous social network formation, to help further develop and test theories of social networks and fertility. Simultaneously, I demonstrate how ABSMs provide a valuable tool for doing so in the absence of such data.

Keywords Childlessness · Social Networks · Agent-based Simulation Model · Statistical and Machine Learning Emulators · Netherlands

¹A version of this chapter is under review at a top journal (Scimago first quartile rank) in the field at the time of writing.

4.1 Introduction

Female childlessness rates have increased substantially across Europe over the past decades (Sobotka, 2017). In the Netherlands in particular, childlessness rates have almost doubled from approximately 10% amongst women born in 1940 to 18% amongst women born in 1970. These trends are concerning not only for the viability of the population and welfare systems in the context of ageing populations, but also with respect to questions of individual agency, social inequality and social cohesion in society (Keizer, 2010).

In the literature on childlessness, various structural and institutional changes have been offered as explanations for these rises in childlessness. Examples of such changes include improvements in female educational and occupational attainment, the availability of modern contraceptive technologies and high levels of economic uncertainty (for example, see Kreyenfeld and Konietzka, 2017). Additionally, ideational changes in terms of norms and values regarding family formation and childbearing that have taken place since the 1960s are increasingly offered as explanations (Bernardi and Klärner, 2014). These ideational changes have been accompanied by increasing autonomy and individualisation as well as rising cohabitation and divorce rates, decreasing marriage rates, growing ages at parenthood and decreasing fertility. This complex course of social change has previously been referred to as the Second Demographic Transition (Lesthaeghe, 2007, 2010; Lesthaeghe and van de Kaa, 1986; van de Kaa, 1997, 2001).

With these changing norms and values on family formation and childbearing, fertility postponement and childlessness became increasingly common and accepted (Bernardi and Klärner, 2014). The diffusion of such altered norms and behaviour largely depended on social networks and was facilitated by information flows, demonstration effects and normative contexts (Burt, 1987; Casterline, 2001). In fact, individuals are embedded in social relationships that shape their decision-making as to whether or not to have children (Keim, 2011), as has been shown in a number of studies (for example, see Balbo and Barban, 2014; Buyukkececi et al., 2020; Kotte and Ludwig, 2011; Lois and Becker, 2014; Lyngstad and Prskawetz, 2010; Pink et al., 2014; Richter et al., 2012). This social interaction creates, diffuses and transforms intentions, values, norms and support regarding family formation (Bernardi and Klärner, 2014; Bongaarts and Watkins, 1996; Kohler, 2001; Kohler et al., 2002, 2006; Mönkediek and Bras, 2016; Montgomery and Casterline, 1996; Myrskylä and Goldstein, 2013). This way, social influences moderate the effect of institutional and structural changes, including technological advancements and policy implementations (Bernardi and Klärner, 2014).

While there has long been an assumption that social network influences on childbearing are of less relevance in secular and individualistic post-industrial societies, a growing literature has more recently

been focusing on social networks and fertility behaviour in these societies (for a review, see [Bernardi and Klärner, 2014](#)). Most of the relevant studies in this respect have been qualitative (e.g. [Bernardi and Klärner, 2014](#); [Power and Parke, 1984](#); [Rossier and Bernardi, 2009](#)), perhaps because large-scale longitudinal data including information on social networks and childbearing do not exist as of yet, and smaller-scale data usually do not capture network measurements because of the high cost and burden associated with gathering network data ([Balbo et al., 2013](#)). Even then, the limited quantitative research that exists on the topic has generally been limited to specific cases and contexts, types of network members, and models not accounting for both observed and unobserved heterogeneity in individuals and social network effects between them (e.g. [Aparicio Diaz et al., 2011](#); [Berndt et al., 2018](#); [Lois, 2016](#); [Lyngstad and Prskawetz, 2010](#); [Pink et al., 2014](#)). The majority of these studies have also focused on the micro-level existence of social influences on childbearing behaviour rather than the role of meso-level social networks in linking micro-level childbearing behaviour and macro-level fertility patterns (e.g. [Aparicio Diaz et al., 2011](#); [Berndt et al., 2018](#); [Lois, 2016](#); [Lyngstad and Prskawetz, 2010](#); [Pink et al., 2014](#)). This is mainly because of methodological limitations in accurately replicating real-life and complex human behaviour in formal models. For instance, commonly used statistical methods generally challenge mathematical tractability in the case of modelling real-life heterogeneity in and interactions amongst humans ([Billari, 2015](#)).

As a result, there still are many open questions when it comes to social network influences on fertility-related behaviour and patterns. For instance, we know very little about the role structural and compositional characteristics of social networks play in affecting macro-level fertility patterns, and how these in turn emerge from micro-level fertility behaviours. In this terminology, network size, density and clustering patterns determine the structure of a network, whereas composition refers to the combination of network members regarding their individual characteristics such as age, gender, parity or education ([Keim, 2011](#)). Yet, scholars have argued that this structure and composition of one's social network should affect the extent to which social influence mechanisms (e.g. social pressure or learning) operate in affecting the factors relevant in the family-formation decision-making process, and therefore also the (speed of) diffusion of family ideals deviating from the traditional norms ([Coleman et al., 1966](#); [Keim, 2011](#); [Kohler et al., 2001](#)). From this, the 'individualisation hypothesis' –which asserts that childlessness may have grown and fertility may have declined because individuals' social networks have changed from being dense and kin-centered ('traditional') to sparse and peer-centered ('individualised') ([Keim, 2011](#); [Wellman, 1979](#))– might follow, although changes in social networks and norm relevance have hardly been investigated empirically ([Billari et al., 2003b](#)). To the best of my knowledge, the only relevant empirical contribution investigating the role of social network characteristics on fertility behaviour has been that of [Lois \(2016\)](#), who used cluster analysis and discrete-time event history analysis to identify different

social network types and their influence on the chances of transitioning to parenthood. Despite being a substantial contribution to the literature, this work was not able to separate different structural and compositional network characteristics (i.e. density and share of kin), nor distinguish between social influence and selection effects. Consequentially, our understanding of the role of network structure and composition on fertility patterns remains limited, as does quantitatively based reasoning for the ‘individualisation hypothesis’.

This chapter fills the gaps in the literature by developing a single-sex agent-based simulation model (ABSM) in conjunction with statistical and machine learning (ML) emulators. Using this model, I am able to quantitatively assess to what extent and how structural and compositional characteristics of social networks influence fertility patterns, and use these results to hypothesise about what trends in social network structures might have influenced these patterns. Hereby, I focus on three such network characteristics, namely density, share of kin and homogeneity, following the individualisation hypothesis as interpreted by [Keim \(2011\)](#). The share of kin refers to the percentage of family members relative to peers (e.g. colleagues, friends); network density refers to the degree to which members of a network are interconnected ([Hanneman and Riddle, 2005](#)); and homogeneity refers to the extent to which the individuals embedded in the network are similar in characteristics and/or values.

ABSMs have previously shown to provide a valuable tool both for aiding intuition; integrating, exploring and advancing theory; and formulating new hypotheses ([Billari et al., 2003a](#); [Bruch and Atwell, 2015](#); [Grow and van Bavel, 2017](#)), also in the context of fertility transitions and how they emerge from micro-level behaviour from the ‘bottom-up’ (e.g. [Aparicio Diaz et al., 2011](#); [González-Bailón and Murphy, 2013](#); [Kashyap and Villavicencio, 2016](#); [Nomes et al., 2019](#)). Through modelling individual agents and the interactions amongst them, ABSMs are valuable for examining out-of-equilibrium phenomena and feedback mechanisms that integrate macro-level patterns which emerge in a ‘bottom-up’ manner from micro-level behaviour ([Billari et al., 2003a](#)). Particularly in the absence of longitudinal social network data, simple heuristics that “can simulate the consequences of a diversity of social interaction conditions on fertility dynamics” (pp.658 [Bernardi and Klärner, 2014](#)) provide a valuable tool for exploring social network effects. ABSMs are especially useful in this context because they allow for the modelling of artificial societies of agents, whom are not fully rational; can learn and adapt; can be heterogeneous in observed and unobserved characteristics; can interact amongst one another; and can make decisions based on simple behavioural rules ([Bernardi and Klärner, 2014](#); [Billari et al., 2003a](#); [Gilbert, 2008](#); [Wilensky and Rand, 2015](#)). Additionally, they can explicitly account for the potential endogeneity of social network effects, incorporating how individuals may choose like-minded peers to join their social networks, which as such may reinforce their own ideas and experiences of parenthood rather than exogenously influence their decision on whether or not to have children ([Aparicio Diaz et al., 2011](#); [Bernardi and Klärner, 2014](#);

Ettrich and Ettrich, 1995; Wellman et al., 1997). All in all, ABSMs allow for modelling artificial societies and human behaviour at a level of abstraction and realism that more generally used statistical models are unable to. Hence, they facilitate a better understanding of the substantive question regarding social network structures and their influence on aggregate fertility patterns, which may in turn help further develop theoretical ideas of fertility-related determinants (Grow and van Bavel, 2017).

In this study, I focus on female childlessness and calibrate the ABSM with empirical data on mortality and fertility transitions as well as population structures for Dutch women born between 1935 and 1965. This context makes for a particularly interesting case study because permanent childlessness in the Netherlands increased from 11.7% amongst women born in 1935 to 18.1% amongst women born in 1965, and followed a sigmoidal curve with particularly large growth during women born between the mid 1940s and mid 1950s. While our understanding of the role of social relationships in the observed growth in childlessness has remained limited, childlessness is particularly interesting in the context of social network effects as research has shown that social influences are much larger for the decision (not) to become a parent than for the transition to higher parities (Lyngstad and Prskawetz, 2010). Further, the absence of actively deciding or trying to have a child is at least as interesting and complex as its presence, especially when viewed from a life course perspective. That is, permanent childlessness is most often a process outcome of “a sequence of socially defined events and roles that the individual enacts over time” (Abbott, 2005; Giele and Elder Jr, 1998, pp. 22), in which individuals have the agency to shape their own life courses (Elder Jr, 1998) within constraints posed by ethical and cultural norms as well as institutions and welfare states (e.g. Mayer, 2009). The sequence of these decisions and actions in different interlinked life domains, such as partnering, education and career, may potentially lead an individual to have children, or to remain childless by choice or postponement (Keizer et al., 2009). Research has shown that the share of individuals actively choosing to remain childless is relatively small, and most childless individuals end up without children despite having non-negative childbearing intentions (Berrington, 2017; Miettinen et al., 2015; Rotkirch and Miettinen, 2017). Therefore, to accurately match the real-life process of remaining childless, I model childlessness as the absence of an active decision to abide by existing societal norms by having children. All in all, examining childlessness amongst Dutch women born between 1935 and 1965 could help us understand how structural and compositional social network characteristics have influenced the increasing prevalence of female childlessness, and to what extent this can be explained from individual life courses. Further, they could guide theory development as to what these influences might imply for trends of social network structures and relevance of norms during the same period of time, which are phenomena that have hardly been investigated (Billari et al., 2003b).

Beyond examining the role of social network structures and compositions on macro-level childlessness patterns and using ABSMs to do so, this study makes a substantive and a methodological contribution

to the literature. From a substantive perspective, I account for the potential endogeneity of social network effects. Some researchers have argued that the influence of one's social network on their childbearing decisions is not exogenous, particularly in low-fertility contexts (Aparicio Diaz et al., 2011; Bernardi and Klärner, 2014). In fact, individualisation and decreasing fertility during the Second Demographic Transition have stimulated the emersion of sparser social networks consisting less often of family members and more often of like-minded peers (Keim, 2011; Murphy, 2011). That is, individuals choose the members of their social networks carefully on the basis of common values, characteristics and interests, wherein ideas and transitions in terms of for example marriage and parenthood may play a role (Aparicio Diaz et al., 2011; Ettrich and Ettrich, 1995; Wellman et al., 1997), making social networks more and more homophilous not only throughout transitions over one's life course (Klärner et al., 2016; Rözer et al., 2017) but also over time (Belot, 2008). As such, social networks may reinforce one's own ideas and experiences of parenthood rather than exogenously influence the decision on whether or not to have children. Such endogeneity has previously been accounted for in studies, but only with regards to age and education (e.g. Aparicio Diaz et al., 2011). Buyukkececi et al. (2020) partially solve this problem of identification using an instrumental variable approach with siblings and colleagues, although they do not rule out intergenerational effects that may select individuals into similar professions, as such indirectly influencing their childbearing outcomes. I account for social network endogeneity by incorporating the importance of similarities in characteristics besides age and education, such as parental status, into my model specification of social network formation. Additionally, I consider and model social network turnover and its variety in rates at different stages of the life course, to take into account how old social bonds may be exchanged for new, more homophilous ones (at different rates) as individuals change roles and statuses throughout the life course.

From a methodological perspective, I leverage ML methods to emulate the ABSM created in addition to more traditional emulators² such as regression metamodels (RMMs). Emulators, or surrogates, are generally used for agent-based modelling to approximate the ABSM and thereby predict its outcomes across the input parameter space without having to run the computationally expensive ABSM oftentimes (Angione et al., 2020). Emulators can come in helpful during calibrating the ABSM as well as when executing sensitivity or uncertainty analyses (Gramacy, 2020). So far, most researchers who have employed ABSMs, have used regression metamodels (RMMs) or Gaussian process emulators (GPEs) as surrogates for their ABSMs (e.g. Grow, 2017; Kashyap and Villavicencio, 2016). However, while such parametric methods might be helpful for sensitivity analyses, non-parametric ML methods have shown to outperform parametric methods –which make assumptions about linearity and smoothness that may not always hold for more complex ABSMs– when it comes to calibration (Angione et al., 2020; Hilton and

²Note that in this chapter, the terms 'emulator', 'surrogate' and 'metamodel' are used interchangeably to refer to a 'model of a model'.

Bijak, 2017; Lamperti et al., 2018). In this study, I use gradient boosted trees (GBMs) as emulators for calibration and RMMs and Sobol indices as emulators for sensitivity analysis, not only to obtain more accurate ABSM predictions but also to demonstrate one way in which ML methods can be leveraged to answer complex questions in social science.

4.2 Childlessness and Social Networks

To give some context on the applied nature of this study, the individual decision to have a child usually depends on three factors: maturity, security and priority on having children (Keim, 2011). People in an individual's social network influence the evaluation and perception of these factors, either directly by affecting the extent to which these factors are achieved (e.g. providing financial support to achieve security), or indirectly by shaping the meaning of these factors (e.g. how much (prospective) income is sufficient to raise children). Indeed, many studies have shown that one's social environment shapes their childbearing intentions and outcomes (e.g. Balbo and Barban, 2014; Buyukkececi et al., 2020; Kotte and Ludwig, 2011; Lois and Becker, 2014; Lyngstad and Prskawetz, 2010; Pink et al., 2014; Richter et al., 2012) in a 'situational' manner (Billari, 2015). In turn, individual fertility intentions, emerging into aggregate patterns of fertility behaviour, can 'transformationally' shape societal norms on family formation by making up the 'status quo' (Billari, 2015; Ciganda and Villavicencio, 2017). In the context of fertility, the macro-level cultural and institutional systems in which individuals are embedded interact with the individuals themselves on the micro level via meso-level 'action-formation mechanisms' facilitated by social networks (Balbo et al., 2013; Billari, 2015). As Balbo et al. (2013, p.3) put it,

Determinants [of fertility] are positioned at the micro-level, including determinants at the individual and/or couple level; the meso-level, which encompasses social relationships and social networks (i.e., characteristics pertaining to the network of friends, coworkers, relatives and/or to the relationship that links them to the individual); at the macro-level of the cultural and institutional settings where individuals and couples are embedded.

In other words, social networks on the meso level connect individual family norms and outcomes at the micro level to societal norms and fertility levels at the macro level, and serve as a feedback channel between the two (Billari, 2015; Ciganda and Villavicencio, 2017). For example, with lower levels of fertility at the macro level, childlessness becomes more accepted and more individuals will remain childless as a result, which in turn affects macro-level fertility and so on (Bernardi and Klärner, 2014). Hereby, an equilibrium is achieved when the micro-level fertility intentions and behaviours are in line with the macro-level fertility levels (e.g. Kohler, 2000). This micro-meso-macro interaction is conceptualised in Figure 4.1.

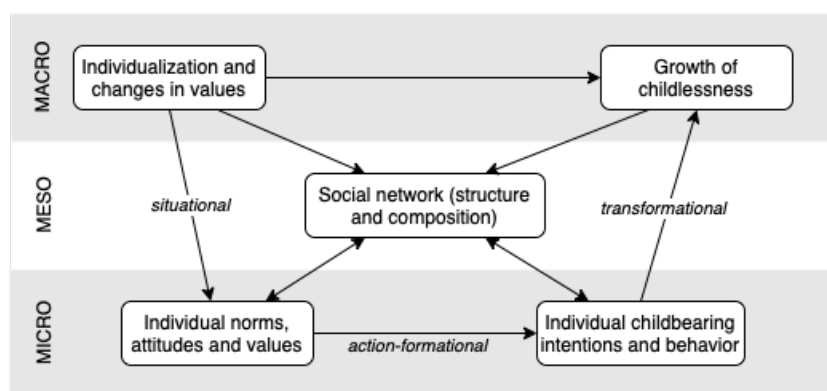


Figure 4.1: Coleman's diagram for macro-meso-micro interaction in the context of childlessness (author's own illustration, adapted from Keim (2011, pp. 238) and based on Burt (1982, pp. 9) and Coleman (1990, pp. 8)

Taking a social network perspective to examine childlessness is important theoretically because the approach interprets (the absence of) childbearing as a social act, and empirically because it complements other commonly used approaches (e.g. life course approach, theory of planned behaviour, rational action) to explain (the pace of) shifts in childlessness (Bernardi and Klärner, 2014). In fact, while studying childlessness at the macro level remains crucial to understand past and predict future trends in population characteristics (Sobotka, 2020), merely examining macro-level trends without considering how they might emerge from micro-level behaviour from the 'bottom-up' might not be sufficient to enhance our understanding of the growth of childlessness observed over the past decades (Billari, 2015).

4.2.1 Mechanisms of Social Influence

In the relevant literature, four meso-level social influence mechanisms have been identified through which childlessness on the micro and macro levels are connected. That is, individuals are influenced by their network members through the *pressure* their family and peers exert on them to conform to social norms (Asch, 1955; Festinger et al., 1950); through the *support* and social capital they experience from their social environment (Bourdieu and Richardson, 1986; Lin, 1999; Portes, 1998); through cognitive *learning* on the basis of the experiences of their network members (Bandura, 1962; Miller and Dollard, 1941; Montgomery and Casterline, 1996); and through the emotional *contagion* of ideas from their network members (Bernardi and Klärner, 2014; Burt and Janicik, 1996). Essentially, social influence, through these four mechanisms, pushes individuals to behave in a way which the majority of people around them do or find appropriate, or in other words to adapt to typical or 'normal' behaviour (Balbo and Barban, 2014; Bernardi, 2003; Billari et al., 2007; Montgomery and Casterline, 1996). In the context of childbearing, this 'typical behaviour' can be conceptualised by focusing on the share of parents versus

childless individuals in one's social network compared to the wider population (Aparicio Diaz et al., 2011; Lois, 2016).

The direction in and extent to which (these four mechanisms of) social influence operate(s) in someone's social network largely depend on the structural and compositional characteristics of their social network (Keim, 2011). Three such characteristics that have been identified in the literature are the share of kin, the density and homogeneity of one's social network. While a larger share of kin may be expected to foster childbearing in any context, network density and homogeneity may play more of a role in affecting the magnitude of social influence rather than its direction (e.g. Kohler et al., 2001; Lois, 2016), as will be elaborated on in the next sections.

4.2.2 Structural and Compositional Characteristics of Social Networks

Individuals who are (ready to become) parents are usually surrounded by a larger share of kin, whereas those who postpone or forego parenthood have networks mainly comprised of peers rather than kin (Keim, 2011; Wagner et al., 2015). One reason for this is because kin will exert more pressure onto their family members to have children than would non-kin members onto their peers (Lois and Becker, 2014), often for reasons related to household economics or maintaining social status (Mönkediek and Bras, 2016). In addition, family members provide social support and security in multiple ways (e.g. financial and babysitting), which increases an individual's likeliness to have a child (Bernardi and Klärner, 2014; Keim, 2011), sometimes even as an investment to achieve social integration and capital (Bernardi and Klärner, 2014; Lois and Becker, 2014). The intergenerational transmission of fertility behaviour may also be expected to be larger in networks with a high share of kin (Axinn et al., 1994; Kotte and Ludwig, 2011; Lois, 2016), where traditional values of family formation and gender roles also prevail more strongly (Keim, 2011). In these parent-focused networks, emotional contagion of and social learning about childbearing occurs more than in networks where a large share of members is childless, simply because there is a higher prevalence of parents and thus focus on (young) children in the network (Balbo and Barban, 2014; Keim, 2011; Lois and Becker, 2014).

On the other hand, network density and homogeneity do not necessarily always foster childbearing, but rather determine the extent to which deviation from the norm is desired or possible (Bott, 1957; Lois, 2016), regardless of what that norm may be. This view is in line with that of Kohler et al. (2001), who found that network content and structure interact: while dense networks discourage contraceptive use when there is a low share of network members using contraceptives, dense networks encourage contraceptive use when many network members have already adopted contraceptive technology. In the context of family formation, this view asserts that in networks where the majority of members have children,

dense and homogeneous networks will foster childbearing (Keim, 2011; Lois, 2016); whereas in networks where the norm is to remain childless, dense and homogeneous networks might foster childlessness instead.

In line with this argument, one might expect that dense and homogeneous networks foster abidance to social norms more than do sparse and heterogeneous networks (Bott, 1957; Lois, 2016). In dense networks, social norms are communal and enforcing measures are adequate (Bongaarts and Watkins, 1996; Bühler and Kohler, 2004). The community-type of formation dense networks facilitate also provides for more intense and high-quality social support (Kohler and Bühler, 2001), whether that is in terms of helping to care and provide for someone else's children on the one hand or in terms of coping with the consequences of childlessness on the other hand (Bernardi and Klärner, 2014). Furthermore, because dense networks generally contain trusted links, social learning about parenthood or perhaps life opportunities besides parenthood is more effective in dense networks than in sparse networks (Bernardi and Klärner, 2014; Bernardi et al., 2008; Bühler and Kohler, 2004). With these trusted links, the intergenerational transmission of fertility behaviours is also more likely to be effective (Lois, 2016). Additionally, emotional contagion occurs more rapidly in dense networks because one individual's intentions and behaviours affect a larger number of network partners directly and indirectly than in sparse networks, facilitating a "cascading of events" (Keim, 2011, p. 239).

In a similar fashion as for density, one might expect norm abidance to be greater in homogeneous networks than in heterogeneous networks. One reason for this is because homogeneous network members will perceive themselves to be socially similar, and will therefore be more likely to be 'infected' but also pressured by their social environment (Bernardi and Klärner, 2014; Bras, 2014; Burt and Janicik, 1996; Lois, 2016). Additionally, in heterogeneous networks individuals more often receive contradictory than concurring information, which can create ambivalence or polarisation towards norm abidance (Keim, 2011). Finally, while individuals embedded in heterogeneous networks might have a larger variety of sources of social support (Granovetter, 1973), the quality of these sources is usually higher amongst strongly tied members of homogeneous networks (Lois, 2016).

4.2.3 Context and Objective

In sum, one might expect that family-centered, dense and homogeneous social networks foster childbearing when the majority of the network members have children. Amongst the earlier birth cohorts considered in this study, pronatalist values were relatively strong compared to younger cohorts and childbearing was considered to be the norm (Noordhuizen et al., 2011). Since then, social networks are thought

to have become less traditional and more individual, i.e. they may have become sparser, more heterogeneous, and less family-centered (Beck, 1986, 1995; Keim, 2011). As a consequence, the encouragement of childbearing may have gradually declined, and more room may have opened up to deviate from the persistent childbearing norm. Indeed, research has shown that while most Dutch people (prefer to) have children, pronatalist values are relatively weak and there is a relatively strong permissiveness to deviant behaviour (Noordhuizen et al., 2011). These processes of declining encouragement for fertility and inclining permissiveness of deviating behaviour may have resulted in a growing share of women remaining permanently childless over the past decades.

In this study, I examine the influence of structural and compositional social network characteristics on the increasing prevalence of childlessness using an ABSM and by means of simulating macro-level childlessness levels and trends emerging from micro-level childbearing behaviour, influenced by different meso-level network structures. More specifically, the ABSM takes compositional and structural social network characteristics as input, constructs social networks amongst agents on the basis of these characteristics, and models social influence on childbearing intentions on the basis of the relative share of parents in individuals' networks. The results of the ABSM can also be used to hypothesise about potential changes in social network structure and composition during the same period of time, given that childlessness has increased quite rapidly over the past decades. This will be especially useful given that data on social network structures are scarce, particularly when it comes to longitudinal data on social network changes (Balbo et al., 2013; Bruch and Atwell, 2015).

4.3 Agent-based Simulation Model

In this section, I elaborate on the ABSM and justify the modelling choices made according to the 'Overview, Design concepts and Details' (ODD) framework (Grimm et al., 2006, 2010, 2020).

4.3.1 Agent-based Simulation Modelling

ABSMs provide a powerful tool to examine how individual-level behavioural decision rules collectively and from the 'bottom-up' result in emerging macro-level patterns (Billari et al., 2003a; Bruch and Atwell, 2015). These models are able to incorporate the interactions amongst agents, taking into account that agents might change their behaviour depending on stimuli from their environment. As such, ABSMs are able to explicitly model contingent behaviour, as well as social learning and feedback loops. The models can therefore be used not only to examine why and how individual micro-level behaviour yields particular macro-level patterns, but also to formulate hypotheses about processes for which there are no

data (Bruch and Atwell, 2015; Grow and van Bavel, 2017). In doing so, ABSMs often borrow from micro-simulation techniques by incorporating empirical data to model transition rates and thereby increase the resemblance between the ABSM and the real world (Bruch and Atwell, 2015; Kashyap and Villavicencio, 2016). As such, “agent-based models help fill the gap between formal but restrictive models and rich but imprecise qualitative description (Holland and Miller (1991), cited in Page (2008))” (pp.187 Bruch and Atwell, 2015). Hence, they are valuable tools to deduce behavioural patterns, especially in cases where empirical data only superficially capture the model objective (Billari et al., 2003a). Previously, ABSMs have been used to model a variety of demographic processes, including marriage market dynamics (e.g. Billari et al., 2007; Grow and van Bavel, 2020), fertility and family formation (e.g. Aparicio Diaz et al., 2011; González-Bailón and Murphy, 2013; Kashyap and Villavicencio, 2016; Nomes et al., 2019) and migration (e.g. Willekens, 2017).

4.3.2 Purpose

The purpose of the ABSM is to examine the role of individuals’ social network structure and composition at the micro and meso levels on the magnitude and trend of permanent childlessness at the macro level. Using the model results to gain understanding of the influence of social network structure and composition on the increasing prevalence of childlessness, one is able to develop hypotheses about the potential changes in network structure over time that might have contributed to the increasing childlessness trend of the past decades. The model aims to reproduce the percentage of Dutch women born between 1935 and 1965 who have remained childless permanently (i.e. at least up to age 50).

4.3.3 Entities, State Variables and Scales

There are two types of entities in the ABSM, namely the overarching model and the individual agents. The model entity is the same for all agents in the sample, and can be seen as the entity that controls the overarching processes and settings of the simulation. Note that the model does not contain any spatial units. Table 4.1 shows the state variables, variable names, values and dynamicity for the model entity. As will be explained later on, the age-group deviation σ determines the age group (i.e. $[age_i - \sigma, age_i + \sigma]$) containing individuals an agent i considers influential to their childbearing intentions. For example, if an agent is 25 years old and $\sigma = 2$, they will consider agents aged between 23 and 27 years old inclusive as influential. Furthermore, the log accuracy λ is used to control the social influence function (see Equation 4.11). Distances d between agents are used to express network homogeneity or similarity in terms of for example education or age. The share of parents π^* in an agent’s age and parity group is used to compute the social influence on an agent’s childbearing intentions. While d and π^* can be computed at the agent

level for each agent in each time step, these distances and shares of parents are computed for all agents at once during each time step at the model level to reduce computational runtime, and are stored in distance matrix Δ respectively pi-star data Π^* .

Table 4.1: Model entity state variables, names, values and dynamicity

State variable	Variable name	Values	Dynamicity
Initial number of females	N_{ini}	1,500	Static
Start year	$year_{start}$	1935	Static
End year	$year_{end}$	1965	Static
Initial year	$year_{ini}$	1900	Static
Minimum childbearing age	age_{min}	15	Static
Maximum childbearing age	age_{max}	50	Static
Current year	$year_{current}$	[1900, 2015]	Dynamic
Target cohort	$cohort_{target} = year_{current} - age_{max}$	[1850, 1965]	Dynamic
Sex ratio at birth (proportion of males)	sr_b	[0, 1]	Dynamic
Age-group deviation	σ	2	Static
Log accuracy	λ	$1 \cdot 10^{-7}$	Static
Distance matrix	Δ	Matrix	Dynamic
Pi-star data	Π^*	Matrix	Dynamic

Individual agents are always female, making this a single-sex model. I exclude male agents from the model because of a lack of historical male fertility data. As social influence in the model is based on the share of parents in one's network (see section 4.3.5.2), having men in the model who do not reproduce (accordingly) would result in an inaccurate representation of the social influence men may have on their social network members. Note that this also means that couple-level dynamics and male partner preferences are excluded from decision-making behaviour. Nevertheless, male births are counted towards a woman's parity, and thus might indirectly play a role in influencing the childbearing intentions of the members of their mother's social network (see section 4.3.5.2). Table 4.2 shows the state variables, variable names, range of values and dynamicity for the individual entities. Dynamicity refers to whether the state variable is static or dynamic over time, or mixed (i.e. it changes only once, at the first instance, and then remains static afterwards). Note that education is static because it refers to expected education at age 20, and therefore is assigned only once and does not change throughout life. This choice was made not only to capture how education might already play a role in social network formation before graduation, as done by [Aparicio Diaz et al. \(2011\)](#) as well, but also to reduce modelling complexity.

Additionally, individuals can be clustered together in a collective by being part of family or peer networks, which together make up their social network, as the model keeps track of who is friends with whom, and also keeps familial bonds intact even as families introduce newborns. The model is able to do so because it makes use of object-oriented programming, and as such the familial bonds are automatically updated once new agents are born. Hence, a newborn baby is added as a daughter to their mother, as a

granddaughter to their mother's mother (the newborn's grandmother), as a niece to their mother's sisters (the newborn's aunts), and as a sister to their mother's daughters (the newborn's sisters). These family members are also added to the newborn's family, e.g. the current agent is added as the newborn's mother, the current agent's mother is added as the newborn's grandmother, etcetera). For example, if an agent A whose mother is agent B and whose sisters are agents C and D, where sister C is childless while sister D has children E and F, has a child (agent G), then automatically A becomes G's mother, B becomes G's grandmother, C and D become G's aunts, and E and F become G's cousins. Additionally, G becomes A's child, B's grandchild, C and D's niece, and E and F's cousin. Note that ρ_e in Table 4.2 refers to the education-specific influence strength, as will be elaborated on in section 4.3.5.2.

Table 4.2: Agent entity state variables, names, values and dynamicity

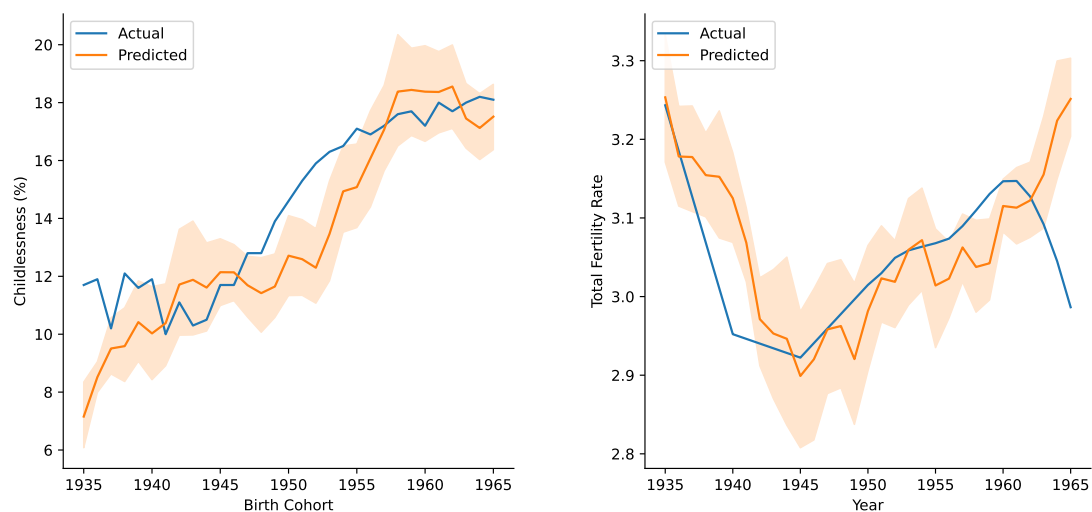
State variable	Variable name	Values	Dynamicity
Unique id	<i>id</i>	[1, N]	Static
Sex	<i>sex</i>	{Female}	Static
Age	<i>age</i>	[0, 110]	Dynamic
Education	<i>education</i>	{None, Primary, Secondary, Tertiary}	Static
Birth cohort	<i>cohort</i>	[1780, 2015]	Static
Parity	<i>parity</i>	[0, ∞)	Dynamic
Age at first birth	<i>afb</i>	[15, 50]	Mixed
Had birth this year	<i>hbty</i>	{True, False}	Dynamic
Birth probability	<i>p_{birth}</i>	[0, 1]	Dynamic
Ages of children	<i>ca</i>	{Age ₁ , Age ₂ , ...}	Dynamic
Peer network	<i>sn</i> (size: <i>pns_a</i> (actual), <i>pns_d</i> (desired))	{Friend ₁ , Friend ₂ , ...}	Dynamic
Family network	<i>fn</i> (size: <i>fns</i>)	{Family ₁ , Family ₂ , ...}	Dynamic
Social network	<i>fn</i> (size: <i>sns</i> = <i>pns_a</i> + <i>fns</i>)	{Friend ₁ , Friend ₂ , ..., Family ₁ , Family ₂ , ...}	Dynamic
Share of parents (and age of their youngest child) in social network	π	[0, exp(1) - 1]	Dynamic
Share of parents (and age of their youngest child) in population	π^*	[0, exp(1) - 1]	Dynamic
Social influence	<i>si</i>	$[1 - \frac{\rho_e}{2}, 1 + \frac{\rho_e}{2}]$	Dynamic
Social influence function slope	ξ	$[\lambda, 1 - \lambda]$	Dynamic

4.3.4 Initialisation

The model is initialised in 1900, 35 years before I start monitoring the first birth cohort, namely that of 1935, in order to allow all women of reproductive ages ([15, 50]) to complete their fertility by 1935 and have their children belong to the starting population of 1935. Using age- and sex-specific population counts ([Statistics Netherlands, 1899](#)), I approximate the female Dutch population structure of 1899/1900 for N_{ini} women. To initialise expected education, I use the distribution of educational attainment in the year available in the five-yearly data (see section 4.4) closest to the year in which the agent would have been 20 years old to draw a level of expected education. For example, for women aged 43 at initialisation (in 1900), I use the educational attainment distribution in 1875 (year closest to $1900 - (43 - 20) = 1877$), which is 27.9% for no education and 72.1% for primary education, as probabilities for the different educational levels. At initialisation, all women have zero parity and empty peer and family networks.

The agents' birth cohorts are computed by deducting their age from the current year, which is 1900 at initialisation. The population structure at initialisation very closely reproduces the actual age structure of the female population in the Netherlands in 1900. There is some stochasticity involved in producing the initial population, however, as a result from drawing the ages and levels of educational attainment from probability distributions.

In the simulation run using this population as a starting base, the agents pass away according to age- and sex-specific mortality rates between 1850 and 2018 for individuals aged between zero and 110 inclusive ([Human Mortality Database, 2020](#)) (see section 4.4). Additionally, female agents aged between 15 and 50 inclusive may bear children according to age-, parity- and year/cohort-specific fertility rates ([Human Fertility Database, 2020a,b,c](#); [O'Neill, 2020](#)), as extensively described in section 4.4. Before 1935, peer and family networks are formed but they do not influence childbearing decisions; these are merely based on empirical fertility rates. From 1935 onwards, agents' childbearing decisions are influenced by their peer and family networks. Figures 4.2a and 4.2b show that the baseline model –without social influence ever– largely reproduces the actual observed childlessness trend from [Statistics Netherlands \(2012\)](#) respectively total fertility rate (TFR) from [Human Fertility Database \(2020c\)](#); [O'Neill \(2020\)](#). However, there is some discrepancy when it comes to the steep increase in childlessness observed between the 1945 and 1955 birth cohorts. That is, the model without social influence reports an increase that starts later but is steeper than the empirically observed trend. Note that the increase in TFR amongst the 1960 to 1965 birth cohorts is the result of using a moving average.



(a) Actual and simulated (five-year moving average and 95% confidence interval) trends in permanent childlessness amongst women born between 1935 and 1965 inclusive (simulation without social influence)

(b) Actual and simulated (five-year moving average and 95% confidence interval) trends in total fertility rate between 1935 and 1965 inclusive (simulation without social influence)

Figure 4.2: Actual and simulated (five-year moving average and 95% confidence interval) trends in (a) permanent childlessness and (b) total fertility rate (simulation without social influence)

4.3.5 Process Overview and Scheduling

Time is modeled discretely, and every time step $t = 1, \dots, T$ marks one year. All agents $i = 1, \dots, N$ perform a step during each year, and the order in which agents do so is random. The simulation runs until 2015 in order to estimate the level of permanent childlessness amongst women born in 1965, given that the cut-off age for determining permanent childlessness is set at $age_{min} = 50$, the cut-off also used by [Statistics Netherlands \(2012\)](#). Agents can be aged between zero and 110 inclusive, but are only allowed to bear children between ages 15 and 50 inclusive, although they can influence another agent's childbearing decisions at all ages. Agents can start forming peer networks from birth onwards; familial bonds are automatically inferred as agents and their family members are born or deceased, as explained earlier.

Figure 4.3 shows the process overview of the ABSM; algorithmic pseudo-code can be found in Algorithm 1 in Appendix 4.A. Note that some individual-level steps, such as computing empirical birth probabilities or distances between agents, are executed at the model level rather than the agent level in order to increase code efficiency and decrease computation time. Whether or not some event will happen (e.g. death or childbirth) is based on empirical probabilities, and is determined by comparing these probabilities to a draw from a Uniform(0, 1) distribution, with the event happening if the value of the draw is smaller than the event probability. The more complex processes/submodels of making and removing friends as well as bearing children are described more extensively in the upcoming sections 4.3.5.1 respectively 4.3.5.2.

4.3.5.1 Befriending and Unfriending: Compositional and Structural Characteristics of Social Networks

As addressed in section 4.2, the direction and magnitude of social influence on one's childbearing intentions and outcomes may be affected by their compositional and structural social network characteristics, and particularly their network share of kin, density, and homophily (i.e. the preference for homogeneity). In the ABSM, these three characteristics are incorporated and implemented through the process of befriending and unfriending other agents. That is, how many agents and, if any, which agents to befriend and unfriend are controlled by the ABSM input parameters for these three characteristics (i.e. ζ , γ and β) and hence in turn determine the composition and structure of agents' resulting social networks, as elaborated on in this section.

If agents have free space in their peer network (i.e. $pns_a < pns_d$) and have not yet made any friends in a given year, they look for potential candidates to make friends with. Realistically, humans might only start forming social networks later on, but given that only one friend can be made per year and that the desired peer network size should ideally be achieved by the time most agents have children, I

excluding their grandmother, aunts and cousins. Only from the third generation onward, families will be complete. While this should not matter for the results, given that I examine the 1935 to 1965 birth cohorts which hardly contain any first- or second-generation agents, I approximate family sizes for these agents nevertheless in order to make sure a sensible pns_d is achieved for them despite their small or even zero actual fns . For first-generation agents, in addition to their automatically inferred (grand)children, I add one mother, one grandmother, x_a aunts, x_c cousins and x_s sisters. For second-generation agents, in addition to their automatically inferred (grand)children, mother and sisters, I add one grandmother, x_a aunts and x_c cousins. For some agent, the approximated number of aunts equals

$$x_a = \frac{\text{TFR of grandmother} - 1}{2} \quad (4.2)$$

Note that the subtraction essentially ignores the agent's mother, and the division by two enforces only female and no male family members are included, given that this is a female-only model. This division by two is based on a sex ratio at birth of approximately 0.5 throughout the years considered ([Statistics Netherlands, 2020](#)). The approximated number of cousins is then computed as

$$x_c = \frac{\text{TFR of mother} \cdot x_a}{2} \quad (4.3)$$

For first-generation agents, the number of sisters is estimated as

$$x_s = \frac{\text{TFR of mother} - 1}{2} \quad (4.4)$$

Note that in the above equations, TFR of grandmother denotes the empirical TFR in the year equal to the current agent's birth cohort minus the mean age at first birth (MAFB, approximately 28 years across the years during which the TFR was observed). TFR of mother denotes the TFR in the year equal to the current agent's birth cohort.

The potential candidates to make friends with should be other agents whom are not yet in the agent's peer or family network, have available space in their peer networks and haven't yet made a friend in that year (or have made a friend that year but were removed from one of their friends' peer network, as explained later on). If there are any potential candidates to make friends with, the number of mutual friends as well as social distance between the current agent and each of these C potential candidates is computed. A mutual friend of agent A and agent B is an agent who is part of both agent A's and agent B's peer network.

Social distances are selected from the model object's Δ . Computation of these distances is done at the model level rather than the agent level to reduce computation time and enforce absolute rather

than relative distances. These social distances are based on agents' age, education and childlessness status. By allowing these distances to rely on childlessness status, I incorporate the endogeneity of peer network formation, i.e. that parental status might influence who one chooses as their friend, which in turn might influence one's childbearing intentions and behaviours (Aparicio Diaz et al., 2011; Durlauf and Walker, 2001). The distances are calculated using Gower distances in order to take into account similarity across both numeric (e.g. age) and categorical (e.g. childlessness, education) characteristics measured on different scales (Gower, 1971). To allow and examine the differential importance of these three characteristics in befriending and unfriending, different weights are assigned to each characteristic in calculating the distances (with the weight for age θ_a equal to one for identification). Gower distances are calculated as a weighted average of the distances per characteristic, which is the absolute value of the difference divided by the range for numeric characteristics, or for categorical characteristics equals one if different and zero if the same. For example, consider four hypothetical agents A: 20 years old, childless, primary education; B: 60 years old, parent, secondary education; C: 15 years old, childless, tertiary education; D: 50 years old, parent, primary education, and weights $\theta_a = 1$, θ_p and θ_e for age, parental status and education, respectively. Then the Gower distance between agents A and D equals

$$\text{Gower distance} = \frac{\sum_{i=1}^n w_i X_i}{\sum_{i=1}^n w_i} \quad (4.5)$$

where for agents A and D $w_i = [\theta_a = 1, \theta_p, \theta_e]$ and $X_i = [\frac{|20-50|}{60-15} = 0.67, 0, 1]$. As Gower distances are scaled between zero and one, agents' (dis)similarity depends on the characteristics of the agents 'at the extremes'. To illustrate, in the above example, agents A and C will be more similar to each other if B and D are also considered than when only A and C are compared. Absolute distances are calculated amongst all agents in the sample at once in each time step to prevent relative distances being computed at every time step for every single agent, which would result in inconsistent distances across agents and years as well as an increased computational burden. Using absolute distances also makes more sense conceptually, because humans would likely choose friends based on their similarity compared to the rest of the population, not only compared to the people directly available to them. Note that because these Gower distances consider agents' ages, the model specification accounts for homophily across cohorts implicitly.

The array containing the number of mutual friends as well as the array containing social distances for each potential candidate are then scaled to a scale between -10 and 10. I rescale both arrays to the same scale to ensure the resulting scores from each will have the same order of magnitude and thus importance in computing a combined score for each candidate. Furthermore, I rescale to a [-10, 10] scale to achieve symmetry in the increasing concave upward probability density function for density

(γ) and the decreasing concave upward probability density function for homophily (β), as defined in Equations 4.6 and 4.7 and visualised in Figure 4.4. In other words, this rescaling ensures that the ranges of $f(x) = \exp(c \cdot x)$ and $f(x) = \exp(-c \cdot x)$ are the same for some constant c and variable x (e.g. number of mutual friends or social distance). On the basis of these scaled numbers of mutual friends and scaled social distances, each candidate j is then assigned a score that will determine their chances of being selected as the current agent's friend:

$$S(nmf_j) = \exp(\gamma \cdot nmf_j) \quad (4.6)$$

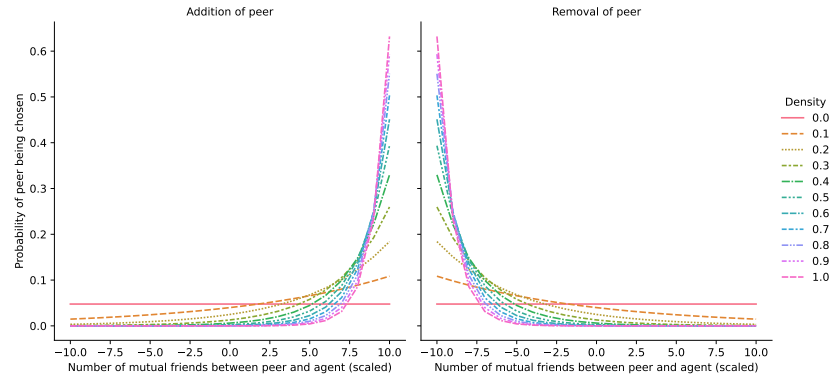
$$S(d_j) = \exp(-\beta \cdot d_j) \quad (4.7)$$

where nmf_j and d_j represent the scaled number of mutual friends respectively scaled social distance for candidate j . Equation 4.6 ensures that all potential candidates have similar scores when γ is low, but that when the model-level parameter of network density is high, agents with a higher number of mutual friends with the current agent are more likely to be selected as friends than agents with a low number of mutual friends. Contrastingly, Equation 4.7 enforces that agents with a smaller distance away from (i.e. with larger similarity to) the current agent are being chosen over agents at larger distance away from the current agent when the model-level homophily parameter is high, as inspired by [Aparicio Diaz et al. \(2011\)](#). Note that when the values of the parameters γ and β for density respectively homophily are low, agents' election scores are approximately equal rather than in the opposite direction. In this case, agents have no preference for candidates instead of preferring a very dissimilar candidate or a candidate with very few mutual friends (as illustrated in Figure 4.4). This choice has been made in line with [Aparicio Diaz et al. \(2011\)](#), mainly because it seems unrealistic for humans to explicitly search for dissimilar or disconnected people when looking for new friends to make. The combined score for each candidate is then calculated as $S(c_j) = S(nmf_j) + S(d_j)$, which is converted into a probability via

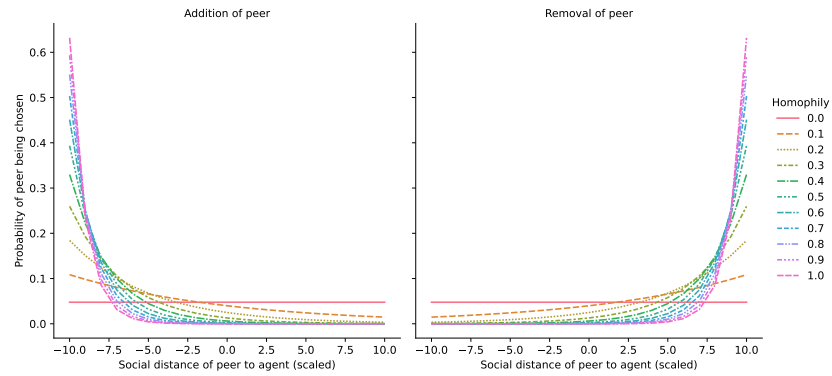
$$P(c_j) = \frac{S(c_j)}{\sum_{j=1}^C S(c_j)} \quad (4.8)$$

Based on these election probabilities for all candidates, one agent is sampled from amongst them to become friends with the current agent. The elected agent is then added to the current agent's peer network and vice versa, and both agents are deleted from the friends-making market for the current time step, given that agents can only form at most one new friendship every year.

In real life, individuals' networks change over the life course, especially as a result of significant life transitions such as getting married and having children ([Billari et al., 2007](#); [Ettrich and Ettrich, 1995](#); [Wellman et al., 1997](#)). Therefore, I allow agents to delete friends from their peer network as well, which



(a) Probability distribution function over the number of mutual friends for varying density (γ) parameters for befriending and unfriending



(b) Probability distribution function over the social distance for varying homophily (β) parameters for befriending and unfriending

Figure 4.4: Probability distribution functions for befriending and unfriending

can be done when an agent's peer network is full (i.e. $pns_a = pns_d$). Note that this removal is about the voluntary decision to remove a friend from one's peer network and not about circumstances such as death, which are separately determined on the basis of empirical age- and year-specific mortality rates (see section 4.4). The probability of removing a current peer from one's peer network is determined on the basis of predicted probabilities from a logistic regression model, which is fit on empirically determined rates of social network turnover at different ages in the life course (see Table 4.B.1 in Appendix 4.B). In the same way as preferences for agents with a certain number of mutual friends or a certain degree of similarity in terms of individual characteristics are considered in the friend-making process, these preferences are also taken into account in reverse in the friend-deletion process. That is, when there is a preference for dense networks, an agent will be more likely to delete an agent with a small number of mutual friends (i.e. $S(nmf_j) = \exp(-\gamma \cdot nmf_j)$). Additionally, agents will be more likely to unfriend the friends least similar to themselves when the preference for homophily is high (i.e. $S(d_j) = \exp(\beta \cdot d_j)$). When an agent is deleted from another agent's peer network, they become available again on the befriending market, even if they had already made a friend that year.

4.3.5.2 Childbearing: Social Influence of Parental Agents in Social Network

As addressed in section 4.2, social influence steers people into following the behaviours the majority of their social environment engages in, or finds openly appropriate. In the case of childbearing, this ‘typical behaviour’ can be conceptualised by relatively how many individuals (do not) have children. Hence, the ABSM models social influence as a deviation of one’s baseline empirical year-, age- and parity-specific birth probability, which is based on the relative share of parents (and the age of their youngest child) in one’s social network compared to the wider population, as elaborated on in this section.

If an agent is female and is aged between 15 and 50 inclusive, then their empirical age-, parity- and cohort-specific birth probability is obtained during each time step at the model level and saved in their individual $p_{birth,i}$ attribute. While education is incorporated in the model to consider education-based homophily in peer network formation as well as educational differences in norm abidance (see section 4.3.6), it is not considered in the birth probabilities as empirical data on education-specific fertility rates are lacking. As mentioned in section 4.3.4, before 1935 individual agents form peer networks, but these networks do not yet influence their childbearing activities. From 1935 onwards, agents’ social networks will have an effect on their childbearing decisions, in a way that is similar to that described in Aparicio Diaz et al. (2011); Billari et al. (2007). In these definitions, an agent’s social network is their combined familial and peer (e.g. friends, colleagues) network. Note that agents’ childbearing is influenced only by their social network members aged at least 15. An agent’s social network influences their childbearing decision in the form of a multiplier si_i :

$$p_{birth,i} = p_{birth,i} \cdot si_i \quad (4.9)$$

where

$$si_i = 1 + \rho_e \cdot \left(\frac{\exp(\xi(\pi_i - \pi_i^*))}{1 + \exp(\xi(\pi_i - \pi_i^*))} - \frac{1}{2} \right) \quad (4.10)$$

In Equation 4.10, ρ_e is a model parameter that controls how strong the influence of one’s social network is in determining childbearing decisions. ρ_e varies depending on one’s level of education (none/primary, secondary or tertiary), given that those with different levels of educational attainment might abide by social norms, and therefore adopt new fertility behaviours, to a different extent (Aparicio Diaz et al., 2011; Klüsener et al., 2019). The reason for having one common parameter for none and primary education, instead of a separate one for each of them, is because I have no reason to suspect a substantial difference in norm abidance between those without education and those primarily educated, and to reduce the number of model parameters. I do explicitly distinguish between secondary and tertiary education, because additional analyses show that it is important to do so given that the share of tertiary educated women is

substantial amongst some of the younger cohorts observed. Furthermore, ξ_i denotes the slope of the social influence function, and essentially is a scaling factor that ensures si_i always lies in the range $[1 - \frac{\rho_e}{2}, 1 + \frac{\rho_e}{2}]$, or in other words that $\frac{\exp(\xi_i(\pi_i - \pi_i^*))}{1 + \exp(\xi_i(\pi_i - \pi_i^*))}$ always lies in the range $[\lambda, 1 - \lambda]$ for every value of π_i^* :

$$\xi_i = \frac{\log \frac{1-\lambda}{\lambda}}{\exp(1) - 1 - \pi_i^*} \quad (4.11)$$

Similarly to Aparicio Diaz et al. (2011), I define π_i and π_i^* for an agent i and other agents $j = 1, \dots, J$ in the sample as

$$\pi_i = \frac{\sum_{j \in \{parity_j \geq 1 \wedge j \in sn_i\}} \left(\exp\left(\frac{1}{yca_j}\right) - 1 \right)}{sns_i} \quad (4.12)$$

where yca_j is the age of the youngest child of agent j . The exponentiated fraction containing yca_j models that social influence, particularly through emotional contagion, is strongest when the children of one's social network members are young, and declines with the age of the youngest child (Aparicio Diaz et al., 2011; Balbo and Barban, 2014). Further,

$$\pi_i^* = \frac{\sum_{j \in \{parity_j \geq parity_i \wedge age_j \in [age_i - \sigma, age_i + \sigma]\}} \left(\exp\left(\frac{1}{yca_j}\right) - 1 \right)}{\sum_{j=1}^J I[age_j \in [age_i - \sigma, age_i + \sigma]]} \quad (4.13)$$

for those agents who have never had a child before ($parity_i = 0$). Here, $I[condition]$ represents the indicator function, which equals one if *condition* is met and zero otherwise. I consider a five-year age group ($\in [age_i - \sigma, age_i + \sigma]$ where $\sigma = 2$) because agents are likely to consider the behaviour not only of those agents exactly of their own age, but also those of an age close to their own. For agents who are already parents ($parity_i > 0$),

$$\pi_i = \frac{\sum_{j=1}^J I[parity_j > parity_i \wedge j \in sn_i]}{\sum_{j=1}^J I[parity_j \geq 1 \wedge j \in sn_i]} \quad (4.14)$$

and

$$\pi_i^* = \frac{\sum_{j=1}^J I[parity_j > parity_i \wedge age_j \in [age_i - \sigma, age_i + \sigma]]}{\sum_{j=1}^J I[parity_j \geq 1 \wedge age_j \in [age_i - \sigma, age_i + \sigma]]} \quad (4.15)$$

Note that π^* , and thus ξ , is the same for all agents who have the same age and parity, which is also why they are computed on the model level (as aforementioned) to reduce computational time. With the current specification of social influence, the social influence function will be a sigmoid function symmetric about $\pi_i = \pi_i^*$ on the x-axis and one on the y-axis (see Figure 4.5). Essentially, social influence as defined here is a function of the proportion of agents of higher parity in some agent's social network relative to the proportion of agents of higher parity and of the same age as that given agent in the population (Aparicio Diaz et al., 2011). Given that the value of ρ_e ranges between 0 and 2 (see also Table 4.3), social influence si_i is strictly non-negative such that some individuals might make childbearing decisions

without being influenced by their social environment. In other words, there is no social influence (i.e. no deviation from the empirically observed birth probability) when the parity distribution of some agent's surroundings is the same as that of the population. This is the way individual agents in the model are influenced by their environment, and follows the reasoning by Keim (2011) that one's intention to have a child (soon) is larger amongst those whose social network members have (young) children already, whereas those with few parents in their social network often postpone childbirth or intend to remain childless (Lois, 2016).

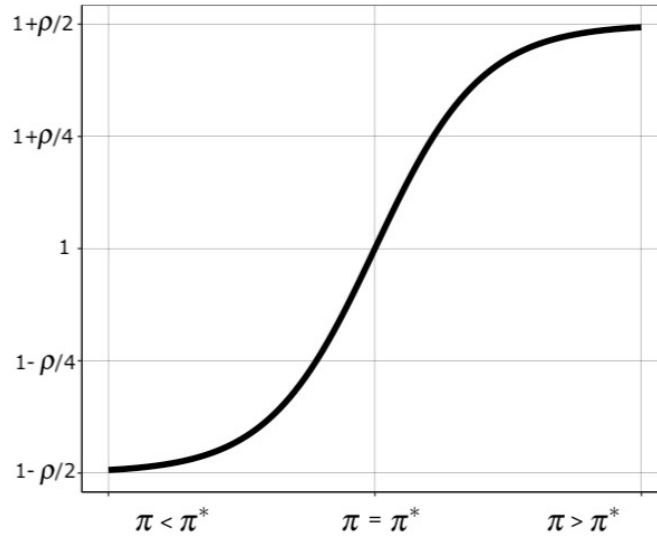


Figure 4.5: Illustration of the social influence function (adapted from Aparicio Diaz et al. (2011))

The exponential decay function in Equations 4.12 and 4.13 takes into account that social influence declines as peers' children grow older (Lyngstad and Prskawetz, 2010). Furthermore, the model specification also considers that social influence is stronger for childless women potentially transitioning into parenthood than for mothers potentially transitioning to higher-order births (*ibid.*). The model will determine whether an agent will have a child by comparing their revised birth probability to a draw from a Uniform(0,1) distribution: if the agent's birth probability is larger than the random draw, she will have a child. The sex of the newborn baby is determined from the empirical sex ratio at birth for that given year. In the case of a newborn girl, a new female agent is created and saved at the model level. In the case of a boy, no newborn agent is created but the boy will count towards his mother's parity, given the ABSM is a single-sex model. As aforementioned, the familial bonds are kept intact. After all agents have performed their step during a given year, all newborn girls are added to the agent sample and model scheduler. This is done all at once at the model level in order to prevent the scheduler from distorting when agents are added or removed while looping through them.

4.3.6 Input Parameters

There are a number of time-invariant input parameters to the ABSM that control the processes described in the previous sections, namely befriending and unfriending as well as the social influencing of network members on one's childbearing intentions (see Table 4.3). These parameters are the inputs of interest, and can be varied throughout the simulations to examine their role on micro-level childbearing and the resulting macro-level childlessness trends. During calibration, these parameters are optimised in such a way that the resulting macro-level childlessness trend from the simulation best matches the empirically observed childlessness trend from [Statistics Netherlands \(2012\)](#). In other words, the calibration finds the values of the parameters such that the individual-level deviation from the actually observed birth probabilities implied by the model in the form of social network formation and their influence, which can be smaller or larger than one on the individual level, results on average in the observed childlessness trend on the macro level.

Table 4.3: Model input parameters, notation and range

Category	Parameter	Notation	Range
Befriending and unfriending	Density	γ	[0, 1]
	Share of kin	ζ	[0, 1]
	Homophily	β	[0, 1]
	Distance weight for parental status	θ_p	[0, 5]
	Distance weight for education	θ_e	[0, 5]
	Distance weight for age	θ_a	1
Social influence of network members	Influence strength (no/primary education)	ρ_p	[0, 2]
	Influence strength (secondary education)	ρ_s	[0, 2]
	Influence strength (tertiary education)	ρ_t	[0, 2]

4.3.7 Design Concepts

As noted earlier, the key results collected from the model in every time step and emerging from the behaviours of individual agents are i) the percentage of women who have remained childless at least up to age 50 by birth cohort (collected every year for the cohort born 50 years prior); ii) the total fertility rate (TFR); and iii) the mean age at first birth (MAFB).

The agents in the ABSM are not adaptive in the way that they update their internal models (i.e. learn and predict) to seek some type of improvement or success. Doing so would require an objective function for agents to optimise by deciding whether or not to have children, which is extremely difficult to incorporate given that there are so many different factors that are important to take into account when making the decision whether or not to have children ([Boivin et al., 2018](#)). However, the agents are

adaptive in the sense that their social environment influences their individual behaviour and outcomes. That is, the process of making friends depends on the available agents in the environment, and one's social network in turn influences their decision to have a child. In this way, agents sense each other, namely by being connected and collected within social networks, of which the structure is largely imposed by the model parameters. Within these networks, agents interact and influence each others' childbearing outcomes indirectly, namely by comparing the proportion of parents in one's network to the proportion of parents in the population, taking into account these parents' youngest children's ages.

There is some level of stochasticity in the model, in the sense that some choices (i.e. distance between potential friends, whether or not to die or have a child) are chosen from different options, each with different probabilities. Additionally, the age and educational attainment of females in the initial population are drawn from probability distributions, which is also the case for the sex and education of a newborn agent. The order in which agents perform their step every year is random as well, which might influence the resulting social networks and thus childbearing outcomes. To examine this variability, the model is run 10 times and the results are aggregated across these runs.

4.3.8 Implementation

The model is implemented from scratch in the Python programming language, with help from the Mesa package, which is an Apache2 licensed framework for agent-based modelling (Kazil et al., 2020).³ Note that the choices made for the number of agents at initialisation (1,500), the number of repetitions (10) and the number of training samples (8,192) are based on extensive testing to find the set-up which optimises the trade-off between model performance and computational cost. The model is calibrated for the Netherlands by matching the model-generated female childlessness trends with the truly observed female childlessness trend from Statistics Netherlands (2012) for birth cohorts between 1935 and 1965 inclusive. The optimal combination of input parameters is the one that optimises the model fit, i.e. minimises the root mean squared error (RMSE), defined as

$$RMSE = \sqrt{\frac{1}{\sum_{c=1935}^{1965} 1} \sum_{c=1935}^{1965} (\text{childlessness}_c - \widehat{\text{childlessness}}_c)^2} \quad (4.16)$$

where childlessness_c and $\widehat{\text{childlessness}}_c$ are the actual respectively simulated levels of permanent childlessness amongst females of birth cohort c . As a check, I also inspect the TFR and MAFB generated by the model with the combination of parameters optimising the RMSE to make sure this optimal combination of input parameters also performs well in predicting the TFR and MAFB besides childlessness.

³All code that was used to obtain the results in this work are available from the author upon request.

I run the ABSM on an exploratory sample of 8,192 rows,⁴ which are generated using Saltelli's extended version of Sobol sequences (Saltelli, 2002; Saltelli et al., 2010; Sobol, 2001) using the SALib package in Python (Herman and Usher, 2017). Sobol sequences are quasi-Monte Carlo methods that distribute samples evenly across multidimensional parameter spaces, and generally outperform other methods such as Latin Hypercube sampling (Burhenne et al., 2011; Kucherenko et al., 2015). The extension of the Sobol sequence by Saltelli reduces the rates of error in the calculations of the sensitivity indices (Herman and Usher, 2017). Every row in this sample of 8,192 rows represents a unique combination of the ABSM parameters summarised in Table 4.3.

Every run of the ABSM returns the childlessness trend for birth cohorts 1935 to 1965 as well as the TFR and MAFB trends for years 1935 to 1965. After each run, two outcome variables are computed on the basis of the model-generated childlessness trend, namely (i) its RMSE compared to the true childlessness trend from Statistics Netherlands (2012), as defined in Equation 4.16, and (ii) the rate of change in permanent childlessness between the 1935 and 1965 birth cohorts as simulated by the model. The Sobol sample and the corresponding two ABSM outcomes are then used to train a surrogate model, which essentially approximates the ABSM and allows one to estimate the two outcome variables for unseen combinations of model parameters. The advantage of using a surrogate for this purpose is that a surrogate will take substantially less time to provide reasonable approximations of the ABSM output than it would take to run the ABSM for all combinations of model parameters (Angione et al., 2020). The surrogate results hence provide the two outcome variables for all possible combinations of model parameters. These results can then be used to find the optimal combination of parameter values that minimises the RMSE, as well as to explore the ABSM's sensitivity to different zones of the parameter space.

4.3.8.1 Calibration

I use a gradient boosted model (GBM) and regression metamodel (RMM) as surrogates for the ABSM. I use the GBM to calibrate the ABSM, or to predict the two outcome variables (i.e. the model fit (RMSE) and childlessness rate of change) across all possible 117,406,179 combinations of the eight input parameter values on the basis of the training sample of 8,192 unique input parameter combinations. A GBM is a type of tree-based ML method, which uses an ensemble of 'weak' decision trees to form a prediction (James et al., 2013). Trees are grown sequentially using residuals from previously grown trees, and learning occurs slowly. ML methods have previously been shown to outperform more traditional emulation methods when it comes to calibration, such as Gaussian process emulators (GPEs) (Angione et al., 2020). I use a GBM because this model provides relatively fast estimation and low variance, and has shown to

⁴The number of Sobol sample rows equals $N(2D + 2)$ where N should ideally be a power of 2 and D is the number of model parameters (i.e. eight) (Herman and Usher, 2017). To optimise the trade-off between computational cost and model performance, here N is set to 512, resulting in $512 \cdot (2 \cdot 8 + 2) = 8,192$ training samples.

achieve high prediction performance across a variety of problems (Angione et al., 2020). Additional analyses also show that the GBM outperforms support vector machines, RMMs and GPEs in this particular context. Although GBMs require relatively extensive parameter optimisation, I use Bayesian distributed asynchronous hyperparameter optimisation (Bergstra et al., 2013) to automatically find the GBM parameters resulting in the lowest cross-validated (CV) prediction error. This method constructs a probability model of the objective function (i.e. the CV MSE) and uses Tree of Parzen Estimators (TPEs) to find the hyperparameters that optimise the objective function (for more details, see Bergstra et al., 2013).

The performance of the surrogates is expressed in terms of the (normalised) RMSE from 5-fold 5-repeated CV. This means that the data are split into $k = 5$ parts of similar size ('folds'), and in every one out of 5 iterations, $k - 1$ folds are used as training data and the one remaining fold is used as test data, and this whole process (including the data splitting) is repeated 5 times. In every iteration, the performance on the test set is measured by computing the RMSE and its normalised version (to compare across outcome variables measured at different scales) as

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (y_i - \hat{y}_i)^2} \quad (4.17)$$

and

$$NRMSE = \frac{RMSE}{\frac{1}{N} \sum_{i=1}^N y_i} \quad (4.18)$$

where N is the number of rows in the testing data in each iteration and repeat, and y_i and $\hat{y}_i$ are the actual (from the ABSM) respectively predicted (by the surrogate) values of either one of the two outcome variables (i.e. the model fit in terms of RMSE between simulated and actual childlessness, and rate of change in simulated childlessness between the 1935 and 1965 birth cohorts). To clarify, the RMSE from Equation 4.16 expresses the model fit measure, i.e. the error between the actual childlessness trend from Statistics Netherlands (2012) and the childlessness trend simulated by the ABSM, whereas the (N)RMSE in Equations 4.17 and 4.18 represents the error between the outputs (i.e. model fit measure and rate of change in childlessness) produced by the ABSM and those predicted by the surrogate. The overall (normalised) RMSE is obtained by averaging the (normalised) RMSEs across all iterations and repeats, and these aggregate values (i.e. CV (N)RMSE) are used to assess the performance of the surrogate. I standardise the input data (i.e. unique combinations of the eight ABSM parameters) to estimate the surrogate because additional analyses showed that doing so yields better performance (i.e. lower CV (N)RMSE) than when scaling the data between zero and one or not scaling the data at all.

4.3.8.2 Sensitivity Analysis

Surrogates can be used not only to predict the two outcome variables of interest (i.e. the model fit (RMSE) and childlessness rate of change), but also to perform sensitivity analysis. To this end, I use and compare three approaches for sensitivity analyses: i) regression coefficients and ANOVA estimates from an RMM; ii) Sobol global sensitivity indices; and iii) the GBM feature importances. I use these three approaches because each comes with their own advantages and drawbacks, and examining and comparing their results will therefore yield a comprehensive overview of the sensitivity of the ABSM's output to its input parameters. As aforementioned, note that the input parameters are scaled in these analyses because they are naturally on different scales.

The first approach uses a parametric RMM, which provides high interpretability and inferential insight when it comes to the variation explained by (combinations of) input parameters, and is easy to implement (Pietzsch et al., 2020). To choose the functional form of the RMM, which is often a polynomial form (Grow, 2017), I compute all one-, two- and three-way interactions between the eight input parameters, and from these $\sum_{k=1}^3 \frac{(8-k-1)!}{k!(8-1)!} = 164$ variables I choose a subset using recursive feature elimination (RFE) with 5-fold 5-repeated CV based on the explained variance criterion. Additional analyses showed that RFE outperformed forward, backward, exhaustive and Lasso feature selection methods in this case. I then regress the dependent variable onto the chosen combination of independent variables; the standardised model coefficients hence give an indication of how (combinations of) input parameters affect each of the two outcome variables.

Regarding the second approach, Sobol indices are a form of model-free variance-based global sensitivity analysis, which decompose the variance in the outcome variable into parts that can be separately attributed to (interactions amongst) the input variables (for a more detailed explanation, see Santner et al., 2003; Sobol, 1993, 2001). Although these indices do not provide any sense of the direction of influence of input parameters on the ABSM outcomes (Ten Broeke et al., 2016), they have often been recommended for sensitivity analysis for ABSMs, partially because of their flexibility (Ligmann-Zielinska et al., 2014; Saltelli et al., 2008).

As for the third approach, it is possible to deduce the importance of each ABSM parameter in predicting the outcome using a GBM by calculating how much purity is gained by splitting on a particular feature across all splits in a tree, and averaging that across all trees in the ensemble (James et al., 2013; Pedregosa et al., 2011). While these results might be harder to interpret and infer from compared to parametric methods like the RMM, they are nevertheless insightful and offer increased flexibility (Lamperti et al., 2018). One way of gaining feature importance is on the basis of (Gini) impurity, whereby the importance of a feature is determined by how much purity is gained by splitting on a particular feature

across all splits in a tree, and averaging that across all trees in the ensemble (James et al., 2013; Pedregosa et al., 2011). As these impurity-based importances might be deceptive for features that have a larger number of unique values (Pedregosa et al., 2011), I also report permutation-based feature importances. These importances are based on the decline in model performance when one feature is randomly shuffled, rather than on impurity (Breiman, 2001).

4.4 Data

Various sources of empirical data are used to initialise, calibrate and validate the ABSM. The actual ‘true’ childlessness trend for Dutch women by birth cohort is combined from different data sources. The data for the birth cohorts between 1935 and 1965 inclusive come from Statistics Netherlands (2012). Childlessness levels for five-year birth cohorts between 1900 and 1934 inclusive come from Dykstra (2009), and for every birth cohort within such a five-year period the level is set to that of the whole period (e.g. if childlessness is 23% for women born 1900-1904, then for each of 1900, 1901, 1902, 1903 and 1904 the level is set to 23%). The same goes for data for the birth cohorts of 1880 to 1899 and birth cohorts of 1850 to 1879, which are calculated as the average values from data by van Bavel and Kok (2010) respectively Rowland (2007).

The structure of the population at initialisation is based on population counts by age, sex and marital status in 1899 from the Dutch Census ("Volkstelling") (Statistics Netherlands, 1899). Age-, sex- and year-specific death rates for years 1850 to 2018 inclusive and ages zero to 110 inclusive for Dutch individuals are taken from Human Mortality Database (2020). The sex ratio at birth (i.e. proportion boys out of all children born alive) is available for years 1950 to 2019 from Statistics Netherlands (2020). For all years prior, the mean sex ratio at birth from years 1950 to 2019 is used, which is a sensible approach because the proportion of boys is stable and similar to 0.5 for all of the available years.

The age-, parity- and cohort-specific fertility rates are taken from the Dutch cohort fertility table for birth cohorts 1935 to 1993 inclusive and ages 12- to 55+ (Human Fertility Database, 2020b). For women born earlier than 1935, I combine the historical TFRs for the Netherlands with the 1950 Dutch age- and parity-specific fertility rates (Human Fertility Database, 2020a) to approximate the age- and parity specific fertility rates for all years between 1840 and 1950. From 1950 onwards, the TFR data come from Human Fertility Database (2020c), and for the period between 1840 and 1950, five-yearly estimates are obtained from O’Neill (2020). I interpolate the TFR for every year in these five-year periods between 1840 and 1950 using local regression. I further assume that the distribution of fertility across ages and parities is the same in all years between 1840 and 1950 as it is in 1950, the earliest year for which age- and parity-specific data are available. Although this assumption might not be completely plausible as earlier

cohorts will have had children at younger ages and of higher parities (de Graaf, 2007), the simulation results show that these approximations do not distort the results. Using the historical TFR and age- and parity-specific distribution of fertility from 1950, I compute the age- and parity-specific fertility rates for each year between 1840 and 1950.

Data on the expected highest achieved educational attainment come from Lee and Lee (2016).⁵ These data contain the distribution across none, primary, secondary and tertiary educational attainment of females aged 15-24 for every five years between 1870 and 2010 inclusive. Given the five-yearly nature of the data, the closest year available in these data is used when the exact target year is not available. At initialisation, I use the distribution in the year in which an agent was 20 years old as probabilities to draw a level of educational attainment. For example, for women aged 37 at initialisation (i.e. in year 1900), I use the distribution of 1885 (i.e. closest year available to $1900 - (37 - 20) = 1883$) to draw a level of educational attainment, which equals in this case 25% and 75% none respectively primary education. When new agents are born, the distribution across levels of educational attainment in the year in which the agent would turn 20 is used. I use the data for ages 15-24 to accurately represent the younger population in a given year, and use age 20 because it is in the middle of this range and seems like a reasonable age at which the level of educational attainment can be accurately estimated or concluded (Latten and van Dijk, 2007). To illustrate, if a child is born in 1952, I use the educational distribution in 1970 (which is the year available in the data closest to $1952 + 20 = 1972$) to draw a future level of educational attainment, according to the rates of that year (i.e. 0.5%, 13.7%, 83.5% and 2.3% in none, primary, secondary and tertiary education, respectively).

4.5 Results

The ABSM extracts the prevalence of permanent childlessness for each birth cohort between 1935 and 1965, after which it compares these values with those observed in reality to compute a model fit measure (RMSE) and computes the change in simulated childlessness levels between the 1935 and 1965 birth cohorts. Both of these outcomes are computed in each run of the ABSM. Descriptive results, including a histogram of predicted outcomes as well as correlation plots between the eight model input parameters and the outcome variables, are shown in Figure 4.C.1 respectively Figures 4.C.2 and 4.C.3 in Appendix 4.C.

⁵These data are available at https://barrolee.github.io/BarroLeeDataSet/LeeLee/LeeLee_attain_F1524.xls.

4.5.1 Model Calibration

Recall that the ABSM was run on 8,192 Sobol samples, of which the results were used to train a GBM with the goal of predicting the two outcome variables (i.e. ABSM fit (RMSE) and childlessness rate of change) on all possible 117,406,179 combinations of the input parameter values. The hyperparameters of this GBM are included in Table 4.D.1 in Appendix 4.D. The optimal combination of model parameters that minimises the error between the simulated and actual childlessness trend is as follows: $\gamma=0.7$, $\zeta=1$, $\beta=0.9$, $\theta_p=1$, $\theta_e=0.5$, $\rho_p=1$, $\rho_s=1$, $\rho_t=1$. Note that these values are not directly comparable to those of Aparicio Diaz et al. (2011), who use a similar social influence function, because their model includes other parameters this model does not, and vice versa.

The results indicate that relatively high values of density, share of kin and homophily are needed to calibrate the model. Interestingly, this suggests that the social networks of Dutch women born between 1935 and 1965 were not all that individualistic, and that abidance to childbearing norms may have been fostered in these networks. Additionally, low to moderate values of distance weights result in a good model fit, *ceteris paribus*. The calibration values suggest that parental status and age are equally important characteristics in determining who to befriend and unfriend, whereas education is of relatively smaller importance. While Aparicio Diaz et al. (2011) did not consider parental status as an endogenous characteristic in social network formation, they found that an educational difference of one level corresponded to an age difference of five years, which is only half a year in this analysis. One reason for this might be that Aparicio Diaz et al. (2011) consider a smaller range of ages, or because they consider later periods of history during which a relatively larger share of women were highly educated.

Further, moderate values of educational influence strengths are needed to calibrate the model, and these values are similar across different levels of education. The value of one across these parameters implies that no additional multiplier of the social influence function is needed, and that the strength of social influence needs not differ by level of education to achieve a good model fit. This contradicts findings from Aparicio Diaz et al. (2011), who argued and found that social influence should be stronger amongst highly educated women. One reason for this may be, as aforementioned, that Aparicio Diaz et al. (2011) consider a relatively larger share of highly educated women. Another reason may be that their argument is based on the expectation of highly educated women being more susceptible to conform to norms than lower-educated women (Cole et al., 1998; Fent et al., 2007), because the former expect to gain from their higher-educated status and community membership in terms of marriage, labour market competition and status (Burke and Heiland, 2006). However, this argument may not hold in the context of childlessness, because it has been shown that highly educated women often tend to depart from fertility norms and forego childbearing instead to maintain their high socio-economic status and human capital

(e.g. Barthold et al., 2012; Miettinen et al., 2015; Tanturri et al., 2015).

Figures 4.6 and 4.7 show the RMSE respectively childlessness change from emulated childlessness trends. In each panel of these figures, two model parameters are varied while the other ones are kept constant at their value in the optimal combination of parameters. Note that while lighter shades always represent larger errors or childlessness changes and darker shades smaller errors or childlessness changes, the colour scales are different throughout the panels of the two figures.

The contour plots in Figure 4.6 show that good model fit is achieved at relatively lower values of share of kin and higher values of density and homophily. In other words, the model fit is sensitive to compositional and structural social network characteristics, which may well be because these characteristics may to a large extent determine the norms that prevail in social networks as well as the extent to which these norms are abided to. Surprisingly, the contour plots suggest a good model fit at low shares of kin, whereas the optimal calibration value for this parameter showed to be relatively high ($\zeta = 1$). One reason for this may be that the differential in model fit between low to moderate shares of kin and high shares of kin is relatively small, being only about one unit of RMSE (Figure 4.6). Regarding the good model fit at higher values of density and homophily, the results suggest that the ABSM better approximates the empirically observed childlessness trend when social networks are relatively dense and homogeneous. In this sense, following the reasoning by Kohler et al. (2001), such social networks should foster abidance to existing social norms, regardless of what those norms may be. Further, while the model fit is better at lower values of the influence strength amongst none, primarily and secondarily educated agents, the model fit is less sensitive to the influence strength amongst tertiary educated agents. As observed earlier, this means that large multipliers of birth probabilities adjusted for social influence are not necessary to calibrate the model, which is in line with findings from Aparicio Diaz et al. (2011). Lower values of the educational distance weight result in smaller errors, which also holds for more moderate values of the parental status distance weight. This observation suggests that a good model fit may result from social network formation based more strongly on similarities in terms of parental status rather than education. Hence, these results also provide preliminary evidence for the notion of endogenous social network influences on childbearing behaviour.

The growth in childlessness (Figure 4.7) is most substantial at high shares of kin combined with low values of density and moderate values of homophily, while moderate to high values of density combined with low values of homophily also result in larger increases in childlessness. These results suggest that social networks can foster childlessness by facilitating deviation from some persistent childbearing norm. Indeed, in line with expectations from the literature, childlessness seems to grow more strongly when there is a childbearing norm—as is likely the case in kin-centered networks—but when conformity to this norm is not strongly fostered due to these networks being rather sparse and heterogeneous (Keim, 2011;

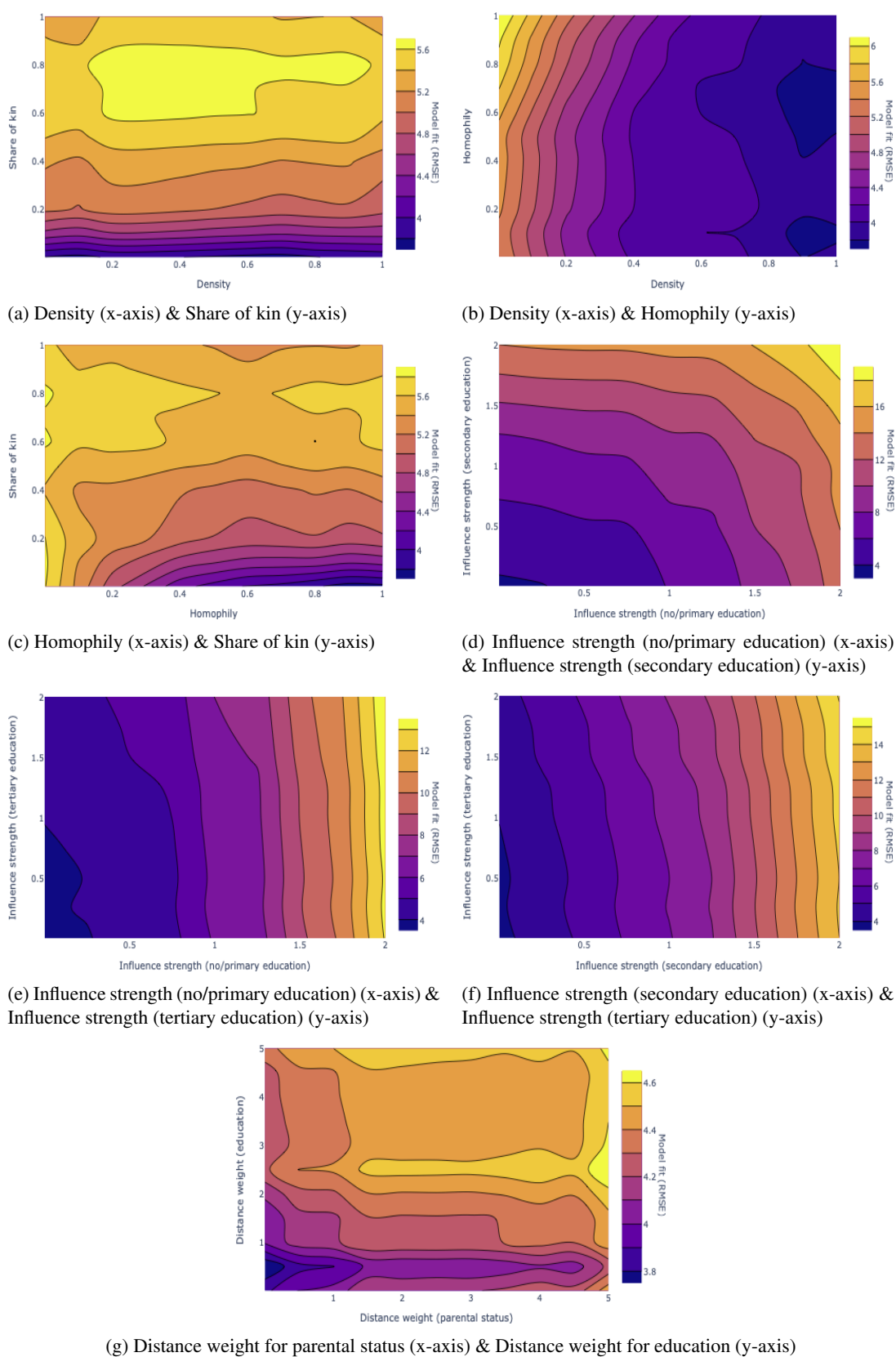


Figure 4.6: Contour plots of ABMS fit (RMSE) for a number of different parameter combinations

Kohler et al., 2001). Further, relatively low values of the social influence strength amongst none and primarily educated agents combined with higher values for secondarily educated agents result in larger simulated changes in childlessness. This makes sense because highly educated women tend to remain childless, and be part of progressive social networks that endorse childlessness rather than childbearing, more often than lower-educated women (Keim, 2011; Merz and Liefbroer, 2012). Therefore, on the one hand a larger social influence amongst these highly educated women might increase their conformity to the childlessness norm that prevails in their particular (clusters of) social networks. On the other hand, a smaller social influence amongst lower-educated women might decrease their propensity to conform to the childbearing norm prevailing in their respective networks. As a result, macro-level childlessness may become increasingly prevalent. In this respect, these observations also suggest that whether social influence should be smaller or larger amongst highly educated women compared to their lower-educated counterparts seems to depend on what the prevailing norms are and to what extent conformity to these norms is believed to help in maintaining one's high status. Nevertheless, the strength of social influence amongst tertiary educated agents does not seem to play a substantial role in the growth of childlessness, which may be because the share of tertiary educated women amongst the birth cohorts considered is relatively small. Further, moderate to high distance weights for parental status result in larger growths in childlessness, although the influence of educational distance weights is less substantial. In other words, childlessness tends to grow more strongly when parental status, especially compared to education or age, is a determinant in the processes of befriending and unfriending as a part of endogenous social network formation.

The ABSM is run 10 times at the optimal combination of the input parameters ($\gamma=0.7$, $\zeta=1$, $\beta=0.9$, $\theta_p=1$, $\theta_e=0.5$, $\rho_p=1$, $\rho_s=1$, $\rho_t=1$). The results (five-year moving average and 95% confidence interval) are shown in Figure 4.8. The trend shows a generally good fit (average RMSE of 4.372 across the 10 runs), with an S-shaped curve and steepest incline between the 1945 and 1955 birth cohorts. Note that the displayed discrepancy between the 1935 and 1940 birth cohorts is the result of moving averaging. While the simulated trends slightly overestimate the actual trend at the flatter parts (amongst the earlier and later of the observed birth cohorts), the ABSM is able to reproduce the steep increase amongst the 1945 to 1955 birth cohorts, which the baseline model (Figure 4.2a) without social influence was not able to do as accurately. This suggests that social influence has played a significant role in the observed increase in childlessness amongst these cohorts. Aparicio Diaz et al. (2011), using a comparable definition of the social influence function, similarly found that their baseline model without social influence could not reproduce fertility developments in Austria while their ABSM with social influence could.

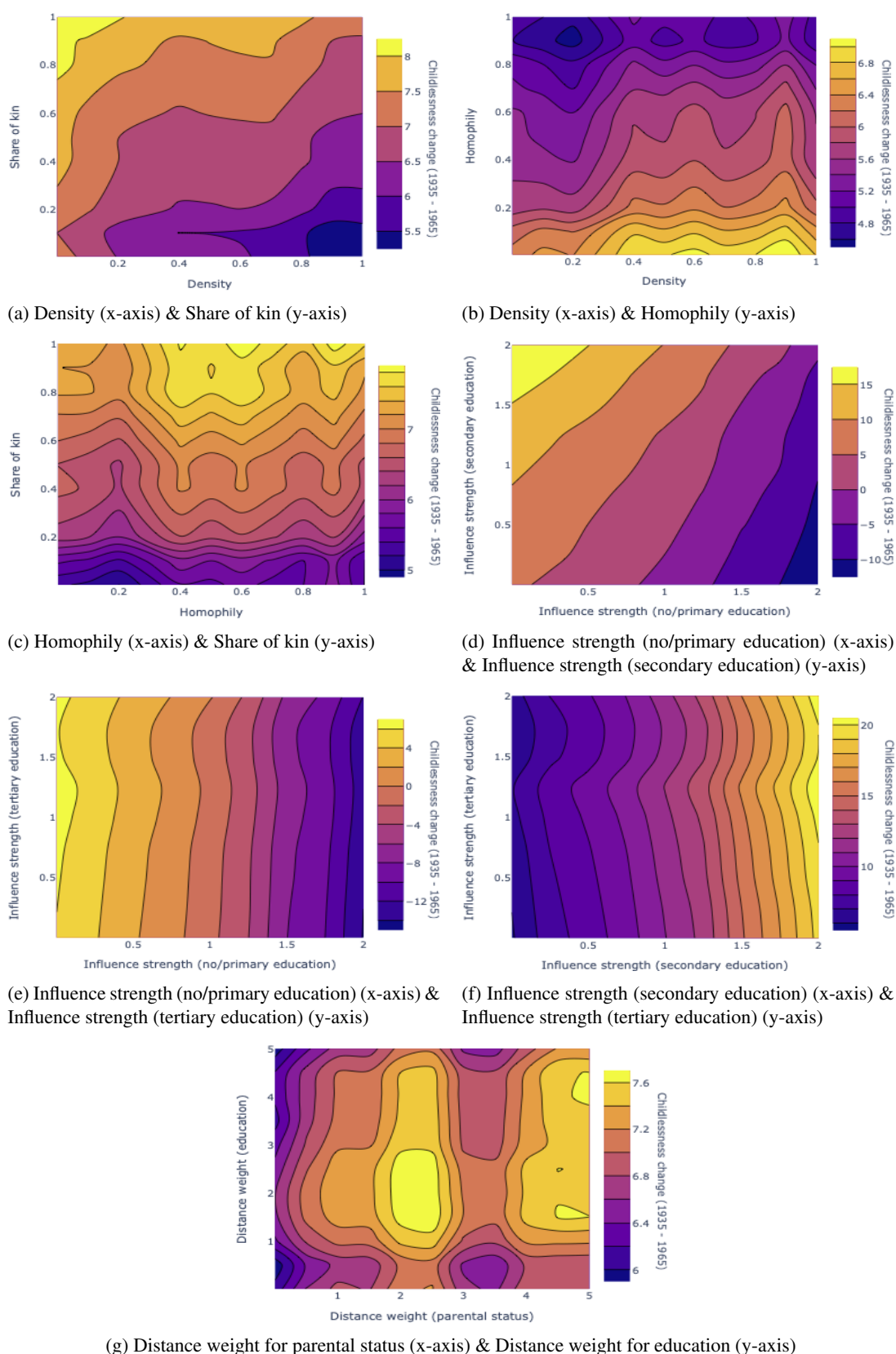


Figure 4.7: Contour plots of change in childlessness between the 1935 and 1965 birth cohorts for a number of different parameter combinations

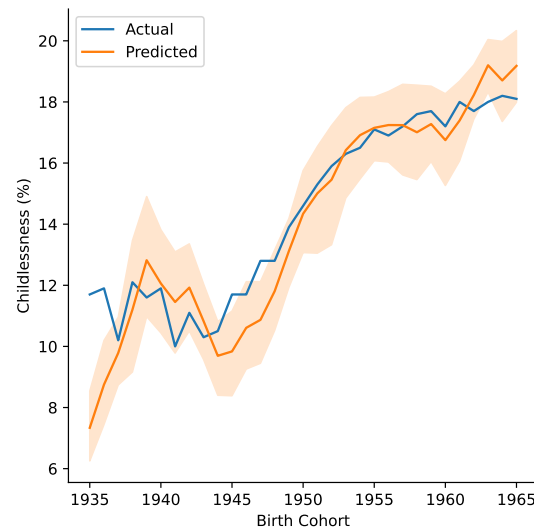


Figure 4.8: Actual and simulated (five-year moving average and 95% confidence interval) trends in permanent childlessness amongst women born between 1935 and 1965 inclusive (simulation with social influence from 1935 onwards)

4.5.2 Experimental Scenarios

To understand how the structural and compositional characteristics of social networks influence the levels and shape of permanent childlessness amongst the 1935 to 1965 Dutch female birth cohorts, I adopt a so-called experimental strategy. For each of the model parameters, I select its minimum, maximum and mean value from the range as specified in Table 4.3. For example, for homophily I select values 0, 0.5 and 1 as the low, medium and high scenarios. For each of the eight model parameters and each of the three scenarios, I run the model 10 times (total of $8 \cdot 3 \cdot 10 = 240$ runs). When one parameter is varied across its low, medium and high values, the other parameters are kept constant at their optimal calibration value. Figure 4.9 shows the five-year moving average of the model-generated childlessness trends for each of the scenarios and model parameters with 95% confidence intervals.

The trends in Figure 4.9 firstly show that levels of childlessness depend quite strongly on the distance weight based on parental status, homophily and the influence strength for none and primarily educated individuals. Higher levels of these parameters result in higher levels of childlessness. While this difference is more pronounced amongst earlier birth cohorts for the parental status distance weight, it is more distinguished amongst later birth cohorts for homophily and none/primary education influence strength. As also observed earlier, these results suggest that the levels (and growth) of childlessness are larger when agents are more likely to befriend and unfriend agents similar respectively dissimilar to themselves, particularly when this (dis)similarity is based on parental status.

Additionally, childlessness would have been higher had the strength of social influence been larger

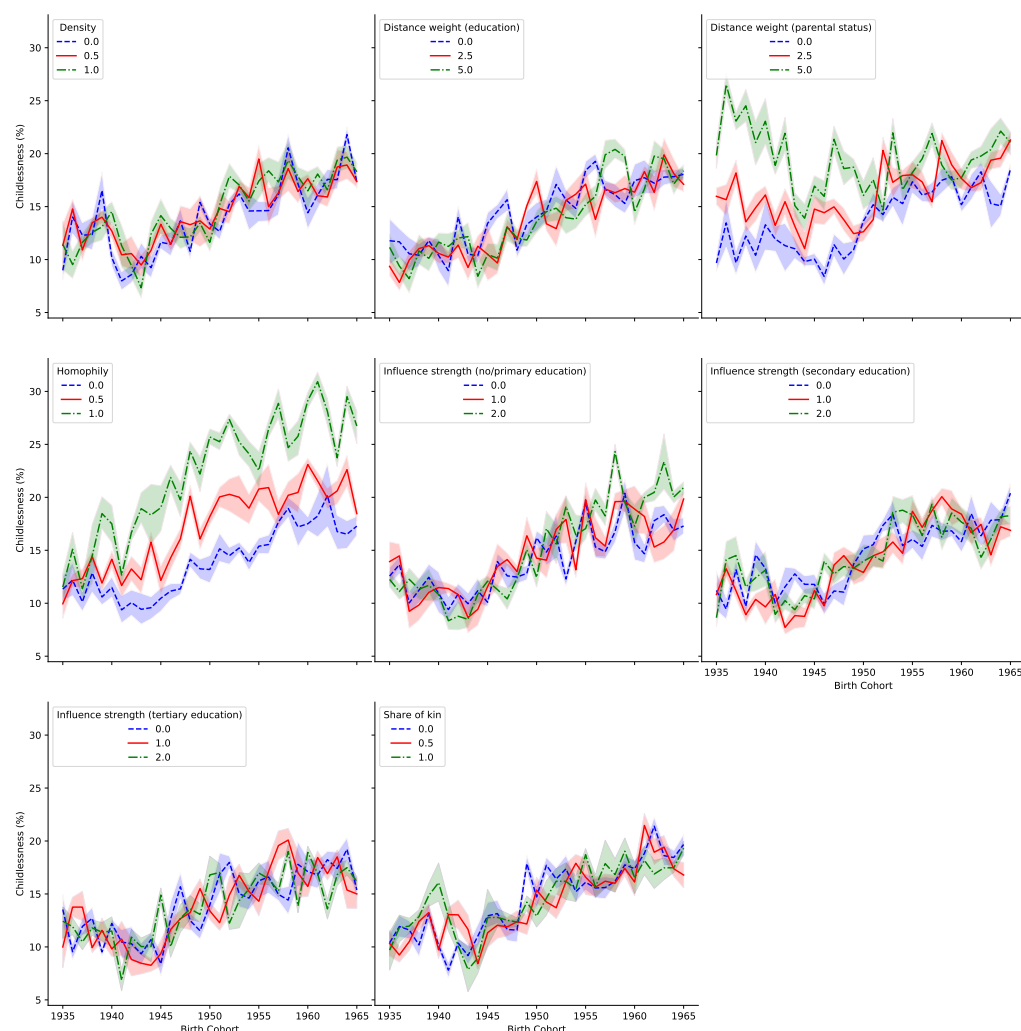


Figure 4.9: Simulated (five-year moving average and 95% confidence interval) trends in permanent childlessness amongst women born between 1935 and 1965 inclusive (simulation with social influence from 1935 onwards), for low, medium and high values of each ABSM parameter

amongst none and primarily educated agents. While this observation seems to contradict the findings presented in Figure 4.7 at first, it should be noted that the resulting childlessness levels in Figure 4.9 tend to be higher merely amongst some of the younger cohorts considered, whereas amongst the older cohorts the social influence strength amongst none and primarily educated agents seems to play less of a role. Following the reasoning from the theory on the diffusion of innovations (Rogers, 2003), these observations could preliminarily point to the speculation that highly educated women might have been ‘innovators’ or ‘early adopters’ of the childless lifestyle, whereas lower-educated women may belong to the ‘late majority’ or ‘laggards’ (Bernardi and Klärner, 2014). In other words, as childlessness becomes more common and perhaps even endorsed over time, likely because highly educated women started deviating from persistent childbearing norms, stronger social influence amongst lower-educated women could reflect how social networks might encourage these lower-educated women to abstain from childbearing

and adopt a childless lifestyle as well, resulting in increasingly large levels of childlessness over time.

Further, in line with the results from Figure 4.7, the S-shaped curve is more pronounced at relatively lower values of homophily, density and parental status distance weight; moderate values of influence strength amongst secondarily educated agents; and higher values of share of kin, educational distance weight and influence strength amongst none and primarily educated agents. At the other extremes of these parameters, the growth of childlessness follows more of a linear trend. In other words, the relatively steep increase in childlessness observed amongst particularly the 1945 to 1955 birth cohorts may likely be the result of social networks becoming less ‘traditional’ over time, i.e. still containing relatively higher shares of kin but facilitating deviation from the up-to-then dominating childbearing norms in favour of childlessness through sparser and more heterogeneous networks. These findings are in line with earlier observations that the growth in childlessness is stimulated by the prevalence of social networks which encourage conformity to childlessness norms or instead allow aberration from persistent childbearing norms. Finally, as observed earlier, there is less of an influence on the trend in childlessness of the influence strength for tertiary educated individuals.

4.5.3 Sensitivity Analysis

To examine to what extent the model parameters account for the variability in the model outcome measures, I perform sensitivity analyses for each of the two outcome variables (i.e. model fit measure (RMSE) with empirically observed childlessness trend and change in childlessness between the 1935 and 1965 birth cohorts). As aforementioned, three types of sensitivity analyses are presented: i) those from regression coefficients and ANOVA estimates from an RMM; ii) those from Sobol sensitivity indices; and iii) those from GBM feature importances. The performances of the RMM and GBM emulators in predicting the simulated childlessness change and its fit with empirically observed childlessness trends are included in Table 4.E.1 in Appendix 4.E. Both emulators perform similarly when it comes to predicting the two outcomes, although the GBM reports a higher adjusted R^2 than the RMM for both outcomes. These results also support the choice for using the GBM as calibration emulator. Overall, both emulators do a decent job at predicting the model fit measure, being only about one unit off. Nevertheless, the emulators have a harder time predicting the change in childlessness, being about 7.5 percentage points off on average.

4.5.3.1 Regression Coefficients and ANOVA Estimates from RMM

Tables 4.4 and 4.5 show the regression coefficients and ANOVA estimates for the linear regressions predicting the model fit measure (RMSE) respectively the change in childlessness between the 1935

and 1965 birth cohorts, predicted from parameters (and interactions between them) as selected using RFE. A large share of the variation (94.5%) in the model fit measure (RMSE) is explained by the model parameters; this is the case for a bit more than half of the variance (57.8%) in the childlessness change outcome variable. For both outcomes, a relatively large share of the variance is explained by the strength of social influence amongst none and primarily educated agents. As also observed in the contour plots in Figure 4.7, the RMM coefficients indicate that a larger social influence strength amongst none and primarily educated agents is associated with a smaller growth in childlessness between the 1935 and 1965 birth cohorts, whereas a larger social influence strength amongst secondarily educated agents is associated with a larger increase in childlessness.

Other important parameter combinations for explaining the variance in the model fit are density interacting with social influence strength for secondarily educated agents (3.2%) as well as the squares of social influence strength for none and primarily educated (3.0%) and secondarily educated agents (8.4%). In line with observations from Figure 4.6, the RMM coefficients suggest that a larger value of density is associated with a better model fit (i.e. smaller RMSE), whereas larger values for the share of kin, parental distance weight and social influence strengths across the three educational levels are related to worse model fit (i.e. larger RMSE). These observations may be explained by the educational parameters being direct multipliers of social influence and therefore birth probabilities. Also, the relatively smaller importance of social influence strength amongst tertiary educated agents compared to none, primarily and secondarily educated agents may be the result of the largest share of agents in the observed cohorts not being tertiary educated. Finally, the interaction between homophily and social influence strength for secondarily educated agents explains a substantial share of the variance in both outcomes. This result may point to the observation that highly educated women may often be part of social networks consisting of other highly educated women (Bernardi and Klärner, 2014; Keim, 2011), who are more likely to remain childless (e.g. Barthold et al., 2012; Miettinen et al., 2015; Tanturri et al., 2015) and therefore also endorse childlessness (Merz and Liefbroer, 2012).

4.5.3.2 Sobol Sensitivity Indices

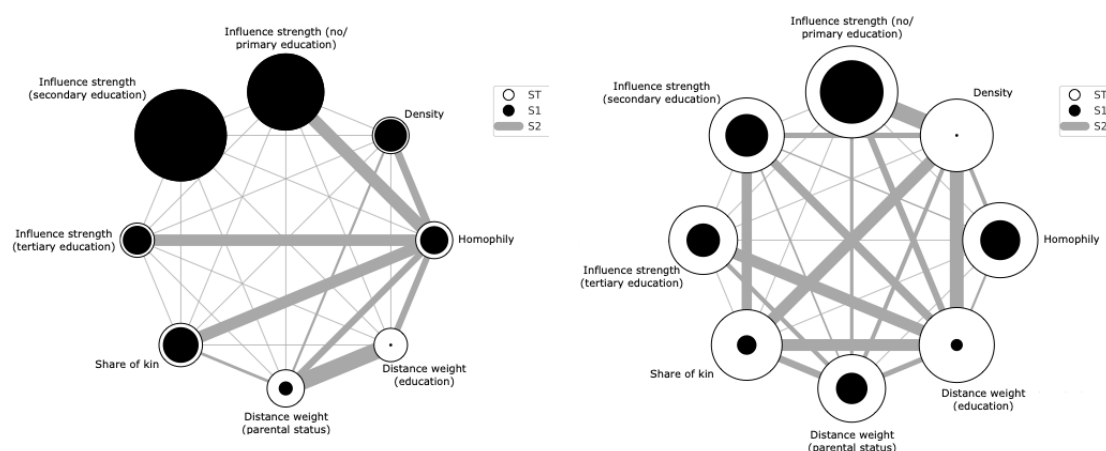
Figure 4.10 visualises the main and interaction Sobol indices (the raw indices are included in Tables 4.F.1 respectively 4.F.2 in Appendix 4.F). The larger the white outer circle for a parameter, the larger its total (combined first- and second-order) effect. The lines between circles represent interactions between parameters; their thickness the strength of these interactions. The black inner circle for each parameter represents its direct, first-order effect.

As observed earlier, the strength of social influence amongst none, primarily and secondarily educated agents has large total and first-order effects on the two outcomes. As aforementioned, these large first-order effects may be the result of these parameters being direct multipliers of social influence, and thus also of birth probabilities. In the case of the model fit (RMSE), smaller total effects are present for density, homophily, share of kin, the two distance weights and social influence strength for tertiary educated agents. The effects of particularly the two distance weights stem from interactions with other parameters, including the one amongst each other. As observed previously, this implies that the relative importance of parental status compared to education in determining similarities between agents plays a role for the model fit, perhaps through the composition of the endogenous social networks formed. In line with this notion, homophily has a relatively large first-order effect, but also strongly interacts with share of kin, density, and social influence strength for all but secondarily educated agents.

For the change in childlessness between the 1935 and 1965 birth cohorts, the total effects of the model parameters are more comparable in magnitude. The effect sizes of density, educational distance weight and share of kin mainly come from interactions with other parameters, particularly those amongst each other. One reason for this might be that mutual friends are generally common in networks with large shares of kin (because family members are automatically connected to one another) as well as in networks that are homogeneous in terms of education (because of groups of individuals who meet in school or college) (Keim, 2011). As observed earlier, homophily and the social influence strength by the three educational gradients have relatively large first-order effects on the change in childlessness, again providing evidence for the notion that women who remain childless are often highly educated (e.g. Barthold et al., 2012; Miettinen et al., 2015; Tanturri et al., 2015), and may be part of social networks of other highly educated, childless women (Bernardi and Klärner, 2014; Keim, 2011).

4.5.3.3 Feature Importances from GBM

As explained earlier, feature and permutation importances can be deduced from the GBM and used to examine how changes in the ABSM parameters affect the two outcome variables. The results are shown in Figure 4.11. The impurity importance measures show that all parameters play a role in predicting each of the two outcomes. The importances are relatively similar across the features in the prediction of the model fit, although the importances are more distinguished across the features for the change in childlessness. Generally, as the permutation feature importances also show, the social influence strength for none, primarily and secondarily educated agents are most important in predicting each of the two outcome measures. For predicting the model fit measure (RMSE), the share of kin, homophily and density matter as well, followed by the distance weights for parental status and education. Following the social influence strength for none, primarily and secondarily educated agents, the change in childlessness



(a) Sobol sensitivity indices for ABSM fit measure (RMSE) (b) Sobol sensitivity indices for change in childlessness between 1935 and 1965 birth cohorts

Figure 4.10: Sobol sensitivity indices (ST=total effects; S1=first-order effects; S2=second-order effects) for each of the two outcome variables (horizontal panels)

observed amongst the 1935 to 1965 birth cohorts seems to be most strongly influenced by the share of kin. Density, homophily and the distance weights for parental status and education all have a smaller but substantial importance for the change in childlessness as well. The social influence strength for tertiary educated agents matters hardly for either outcome. These results are largely in line with those from the RMM and Sobol sensitivity analyses.

Taken together, the results from the sensitivity analyses indicate that neither the model fit nor childlessness rate of change are very sensitive to the influence of education in seeking like-minded friends nor the social influence strength amongst tertiary educated agents. Rather, the sensitivity analyses indicate that particularly the social influence strength amongst none, primarily and secondarily educated agents affects both the model fit and childlessness rate of change. Whilst homophily (largely based on parental status) and density affect both outcomes in their interaction with the social influence strength amongst secondarily educated agents, the share of kin tends to more directly influence both outcomes. These results altogether imply that social influence is of importance for both the model fit as well as the change in childlessness, not only directly but also indirectly via endogenous social network formation. Hereby, the structural and compositional characteristics of the social networks producing this influence affect both the growth in childlessness prevalences as well as the shape of this growth. They seem to do so not only by playing a role in determining the social norms around family formation in these social networks, but also the extent to which these norms should be abided to or can instead be deviated from.

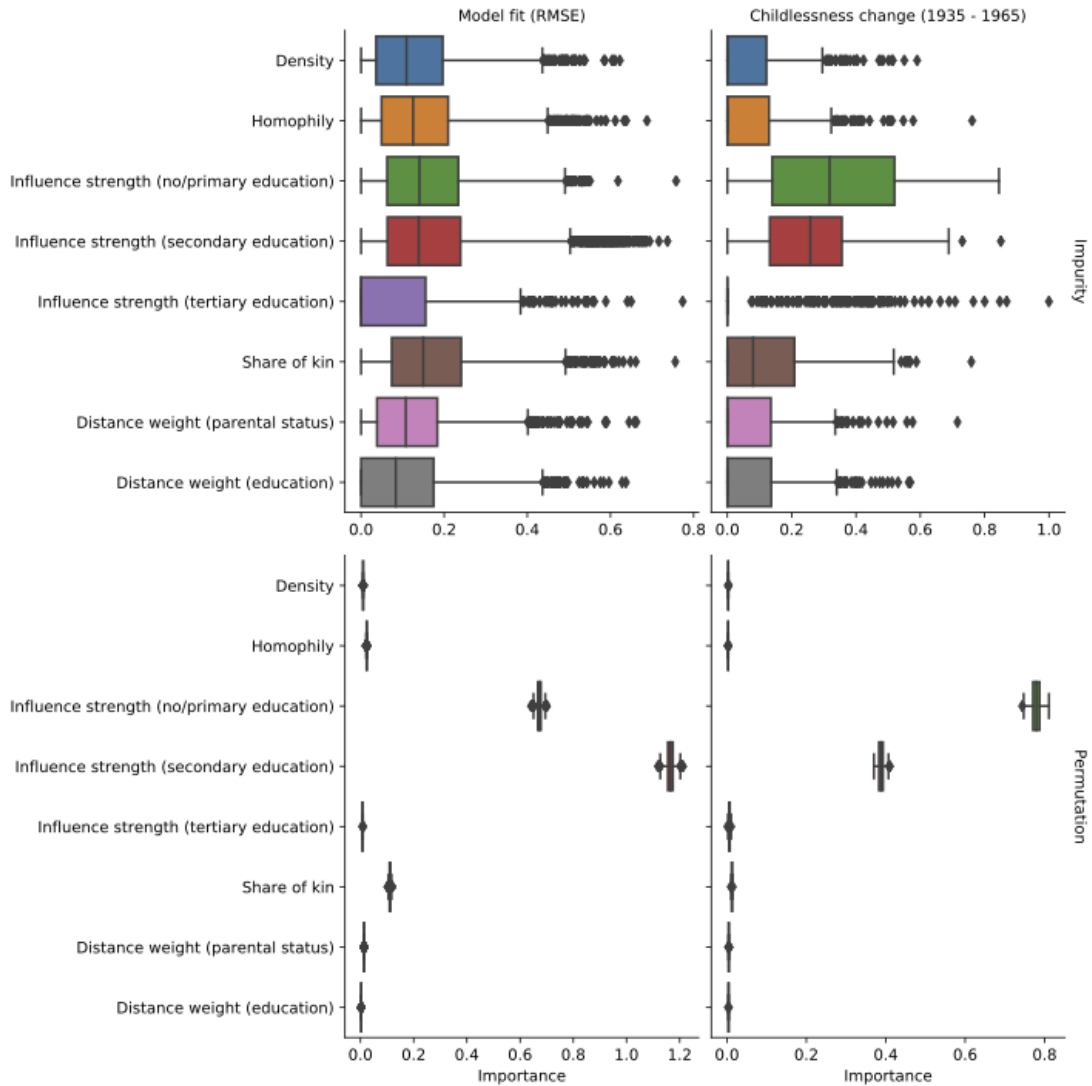


Figure 4.11: Impurity (top panels) and permutation (bottom panels) feature importance for each of the two outcome variables (horizontal panels)

4.6 Conclusion and Discussion

This work has, to the best of my knowledge, been the first to investigate the role of structural and compositional characteristics of social networks in explaining macro-level childlessness patterns which emerge from micro-level childbearing life-course outcomes. By means of developing an ABSM, I was able to explicitly model interactions amongst heterogeneous agents whom tend to form social networks endogenously and make not fully rational childbearing decisions based on simple heuristics and behavioural rules. I also gave one of the first demonstrations of how ML models, besides more commonly used statistical approaches, can be leveraged to understand the ABSM's sensitivity to the input parameter space. The use and advantages of the ABSM and its emulators were demonstrated to a case study of Dutch

women born between 1935 and 1965, amongst whom childlessness increased from 11.7% to 18.1%. As such, I have been able to assess how meso-level social networks link micro-level childbearing behaviour and macro-level childlessness patterns, and consequentially hypothesise about the potential (trends in) social network characteristics that may underlie these patterns.

Interestingly, the baseline model without social influence was not able to reproduce the steep increase in childlessness observed between the 1945 and 1955 birth cohorts, while the ABSM with social influence was. These results suggest that social influence is an important factor in explaining the development of childlessness over the past decades. While there has been less of a focus on childlessness, similar conclusions have been drawn for other fertility-related transitions (e.g. [González-Bailón and Murphy, 2013](#); [Kashyap and Villavicencio, 2016](#); [Nomes et al., 2019](#)). For example, [Aparicio Diaz et al. \(2011\)](#) were not able to replicate Austrian fertility patterns with a baseline model excluding social influence, while their ABSM with social influence could. Further, [Lois \(2016\)](#) found evidence for the four mechanisms of social influence (i.e. social pressure, emotional contagion, social support and social learning) beyond intergenerational fertility models. While agents' ages and intentions to have children most strongly predict their childbearing behaviour, these mechanisms of social influence seem to be non-negligible when examining factors affecting childbearing outcomes ([Berndt et al., 2018](#)). Future research on fertility-related transitions would therefore benefit from increasingly considering social network effects as a potential explanation for the observed developments. Increased calls for relevant large-scale data might provide researchers with the information needed to explore these social network effects further ([Balbo et al., 2013](#)), although in the meantime simulation-based methods may provide a valuable tool for doing so in the absence of such data.

Further, relatively high values of homophily, density and share of kin were needed to calibrate the model. This observation is in line with the scarce information available about historical social networks of the Dutch: [Bras and Van Tilburg \(2007\)](#) found that relatively high values of kinship and social homogeneity existed in the social networks of Dutch people in the twentieth century. Additionally, both outcomes proved sensitive to these structural and compositional social network characteristics. In line with observations by [Aparicio Diaz et al. \(2011\)](#), these findings indicate that the characteristics of social networks are important for explaining fertility-related historical patterns. Further, the results suggest that social networks amongst the observed cohorts were actually not that 'individualistic', and that conforming to normative behaviour of childbearing should have been strongly fostered, at least amongst the earlier cohorts considered. These observations are in line with findings from the literature, i.e. that dense 'family-centered' social networks with strong ties tend to most effectively foster childbearing ([Lois, 2016](#)). However, levels and (speed of) growth of childlessness tended to increase with lower density and

homophily, suggesting that deviation from social norms through increasingly sparse and more heterogeneous networks might have contributed to the S-curved growth in childlessness observed over the past decades. Hence, the findings provide some preliminary quantitative reasoning for the hypothesis that individuals' social networks have become decreasingly traditional, with the focus shifting from low-mobility, long-term, activity-based and kin-centered networks to high-mobility, short-term, interest-based friend-centered networks (Keim, 2011; Wellman, 1979). Investigating this hypothesis further would be an interesting avenue for future research. A first step that could be made in this direction would be to extend the ABSM developed in this chapter to include dynamic parameters, and assess the simulated childlessness trends for different trends in compositional and structural characteristics of social networks. Additionally, a better understanding of the actual mechanisms linking these structural and compositional social network characteristics to individual decisions would help enhance our understanding of the mechanisms by which different types of social network members have a differential influence on an individual. For example, could it be perhaps that more similar or connected network members exert more pressure on individuals to have children than do less similar or connected members, or could it be that the extent of pressure exerted is the same, but an individual takes it more seriously coming from a 'closer' member?

The ABSM further proved sensitive to the strength of social influence amongst none, primarily and secondarily educated agents. Similarly as what Aparicio Diaz et al. (2011) concluded, the ABSM results were less sensitive to social influence amongst tertiary educated agents, likely because the share of such highly educated women is relatively small although not insignificant amongst the observed cohorts. While the results implied that different educational groups do not seem to experience different levels of exposure to pressure to conform to social norms, the strength of social influence amongst none, primarily and secondarily educated agents affected both model fit and change in childlessness. The results showed that more social influence amongst secondarily educated agents increases childlessness, which is the contrary for none and primarily educated agents. This observation is in line with notions from the literature about highly educated women, more often than their lower-educated counterparts, remaining childless (e.g. Aparicio Diaz et al., 2011; Barthold et al., 2012; Miettinen et al., 2015; Tanturri et al., 2015) and being part of social networks of other highly-educated childless women (Bernardi and Klärner, 2014; Keim, 2011). Furthermore, while other studies have suggested or found that abidance to social norms should be stronger amongst highly educated women (Aparicio Diaz et al., 2011; Cole et al., 1998; Fent et al., 2007), this might actually not be the case when it comes to childlessness. Rather, it seems that highly educated women were 'frontiers' in letting go of childbearing norms in favour of childlessness, likely because they spent more time in education and were the first to experience life opportunities beyond family formation (e.g. Neyer et al., 2017; Oppenheimer, 1994; Surkyn and Lesthaeghe, 2004). Further research would benefit from developing a deeper understanding of educational gradients when it comes

to exercising social influence and being affected by it.

The model fit and change in childlessness were sensitive to homophily and the role of parental status in determining such similarity amongst agents. While the optimal value of the homophily parameter found here is substantially larger than that observed by Aparicio Diaz et al. (2011), the explanation for this might be that parental status, beyond age and education, was considered as a determinant for the social distances computed in the ABSM developed here. A higher importance of parental status as a determinant for similarity in terms of choosing social network members resulted in both better model fit and higher levels and growth of childlessness. These results imply that parental status is, besides age and to a smaller extent education, an important characteristic in choosing other social network members, whom then in turn influence one's childbearing outcomes. This notion of endogenous social network formation has also been observed in other studies of social influences on childbearing (e.g. Aparicio Diaz et al., 2011; Balbo and Barban, 2014; Mönkediek and Bras, 2016), although not necessarily based on parental status but rather age and education. Other studies, yet, have not found any evidence for such selection of individuals with certain childbearing intentions into particular social networks (Lois, 2016). Nevertheless, Lois (2016) only considered a time span of two years, in which they did observe childless individuals more often transferring to the so-called 'polarised' social networks which do not foster childbearing. Therefore, endogeneity of social network formation based on a variety of characteristics, including age and parental status, should be taken into account in future similar quantitative analyses to provide unbiased estimates of social network effects on childbearing. Additionally, perhaps future analyses of the selection of social network members and its consequent impact on childbearing intentions and behaviour could shed more light on the actual mechanisms at play in endogenous social network formation. For example, do individuals tend to choose social network members of similar parental status because this makes them feel more conform, or perhaps because these social network members can better provide them with different forms of support as a consequence of being in a similar situation (Bernardi and Klärner, 2014)? Simulation-based methods similar to the one developed in this work could provide helpful in answering such questions.

The model developed in this study has some limitations that need to be considered. First, as male agents have been excluded from the ABSM, I have not been able to assess the influence of structural and compositional social network characteristics on male childlessness, and therefore neither gender differences nor couple-level dynamics herein. The main reason for this is that historical and age- and parity-specific fertility and childlessness data are not as extensively available for men as they are for women, which made this endeavour practically impossible. Nevertheless, related studies have shown that most often the decision (not) to have children is taken jointly by both partners in a couple; and that their individual circumstances, desires and intentions interact in influencing this decision (Berrington, 2004;

McAllister and Clarke, 2000; Rijken, 2009). Furthermore, men and women tend to experience social network influences differently, with women experiencing more influence from their siblings for instance (Buyukkececi et al., 2020). Therefore, future research should aim to collect and analyse data for social network influences on childbearing of males as well.

Second, this chapter has assessed the role of structural and compositional social network characteristics on the increasing prevalence of childlessness. However, this is not to say that these mechanisms are the only ones at play in influencing childlessness, which also shows from the limited variation in childlessness change explained by the model parameters. There might be many other relevant mechanisms or phenomena important in this process, such as the diffusion of the contraceptive pill or the increased educational attainment of women in particular (e.g. Sobotka, 2017). Although this is important to recognise, it is simultaneously important to note that the goal of ABSMs is not necessarily to identify some mechanism as *the* mechanism only because it yields emerging patterns like those observed in reality, but rather to identify potential mechanisms for a phenomenon and thereby advance theory (Bruch and Atwell, 2015; Grow and van Bavel, 2017). This work has focused on doing the latter.

Third, the ABSM developed here does not incorporate any spatial elements, but rather includes social distances and variation over time. Nevertheless, (the strength of) social influence might be larger amongst agents in closer physical proximity of one another (Nomes et al., 2019). While technological advancements may have improved communication over larger physical distances over the past decades (Mok et al., 2007), these developments might not have been as relevant for the birth cohorts considered here. Most similar studies of ABSMs and fertility have neither considered physical distances (e.g. Aparicio Diaz et al., 2011; Berndt et al., 2018; Kashyap and Villavicencio, 2016), albeit with some exceptions (e.g. Billari et al., 2007; González-Bailón and Murphy, 2013; Nomes et al., 2019). Therefore, an interesting possible extension of this study would be to incorporate these and examine the role of micro-level physical proximity, and macro-level globalisation more broadly, on trends in childlessness.

Fourth, social networks have been shown to change across the life course, particularly with certain transitions such as entering college, marriage, parenthood, employment or retirement (e.g. Cornwell et al., 2014; Hartl et al., 2015; Moody et al., 2011; Wellman et al., 1997). The current model does not perfectly accurately reflect how social networks may more abruptly change as a result of certain life course transitions, nor how this might have changed across birth cohorts. For example, college education, and therefore the network turnover resulting from that experience, might be more common amongst younger birth cohorts. Nevertheless, agents in the model delete current friendships and make new ones according to smoothed empirical turnover rates, and individuals' more general social network type tends to remain stable over time regardless (Lois, 2016). Future research could perhaps more closely examine the changes in social networks, social influence mechanisms, and endogeneity of social network formation across the

life course. For instance, Aparicio Diaz et al. (2011) concluded that this endogeneity accounted for a fertility decline amongst individuals of younger ages and a fertility increase amongst older individuals. Similarly, social support may be more important for younger potential parents, whereas social pressure seems to play a larger role for individuals closer towards reaching the end of the reproductive period, resulting in ‘homogenising’ networks as individuals age (Berndt et al., 2018). Researching and accounting for such social network dynamics across the life course may help enhance our understanding of social network influences on childbearing determinants, particularly in the context of fertility postponement and ageing populations.

Notwithstanding these limitations, this study examined the role of structural and compositional social network characteristics on the increasing prevalence of childlessness amongst Dutch women born between 1935 and 1965, and provides evidence for the emergence of macro-level childlessness patterns from micro-level childbearing decisions via meso-level social network influences. In addition to the vast amount of qualitative studies, this study has taken a first step towards a quantitative analysis of structural and compositional characteristics of social networks and their role in individual-level childbearing decisions and macro-level fertility patterns. Not only have I provided preliminary quantitative evidence for qualitative hypotheses about social network influences; with this analysis I have also identified a number of areas for future research to explore. Furthermore, this analysis provides additional support for the increased notion that social network influences should be considered in theories and analyses of fertility. However, in the absence of relevant large-scale data, there still are many unresolved issues and unanswered questions when it comes to social networks, fertility and childlessness. This study highlights the relevance for future endeavours to collect such data or turn to newer ‘digital trace’ and social media data sources instead, particularly when it comes to the strength of social influence across educational groups as well as endogenous social network formation. Alternatively, this study at the same time demonstrates how ABSMs provide a valuable tool to overcome these data limitations.

An open question that remains is how childlessness levels will develop further in the future. On the one hand, we might expect childlessness to continue increasing because societies are becoming increasingly progressive and individualistic (Lesthaeghe, 2007, 2010; Lesthaeghe and van de Kaa, 1986), with childlessness more often being a voluntary choice. On the other hand, with more and more governments taking policy measures to increase fertility, for example through increased work-family support or parenting benefits (United Nations Population Division, 2017), we might instead expect a decrease in childlessness over the next years. In any case, with the rapid uptake of social media platforms, which allow individuals to easily seek like-minded potential friends, clusters of social networks might become increasingly homogeneous, dense and centralised (Himmelboim et al., 2017). Given that homogeneity and density generally tend to influence the extent to which norms are abided to, this may result in a strong

endorsement of childbearing in networks in which most members have children, and a strong encouragement of childlessness in networks where remaining childless is the norm. In this case, we might not expect some universal convergence of childlessness across groups within society, but rather some substantial polarisation in childbearing behaviour between these groups. A valuable avenue for further research would be to use the proposed ABSM to forecast future levels of childlessness amongst different groups in society to shed more light on these questions.

Table 4.4: Regression coefficients and ANOVA estimates for the RMM estimating the ABSM fit (RMSE)

Parameter	Dependent variable: Model fit (RMSE)					
	Linear Regression			ANOVA		
	Coef.	Std. Err.	P-value	F	P-value	% Var. Expl.
Intercept	13.905	0.028	0.000			
β	-2.440	0.520	0.000	40.672	0.000	0.128
ρ_p	0.634	0.408	0.120	9771.971	0.000	30.766
ζ	-1.804	0.505	0.000	810.627	0.000	2.552
θ_p	1.340	0.490	0.006	127.958	0.000	0.403
β^2	2.461	0.830	0.003	28.685	0.000	0.090
$\beta * \rho_p$	-0.749	0.442	0.091	151.444	0.000	0.477
$\beta * \rho_s$	-0.472	0.344	0.170	13081.892	0.000	41.187
$\beta * \zeta$	3.408	0.529	0.000	49.241	0.000	0.155
$\beta * \theta_p$	1.476	0.461	0.001	3.079	0.079	0.010
$\gamma * \rho_p$	-1.035	0.242	0.000	1.233	0.267	0.004
$\gamma * \rho_s$	0.459	0.195	0.018	1018.102	0.000	3.205
$\gamma * \rho_t$	0.480	0.129	0.000	8.845	0.003	0.028
$\gamma * \theta_e$	-0.408	0.156	0.009	85.287	0.000	0.269
ρ_p^2	2.457	0.765	0.001	938.274	0.000	2.954
$\rho_p * \zeta$	0.958	0.333	0.004	14.717	0.000	0.046
ρ_s^2	1.535	0.483	0.002	2653.694	0.000	8.355
$\rho_s * \rho_t$	1.348	0.219	0.000	50.991	0.000	0.161
$\rho_s * \zeta$	2.394	0.339	0.000	236.946	0.000	0.746
$\rho_s * \theta_p$	1.570	0.409	0.000	1.163	0.281	0.004
$\rho_t * \theta_p$	-0.444	0.118	0.000	0.125	0.724	0.000
ζ^2	2.170	0.478	0.000	224.138	0.000	0.706
$\zeta * \theta_p$	-0.383	0.501	0.445	27.245	0.000	0.086
$\theta_p * \theta_p$	-2.767	0.817	0.001	15.972	0.000	0.050
β^3	-0.607	0.445	0.173	0.017	0.896	0.000
$\beta^2 * \rho_p$	0.463	0.261	0.076	10.153	0.001	0.032
$\beta^2 * \zeta$	-1.097	0.283	0.000	28.678	0.000	0.090
$\beta^2 * \theta_p$	-0.298	0.284	0.294	0.103	0.749	0.000
$\beta * \gamma^2$	-0.650	0.148	0.000	29.844	0.000	0.094
$\beta * \gamma * \rho_s$	-0.545	0.171	0.001	21.985	0.000	0.069
$\beta * \gamma * \zeta$	0.905	0.167	0.000	0.182	0.670	0.001
$\beta * \rho_p^2$	-0.369	0.261	0.157	0.005	0.943	0.000
$\beta * \rho_p * \zeta$	0.733	0.170	0.000	6.071	0.014	0.019
$\beta * \rho_s^2$	1.114	0.271	0.000	15.064	0.000	0.047
$\rho_s * \zeta$	0.487	0.175	0.005	3.700	0.055	0.012
$\beta * \rho_s * \theta_p$	-0.632	0.205	0.002	24.373	0.000	0.077
$\beta * \zeta^2$	-2.753	0.281	0.000	101.539	0.000	0.320
$\beta * \theta_p^2$	-0.490	0.300	0.103	2.527	0.112	0.008
γ^3	1.093	0.185	0.000	6.709	0.010	0.021
$\gamma^2 * \rho_p$	0.545	0.221	0.014	8.259	0.004	0.026
$\gamma^2 * \zeta$	-1.429	0.199	0.000	72.883	0.000	0.229
$\gamma^2 * \theta_p$	-0.737	0.171	0.000	10.207	0.001	0.032
$\gamma^2 * \theta_p$	0.482	0.186	0.010	9.114	0.003	0.029
$\gamma * \rho_s * \rho_p$	0.368	0.155	0.018	98.526	0.000	0.310
$\gamma * \rho_s * \rho_t$	-0.513	0.136	0.000	17.766	0.000	0.056
$\gamma * \rho_t * \zeta$	-0.346	0.122	0.004	0.253	0.615	0.001
$\gamma * \zeta^2$	0.931	0.212	0.000	13.705	0.000	0.043
$\gamma * \theta_p^2$	0.481	0.169	0.005	3.898	0.049	0.012
ρ_p^3	0.963	0.453	0.034	1.289	0.256	0.004
$\rho_p^2 * \rho_s$	-1.234	0.122	0.000	91.055	0.000	0.287
$\rho_p * \zeta^2$	-1.013	0.266	0.000	11.921	0.001	0.038
ρ_s^3	0.654	0.388	0.092	0.391	0.532	0.001
$\rho_s^2 * \rho_t$	-0.757	0.221	0.001	14.879	0.000	0.047
$\rho_s^2 * \theta_p$	-0.442	0.272	0.105	5.978	0.015	0.019
$\rho_s * \zeta^2$	-1.633	0.277	0.000	36.705	0.000	0.116
$\rho_s * \theta_p^2$	-0.472	0.280	0.092	1.377	0.241	0.004
$\rho_t * \zeta * \theta_p$	0.368	0.124	0.003	9.603	0.002	0.030
$\zeta^2 * \theta_p$	-0.730	0.284	0.010	7.700	0.006	0.024
$\zeta * \theta_p^2$	0.624	0.283	0.028	4.170	0.041	0.013
θ_p^3	1.330	0.446	0.003	8.884	0.003	0.028
Residual						5.478
Observations		8,192				
R ²		0.945				
Adj. R ²		0.943				
AIC		5,742				
BIC		6,072				

Note: γ = Density; ζ = Share of kin; β = Homophily; θ_p = Distance weight (parental status); θ_e = Distance weight (education); ρ_p = Influence strength (no/primary education); ρ_s = Influence strength (secondary education); ρ_t = Influence strength (tertiary education)

Table 4.5: Regression coefficients and ANOVA estimates for the RMM estimating the change in childlessness between the 1935 and 1965 birth cohorts

Parameter	<i>Dependent variable: Childlessness change (1935-1965 birth cohorts)</i>					
	Linear Regression			ANOVA		
	Coef.	Std. Err.	P-value	F	P-value	% Var. Expl.
Intercept	5.064	0.217	0.000			
γ	-7.097	2.681	0.008	0.084	0.772	0.003
ρ_p	-7.410	0.220	0.000	1156.625	0.000	35.180
$\beta * \gamma$	-4.288	1.666	0.010	0.477	0.490	0.015
$\beta * \rho_s$	6.568	1.471	0.000	625.476	0.000	19.025
$\beta * \zeta$	-4.724	1.442	0.001	3.044	0.081	0.093
γ^2	10.068	5.360	0.061	0.061	0.804	0.002
$\gamma * \rho_s$	6.857	1.674	0.000	60.250	0.000	1.833
$\gamma * \zeta$	4.255	1.602	0.008	1.601	0.206	0.049
$\beta^2 * \gamma$	3.997	1.447	0.006	0.019	0.890	0.001
$\beta^2 * \rho_s$	-4.945	1.374	0.000	29.160	0.000	0.887
$\beta * \zeta^2$	4.472	1.337	0.001	5.284	0.022	0.161
γ^3	-3.670	3.256	0.260	0.809	0.369	0.025
$\gamma^2 * \rho_s$	-5.220	1.616	0.001	12.360	0.000	0.376
$\gamma * \zeta^2$	-3.889	1.432	0.007	7.378	0.007	0.224
Residual						42.129
Observations		8,192				
R ²		0.579				
Adj. R ²		0.578				
AIC		5.609·10 ⁴				
BIC		5.615·10 ⁴				

Note: γ = Density; ζ = Share of kin; β = Homophily; θ_p = Distance weight (parental status); θ_e = Distance weight (education); ρ_p = Influence strength (no/primary education); ρ_s = Influence strength (secondary education); ρ_t = Influence strength (tertiary education)

References

- Abbott, A. (2005). Process and Temporality in Sociology: The Idea of Outcome in U.S. Sociology. In Steinmetz, G., editor, *The Politics of Method in the Human Sciences: Positivism and Its Epistemological Others*, pages 393–426. Durham, NC: Duke University Press.
- Angione, C., Silverman, E., and Yaneske, E. (2020). Using Machine Learning to Emulate Agent-Based Simulations. arXiv preprint: 2005.02077.
- Aparicio Diaz, B., Fent, T., Prskawetz, A., and Bernardi, L. (2011). Transition to parenthood: The role of social interaction and endogenous networks. *Demography*, 48(2):559–579.
- Asch, S. E. (1955). Opinions and social pressure. *Scientific American*, 193(5):31–35.
- Axinn, W. G., Clarkberg, M. E., and Thornton, A. (1994). Family influences on family size preferences. *Demography*, 31(1):65–79.
- Balbo, N. and Barban, N. (2014). Does fertility behavior spread among friends? *American Sociological Review*, 79(3):412–431.
- Balbo, N., Billari, F. C., and Mills, M. (2013). Fertility in advanced societies: A review of research. *European Journal of Population*, 29(1):1–38.
- Bandura, A. (1962). *Social learning through imitation*. Lincoln, NE: University of Nebraska Press.
- Barthold, J. A., Myrskylä, M., and Jones, O. R. (2012). Childlessness drives the sex difference in the association between income and reproductive success of modern Europeans. *Evolution and Human Behavior*, 33(6):628–638.
- Beck, U. (1986). *Risikogesellschaft. Auf dem Weg in eine andere Moderne*. Frankfurt am Main, Deutschland: Suhrkamp.
- Beck, U. (1995). Eigenes Leben. Skizzen einer biographischen Gesellschaftsanalyse. In Beck, U., Vossenkühl, W., and Ziegler, U., editors, *Eigenes Leben. Ausflüge in die unbekannte Gesellschaft, in der wir leben*, pages 9–174. München, Deutschland: C.H. Beck.
- Belot, M. (2008). Gender differences in close friendship networks over the life cycle. In Brynin, M. and Ermisch, J., editors, *Changing Relationships*, pages 44–58. Routledge.
- Bergstra, J., Yamins, D., and Cox, D. (2013). Making a science of model search: Hyperparameter optimization in hundreds of dimensions for vision architectures. In *International Conference on Machine Learning*, pages 115–123. PMLR.
- Bernardi, L. (2003). Channels of social influence on reproduction. *Population Research and Policy Review*, 22(5):427–555.
- Bernardi, L. and Klärner, A. (2014). Social networks and fertility. *Demographic Research*, 30:641–670.
- Bernardi, L., Klärner, A., and Von der Lippe, H. (2008). Job insecurity and the timing of parenthood: A comparison between Eastern and Western Germany. *European Journal of Population/Revue Européenne de Démographie*, 24(3):287–313.
- Berndt, J. O., Rodermund, S. C., and Timm, I. J. (2018). Social contagion of fertility: an agent-based simulation study. In *2018 Winter Simulation Conference (WSC)*, pages 953–964. IEEE.
- Berrington, A. (2004). Perpetual postponers? women’s, men’s and couple’s fertility intentions and subsequent fertility behaviour. *Population Trends*, 117:9–19.
- Berrington, A. (2017). Childlessness in the UK. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 57–76. Springer.
- Billari, F. C. (2015). Integrating macro-and micro-level approaches in the explanation of population change. *Population Studies*, 69(sup1):S11–S20.
- Billari, F. C., Ongaro, F., and Prskawetz, A. (2003a). Introduction: Agent-based computational demography. In Billari, F. C. and Prskawetz, A., editors, *Agent-based Computational Demography*, pages 1–17. Springer.
- Billari, F. C., Prskawetz, A., Aparicio Diaz, B., and Fent, T. (2007). The “wedding-ring” an agent-based marriage model based on social interaction. *Demographic Research*, 17:59–82.
- Billari, F. C., Prskawetz, A., and Fürnkranz, J. (2003b). On the cultural evolution of age-at-marriage norms. In Billari, F. C. and Prskawetz, A., editors, *Agent-based Computational Demography*, pages 139–157. Springer.
- Boivin, J., Buntin, L., and Kalebic, N. (2018). What makes people ready to conceive? Findings from the International Fertility Decision-Making Study. *Reproductive Biomedicine & Society Online*, 6:90–101.
- Bongaarts, J. and Watkins, S. C. (1996). Social interactions and contemporary fertility transitions. *Population and Development Review*, 22(4):639–682.

- Bott, E. (1957). *Family and social network. Roles, norms, and external relationships in ordinary urban families*. London, United Kingdom: Tavistock Publications.
- Bourdieu, P. and Richardson, J. G. (1986). Handbook of theory and research for the sociology of education. In Richardson, J., editor, *The Forms of Capital*, pages 241–258. New York, NY: Greenwood.
- Bras, H. (2014). Structural and diffusion effects in the Dutch fertility transition, 1870–1940. *Demographic Research*, 30:151–186.
- Bras, H. and Van Tilburg, T. (2007). Kinship and social networks: A regional analysis of sibling relations in twentieth-century Netherlands. *Journal of Family History*, 32(3):296–322.
- Breiman, L. (2001). Random forests. *Machine Learning*, 45(1):5–32.
- Bruch, E. and Atwell, J. (2015). Agent-based models in empirical social research. *Sociological Methods & Research*, 44(2):186–221.
- Bühler, C. and Kohler, H.-P. (2004). Der Einfluss starker Beziehungen auf die Nutzung moderner Kontrazeptiva in Kenia/the influence of strong ties on the use of modern contraceptives in Kenya. *Zeitschrift für Soziologie*, 33(1):5–25.
- Burhenne, S., Jacob, D., and Henze, G. P. (2011). Sampling based on Sobol’ sequences for Monte Carlo techniques applied to building simulations. In *Proc. Int. Conf. Build. Simulat.*, pages 1816–1823.
- Burke, M. A. and Heiland, F. (2006). The strength of social interactions and obesity among women. In Billari, F., Fent, T., Prskawetz, A., and Scheffran, J., editors, *Agent-based computational modelling: Applications in demography, social, economic and environmental sciences*, pages 117–137. Heidelberg, Germany: Physica Verlag.
- Burt, R. S. (1982). *Toward a structural theory of action: Network models of social structure, perception, and action*. New York, NY: Academic Press.
- Burt, R. S. (1987). Social contagion and innovation: Cohesion versus structural equivalence. *American Journal of Sociology*, 92(6):1287–1335.
- Burt, R. S. and Janicik, G. A. (1996). Social contagion and social structure. In Iacobucci, D., editor, *Networks in Marketing*, pages 32–49. Sage Thousand Oaks, CA.
- Buyukkececi, Z., Leopold, T., van Gaalen, R., and Engelhardt, H. (2020). Family, Firms, and Fertility: A Study of Social Interaction Effects. *Demography*, 57:243–266.
- Casterline, J. B. (2001). Diffusion processes and fertility transition: Introduction. In on Population, N. R. C. U. C., editor, *Diffusion processes and fertility transition: Selected perspectives*. Washington, DC: The National Academies Press.
- Ciganda, D. and Villavicencio, F. (2017). Feedback mechanisms in the postponement of fertility in Spain. In Grow, A. and Van Bavel, J., editors, *Agent-Based Modelling in Population Studies*, pages 405–435. Springer.
- Cole, H. L., Mailath, G. J., and Postlewaite, A. (1998). Class systems and the enforcement of social norms. *Journal of Public Economics*, 70(1):5–35.
- Coleman, J. S. (1990). *Foundations of social theory*. Cambridge, MA: Belknap.
- Coleman, S., Katz, E., and Menzel, H. (1966). *Medical innovation: A diffusion study*. Indianapolis, IN: The Bobbs-Merrill Company.
- Cornwell, B., Schumm, L. P., Laumann, E. O., Kim, J., and Kim, Y.-J. (2014). Assessment of social network change in a national longitudinal survey. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 69(Suppl. 2):S75–S82.
- de Graaf, A. (2007). De vruchtbaarheid van vrouwen in de twintigste eeuw. In Boonstra, O. W. A., Doorn, P. K., van Horik, M. P. M., van Maarseveen, J. G. S. J., and Oudhof, J., editors, *Twee eeuwen Nederland geteld. Onderzoek met de digitale Volks-, Beroeps- en Woningtellingen 1795–2001*, pages 99–128. Symposium publicaties 2. DANS, Den Haag.
- Durlauf, S. N. and Walker, J. (2001). Social interactions and fertility transitions. In National Research Council (US) Committee on Population, editor, *Diffusion processes and fertility transition: Selected perspectives*. Washington, DC: The National Academies Press.
- Dykstra, P. A. (2009). Childless old age. In Uhlenberg, P., editor, *International Handbook of Population Aging*, pages 671–690. Springer.
- Elder Jr, G. H. (1998). The life course as developmental theory. *Child Development*, 69(1):1–12.
- Ettrich, C. and Ettrich, K. U. (1995). Die bedeutung sozialer netzwerke und erlebter sozialer unterstützung beim übergang zur elternschaft—Ergebnisse einer längsschnittstudie [The impact of social networks and social support on the transition to parenthood—Results of a longitudinal study]. *Psychologie in Erziehung und Unterricht*, 42:29–39.

- Fent, T., Groeber, P., and Schweitzer, F. (2007). Coexistence of social norms based on in-and out-group interactions. *Advances in Complex Systems*, 10(2):271–286.
- Festinger, L., Schachter, S., and Back, K. (1950). *Social pressures in informal groups; a study of human factors in housing*. Harper.
- Giele, J. and Elder Jr, G. (1998). *Methods of life course research: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications.
- Gilbert, N. (2008). *Agent-Based Models*. Sage Publications.
- González-Bailón, S. and Murphy, T. E. (2013). The effects of social interactions on fertility decline in nineteenth-century France: An agent-based simulation experiment. *Population Studies*, 67(2):135–155.
- Gower, J. C. (1971). A general coefficient of similarity and some of its properties. *Biometrics*, 27(4):857–871.
- Gramacy, R. B. (2020). *Surrogates: Gaussian process modeling, design, and optimization for the applied sciences*. CRC Press.
- Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology*, 78(6):1360–1380.
- Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., Goss-Custard, J., Grand, T., Heinz, S. K., Huse, G., Huth, A., JU, J., Jørgensen, C., Mooij, W., Muller, B., Pe'er, G., and Piou, C., Railsback, S., Robbins, A., MM, R., Rossmanith, E., R"uger, N., Strand, E., Souissi, S., Stillman, R., Vabø, R., Visser, U., and DeAngelis, D. (2006). A standard protocol for describing individual-based and agent-based models. *Ecological Modelling*, 198(1-2):115–126.
- Grimm, V., Berger, U., DeAngelis, D. L., Polhill, J. G., Giske, J., and Railsback, S. F. (2010). The ODD protocol: a review and first update. *Ecological modelling*, 221(23):2760–2768.
- Grimm, V., Railsback, S. F., Vincenot, C. E., Berger, U., Gallagher, C., DeAngelis, D. L., Edmonds, B., Ge, J., Giske, J., Groeneveld, J., Johnston, A., Milles, A., Nabe-Nielsen, J., Polhill, J., Radchuk, V., Rohwäder, M., Stillman, R., Thiele, J., and Ayllón, D. (2020). The ODD protocol for describing agent-based and other simulation models: A second update to improve clarity, replication, and structural realism. *Journal of Artificial Societies and Social Simulation*, 23(2):7.
- Grow, A. (2017). Regression metamodels for sensitivity analysis in agent-based computational demography. In Grow, A. and van Bavel, T. J., editors, *Agent-based modelling in population studies*, pages 185–210. Springer.
- Grow, A. and van Bavel, J. (2020). The Gender Cliff in the Relative Contribution to the Household Income: Insights from Modelling Marriage Markets in 27 European Countries. *European Journal of Population*, 36:1–23.
- Grow, A. and van Bavel, T. J. (2017). *Agent-Based Modelling in Population Studies*. Springer.
- Hanneman, R. A. and Riddle, M. (2005). *Introduction to social network methods*. Riverside, CA: University of California, Riverside.
- Hartl, A. C., Laursen, B., and Cillessen, A. H. (2015). A survival analysis of adolescent friendships: The downside of dissimilarity. *Psychological Science*, 26(8):1304–1315.
- Herman, J. and Usher, W. (2017). SALib: An open-source python library for sensitivity analysis. *The Journal of Open Source Software*, 2(9).
- Hilton, J. and Bijak, J. (2017). Design and analysis of demographic simulations. In Grow, A. and van Bavel, T. J., editors, *Agent-based Modelling in Population Studies*, pages 211–235. Springer.
- Himmelboim, I., Smith, M. A., Rainie, L., Shneiderman, B., and Espina, C. (2017). Classifying Twitter topic-networks using social network analysis. *Social Media + Society*, 3(1):1–13.
- Holland, J. H. and Miller, J. H. (1991). Artificial adaptive agents in economic theory. *The American Economic Review*, 81(2):365–370.
- Human Fertility Database (2020a). Netherlands age-specific fertility rates by birth order, year and age [Data set]. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Retrieved from: <https://www.humanfertility.org/cgi-bin/getfile.plx?f=NLD\20200929\NLDasfrRRbo.txt>.
- Human Fertility Database (2020b). Netherlands cohort fertility tables [Data set]. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Retrieved from: <https://www.humanfertility.org/cgi-bin/getfile.plx?f=NLD\20200929\NLDcft.txt>.
- Human Fertility Database (2020c). Netherlands total fertility rate [Data set]. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Retrieved from: <https://www.humanfertility.org/cgi-bin/getfile.plx?f=NLD\20200929\NLDtfrRR.txt>.

- Human Mortality Database (2020). Netherlands death rates [Data set]. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Retrieved from: https://www.mortality.org/hmd/NLD/STATS/Mx_1x1.txt.
- James, G., Witten, D., Hastie, T., and Tibshirani, R. (2013). *An introduction to statistical learning*. Springer.
- Kashyap, R. and Villavicencio, F. (2016). The dynamics of son preference, technology diffusion, and fertility decline underlying distorted sex ratios at birth: A simulation approach. *Demography*, 53(5):1261–1281.
- Kazil, J., Masad, D., and Crooks, A. (2020). Utilizing Python for Agent-Based Modeling: The Mesa Framework. In *International Conference on Social Computing, Behavioral-Cultural Modeling and Prediction and Behavior Representation in Modeling and Simulation*, pages 308–317. Springer.
- Keim, S. (2011). *Social networks and family formation processes*. Springer.
- Keizer, R. (2010). *Remaining childless: Causes and consequences from a life course perspective*. PhD thesis, Utrecht University.
- Keizer, R., Dykstra, P. A., and Poortman, A.-R. (2009). Life outcomes of childless men and fathers. *European Sociological Review*, 26(1):1–15.
- Klärner, A., Keim, S., and von der Lippe, H. (2016). Social network dynamics in the course of family formation: Results from a mixed-methods longitudinal study. *International Review of Social Research*, 6(4):245–255.
- Klüsener, S., Dribe, M., and Scalone, F. (2019). Spatial and social distance at the onset of the fertility transition: Sweden, 1880–1900. *Demography*, 56(1):169–199.
- Kohler, H.-P. (2000). Social interactions and fluctuations in birth rates. *Population Studies*, 54(2):223–237.
- Kohler, H.-P. (2001). *Fertility and social interaction: An economic perspective*. Oxford, United Kingdom: Oxford University Press.
- Kohler, H.-P., Behrman, J. R., and Watkins, S. C. (2001). The density of social networks and fertility decisions: Evidence from South Nyanza District, Kenya. *Demography*, 38(1):43–58.
- Kohler, H.-P., Billari, F. C., and Ortega, J. A. (2002). The emergence of lowest-low fertility in Europe during the 1990s. *Population and Development Review*, 28(4):641–680.
- Kohler, H.-P., Billari, F. C., and Ortega, J. A. (2006). Low fertility in Europe: Causes, implications and policy options. In Harris, F., editor, *The Baby Bust: Who will do the Work? Who Will Pay the Taxes?*, pages 48–109. Lanham, MD: Rowman & Littlefield Publishers.
- Kohler, H.-P. and Bühler, C. (2001). Social networks and fertility. In Smelser, N. and Baltes, P., editors, *International Encyclopedia of the Social & Behavioral Sciences*, pages 14380–14384. Oxford, United Kingdom: Pergamon/Elsevier Sciences.
- Kotte, M. and Ludwig, V. (2011). Intergenerational transmission of fertility intentions and behaviour in Germany: The role of contagion. *Vienna Yearbook of Population Research*, 9:207–226.
- Kreyenfeld, M. and Konietzka, D. (2017). *Childlessness in Europe: Contexts, Causes, and Consequences*. Springer.
- Kucherenko, S., Albrecht, D., and Saltelli, A. (2015). Exploring multi-dimensional spaces: a Comparison of Latin Hypercube and Quasi Monte Carlo Sampling Techniques.
- Lamperti, F., Roventini, A., and Sani, A. (2018). Agent-based model calibration using machine learning surrogates. *Journal of Economic Dynamics and Control*, 90:366–389.
- Latten, J. and van Dijk, W. (2007). Jonge vrouwen hoger opgeleid dan mannen. Statistics Netherlands. Retrieved from: <https://www.cbs.nl/nl-nl/nieuws/2007/10/jonge-vrouwen-hoger-opgeleid-dan-mannen>.
- Lee, J.-W. and Lee, H. (2016). Human capital in the long run. *Journal of Development Economics*, 122:147–169.
- Lesthaeghe, R. J. (2007). *Second demographic transition*. Wiley Online Library.
- Lesthaeghe, R. J. (2010). The unfolding story of the second demographic transition. *Population and Development Review*, 36(2):211–251.
- Lesthaeghe, R. J. and van de Kaa, D. J. (1986). Twee demografische transitie. *Bevolking: Groei en Krimp*, pages 9–24.
- Li, G., Rabitz, H., Yelvington, P. E., Oluwole, O. O., Bacon, F., Kolb, C. E., and Schoendorf, J. (2010). Global sensitivity analysis for systems with independent and/or correlated inputs. *The Journal of Physical Chemistry A*, 114(19):6022–6032.

- Ligmann-Zielinska, A., Kramer, D. B., Cheruvelil, K. S., and Soranno, P. A. (2014). Using uncertainty and sensitivity analyses in socioecological agent-based models to improve their analytical performance and policy relevance. *PLoS One*, 9(10):e109779.
- Lin, N. (1999). Social networks and status attainment. *Annual Review of Sociology*, 25(1):467–487.
- Lois, D. (2016). Types of social networks and the transition to parenthood. *Demographic Research*, 34:657–688.
- Lois, D. and Becker, O. A. (2014). Is fertility contagious? Using panel data to disentangle mechanisms of social network influences on fertility decisions. *Advances in Life Course Research*, 21:123–134.
- Lyngstad, T. H. and Prskawetz, A. (2010). Do siblings' fertility decisions influence each other? *Demography*, 47(4):923–934.
- Mayer, K. U. (2009). New directions in life course research. *Annual Review of Sociology*, 35:413–433.
- McAllister, F. and Clarke, L. (2000). Voluntary childlessness: Trends and implications. In Bentley, G. R. & Mascie-Taylor, C. G., editor, *Infertility in the modern world. Present and future prospects*, pages 189–237. Cambridge, United Kingdom: Cambridge University Press.
- Merz, E.-M. and Liefbroer, A. C. (2012). The attitude toward voluntary childlessness in Europe: Cultural and institutional explanations. *Journal of Marriage and Family*, 74(3):587–600.
- Miettinen, A., Rotkirch, A., Szalma, I., Donno, A., and Tanturri, M.-L. (2015). Increasing childlessness in Europe: Time trends and country differences. *Families and Societies: Working Paper Series*, 33.
- Miller, N. E. and Dollard, J. (1941). *Social learning and imitation*. New Haven, CT: Yale University Press.
- Mok, D., Wellman, B., and Basu, R. (2007). Did distance matter before the Internet?: Interpersonal contact and support in the 1970s. *Social Networks*, 29(3):430–461.
- Mönkediek, B. and Bras, H. A. (2016). The interplay of family systems, social networks and fertility in Europe cohorts born between 1920 and 1960. *Economic History of Developing Regions*, 31(1):136–166.
- Montgomery, M. R. and Casterline, J. B. (1996). Social learning, social influence, and new models of fertility. *Population and Development Review*, 22:151–175.
- Moody, J., Brynildsen, W. D., Osgood, D. W., Feinberg, M. E., and Gest, S. (2011). Popularity trajectories and substance use in early adolescence. *Social Networks*, 33(2):101–112.
- Murphy, M. (2011). Long-term effects of the demographic transition on family and kinship networks in Britain. *Population and Development Review*, 37:55–80.
- Myrskylä, M. and Goldstein, J. R. (2013). Probabilistic forecasting using stochastic diffusion models, with applications to cohort processes of marriage and fertility. *Demography*, 50(1):237–260.
- Neyer, G., Hoem, J. M., and Andersson, G. (2017). Education and Childlessness: The Influence of Educational Field and Educational Level on Childlessness among Swedish and Austrian Women. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 183–207. Springer.
- Nomes, E., Grow, A., and van Bavel, J. (2019). The mid-twentieth century baby boom and the role of social influence. an agent-based modelling approach. *Historical Life Course Studies*, 8:1–26.
- Noordhuizen, S., de Graaf, P. M., and Sieben, I. (2011). Explaining fertility norms in the Netherlands: The influence of sociodemographics, family networks, and life course events on pronatalism. *Journal of Family Issues*, 32(12):1647–1673.
- O'Neill, A. (2020). Total fertility rate of the Netherlands from 1840 to 2020 [Data set]. Statista. Retrieved from: <https://www.statista.com/statistics/1033478/fertility-rate-netherlands-1840-2020/>.
- Oppenheimer, V. K. (1994). Women's rising employment and the future of the family in industrial societies. *Population and Development Review*, 20(2):293–342.
- Page, S. E. (2008). Uncertainty, difficulty, and complexity. *Journal of Theoretical Politics*, 20(2):115–149.
- Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., Blondel, M., Prettenhofer, P., Weiss, R., Dubourg, V., Vanderplas, J., Passos, A., Cournapeau, D., Brucher, M., Perrot, M., and Duchesnay, E. (2011). Scikit-learn: Machine learning in Python. *Journal of Machine Learning Research*, 12:2825–2830.
- Pietzsch, B., Fiedler, S., Mertens, K. G., Richter, M., Scherer, C., Widyastuti, K., Wimmmler, M.-C., Zakharova, L., and Berger, U. (2020). Metamodels for evaluating, calibrating and applying agent-based models: A review. *Journal of Artificial Societies and Social Simulation*, 23(2).

- Pink, S., Leopold, T., and Engelhardt, H. (2014). Fertility and social interaction at the workplace: Does childbearing spread among colleagues? *Advances in Life Course Research*, 21:113–122.
- Portes, A. (1998). Social capital: Its origins and applications in modern sociology. *Annual Review of Sociology*, 24(1):1–24.
- Power, T. G. and Parke, R. D. (1984). Social network factors and the transition to parenthood. *Sex Roles*, 10(11-12):949–972.
- Richter, N., Lois, D., Arránz Becker, O., and Kopp, J. (2012). Mechanismen des Netzwerkeinflusses auf Fertilitätsentscheidungen in Ost- und West-Deutschland [Mechanisms of social network influences on fertility decisions in East and West Germany]. In Huinink, J., Kreyenfeld, M., and Trappe, H., editors, *Special Issue 2012 of Journal of Family Research-Zeitschrift für Familienforschung*, pages 95–118. Verlag Barbara Budrich.
- Rijken, A. J. (2009). *Happy families, high fertility? Childbearing choices in the context of family and partner relationships*. PhD thesis, Utrecht University.
- Rogers, E. (2003). *The Diffusion of Innovations*. New York, NY: Free Press.
- Rossier, C. and Bernardi, L. (2009). Social interaction effects on fertility: Intentions and behaviors. *European Journal of Population/Revue européenne de Démographie*, 25(4):467–485.
- Rotkirch, A. and Miettinen, A. (2017). Childlessness in Finland. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 139–158. Springer.
- Rowland, D. T. (2007). Historical trends in childlessness. *Journal of Family Issues*, 28(10):1311–1337.
- Rözer, J. J., Poortman, A.-R., and Mollenhorst, G. (2017). The timing of parenthood and its effect on social contact and support. *Demographic Research*, 36:1889–1916.
- Saltelli, A. (2002). Making best use of model evaluations to compute sensitivity indices. *Computer Physics Communications*, 145(2):280–297.
- Saltelli, A., Annoni, P., Azzini, I., Campolongo, F., Ratto, M., and Tarantola, S. (2010). Variance based sensitivity analysis of model output: Design and estimator for the total sensitivity index. *Computer Physics Communications*, 181(2):259–270.
- Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M., and Tarantola, S. (2008). *Global sensitivity analysis: the primer*. John Wiley & Sons.
- Santner, T. J., Williams, B. J., Notz, W. I., and Williams, B. J. (2003). *The design and analysis of computer experiments*, volume 1. Springer.
- Sobol, I. (1993). Sensitivity estimates for nonlinear mathematical models. *Mathematical Modelling and Computational Experiments*, 1(4):407–414.
- Sobol, I. M. (2001). Global sensitivity indices for nonlinear mathematical models and their Monte Carlo estimates. *Mathematics and Computers in Simulation*, 55(1-3):271–280.
- Sobotka, T. (2017). Childlessness in Europe: Reconstructing long-term trends among women born in 1900–1972. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 17–53. Springer.
- Sobotka, T. (2020). Introduction: the relevance of studying fertility across time and space. *Vienna Yearbook of Population Research*, 18:1–24.
- Statistics Netherlands (1899). Volkstelling 1899: RY - Vierde gedeelte: indeeling der werkelijke bevolking naar den leeftijd en den burgerlijken staat [Data set]. Retrieved from: http://www.volkstellingen.nl/web/excel/VT_1899_12_H4.xls.
- Statistics Netherlands (2012). Kerncijfers vruchtbaarheid gebruikt in de bevolkingsprognose, 1935-2020 [Data set]. Retrieved from: <https://opendata.cbs.nl/#/CBS/nl/dataset/80753ned/table?dl=4BE1B>.
- Statistics Netherlands (2020). Geboorte kerncijfers, levend geboren kinderen naar geslacht [Data set]. Retrieved from: <https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37422ned/table?dl=3EE75>.
- Surkyn, J. and Lesthaeghe, R. (2004). Value orientations and the second demographic transition (SDT) in Northern, Western and Southern Europe: An update. *Demographic Research*, 3:45–86.
- Tanturri, M. L., Mills, M., Rotkirch, A., Sobotka, T., Takács, J., Miettinen, A., Faludi, C., Kantsa, V., and Nasiri, D. (2015). State-of-the-art report: Childlessness in Europe. *Families and Societies*, 32:1–53.
- Ten Broeke, G., Van Voorn, G., and Ligtenberg, A. (2016). Which sensitivity analysis method should i use for my agent-based model? *Journal of Artificial Societies and Social Simulation*, 19(1):5.
- United Nations Population Division (2017). Government policies to raise or lower the fertility level. Retrieved from: https://www.un.org/en/development/desa/population/publications/pdf/popfacts/PopFacts_2017-10.pdf.

- van Bavel, J. and Kok, J. (2010). Pioneers of the modern lifestyle?: Childless couples in the early-twentieth-century Netherlands. *Social Science History*, 34(1):47–72.
- van de Kaa, D. J. (1997). Options and sequences: Europe's demographic patterns. *Journal of Population Research*, 14(1):1–29.
- van de Kaa, D. J. (2001). Postmodern fertility preferences: From changing value orientation to new behavior. *Population and Development Review*, 27:290–331.
- Wagner, J., Wrzus, C., Neyer, F. J., and Lang, F. R. (2015). Social network characteristics of early midlife voluntarily and involuntarily childless couples. *Journal of Family Issues*, 36(1):87–110.
- Wellman, B. (1979). The community question: The intimate networks of East Yorkers. *American Journal of Sociology*, 84(5):1201–1231.
- Wellman, B., Wong, R. Y.-I., Tindall, D., and Nazer, N. (1997). A decade of network change: Turnover, persistence and stability in personal communities. *Social Networks*, 19(1):27–50.
- Wilensky, U. and Rand, W. (2015). *An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo*. Cambridge, MA: MIT Press.
- Willekens, F. (2017). The decision to emigrate: a simulation model based on the theory of planned behaviour. In Grow, A. and van Bavel, T. J., editors, *Agent-based Modelling in Population Studies*, pages 257–299. Springer.

Appendices

Appendix 4.A Pseudo-code for ABSM

Algorithm 1 summarises the high-level pseudo-code for the ABSM.

Algorithm 1: Process overview of agent-based simulation model

```

1   $year_{current} = 1900$ ;
2   $cohort_{target} = year_{current} - age_{max}$ ;
3  Initialisation;
4  for  $t \leftarrow year_{start}$  to  $(year_{end} + age_{max})$  do
5      obtain this year's empirical death probabilities for all agents, remove agents who will die from
        scheduler and update all agents' familial and peer networks accordingly;
6      calculate the desired peer network size  $pns_d$  on the basis of preset share of kin  $\zeta$  and family
        network size  $fns$  (Equation 4.1), or approximate for first- and second-generation agents;
7      obtain this year's empirical birth probabilities for female agents aged between  $age_{min}$  and
         $age_{max}$  and save in  $p_{birth}$  for each of these agents;
8      obtain this year's empirical sex ratio at birth and save in model variable  $srbh$ ;
9      calculate proportion of parents in the population by age (group), taking into account the ages
        of their youngest child, and save in model variable  $\Pi^*$  (Equations 4.13 and 4.15);
10     calculate Gower distances between agents based on their age, education and childlessness
        status and save in model variable  $\Delta$ ;
11     for agent  $i \leftarrow 1$  to  $N$  do
12          $hbt_i = \text{False}$ ;
13         for agent's child  $j \leftarrow 1$  to  $C$  do
14              $ca_j + 1$ ;
15         end
16         if  $age_i \geq age_{min}$  then
17             if  $(pns_a)_i > 0$  and  $(pns_a)_i \geq (pns_d)_i$  then
18                 decide whether a friend will be deleted from the agent's peer network based on
                    empirical age-specific network turnover rates;
19                 if friend will be deleted then
20                     delete friend according to preset density  $\gamma$  and homophily  $\beta$ ;
21             if  $(sns_a)_i < (sns_d)_i$  and agent has not made a new friend yet this year then
22                 determine whether any potential friends are available;
23                 if potential friends are available then
24                     make friends with one of potential friends according to preset density  $\gamma$  and
                        homophily  $\beta$  (Equations 4.6 and 4.7);
25             if  $age_i < age_{max}$  and  $sex_i = \text{Female}$  then
26                 obtain empirical birth probability  $p_{birth,i}$ ;
27                 calculate social influence  $si_i$  (Equation 4.10);
28                 multiply empirical birth probability by social influence (Equation 4.9);
29                 determine whether agent will have child based on revised  $p_{birth,i}$ ;
30                 if agent will have child then
31                     determine sex of the newborn according to  $srb$ ;
32                     if sex of the newborn is Female then
33                         create newborn agent;
34                         update familial bonds of newborn agent and their family members;
35                     if  $parity_i = 0$  then
36                          $afb_i = age_i$ ;
37                          $parity_i + 1$ ;
38                          $hbt_i = \text{True}$ ;
39                         Append age of newborn child (=0) to  $ca$ ;
40                  $age_i + 1$ 
41             end
42         calculate the percentage of childless women amongst all women born in  $cohort_{target}$ ;
43         calculate the total fertility rate for this year  $year_{current}$ ;
44         calculate the mean age at first birth for this year  $year_{current}$ ;
45         add all newborn babies to the agent sample and scheduler;
46          $year_{current} + 1$ ;
47          $cohort_{target} + 1$ ;
48 end

```

Appendix 4.B Rates of Social Network Turnover as Input for Logistic Regression Model Predicting Agents' Probability of Removing a Friend from their Full Network

Table 4.B.1 shows the empirical data and sources used to predict the probability of losing a peer on the basis of age using a logistic regression model. Figure 4.B.1 shows the resulting decay function. Note that these probabilities are about the voluntary decision to remove a friend from one's peer network; not about circumstances such as death.

Table 4.B.1: Empirical findings of social network turnover rates by age as used to compute probabilities of removing a peer from agents' peer networks

Age	Rate of social network turnover	Reference
12 - 15	.99	Hartl et al. (2015)
12 - 15	.85	Moody et al. (2011)
19 - 23	.91	Wellman et al. (1997)
24 - 33	.67	Wellman et al. (1997)
34 - 39	.62	Wellman et al. (1997)
40 - 56	.61	Wellman et al. (1997)
55 - 85	.13*	Cornwell et al. (2014)

* computed from ratio of 0.47 (number of lost confidants) and 3.7 (average network size over W1 and W2)

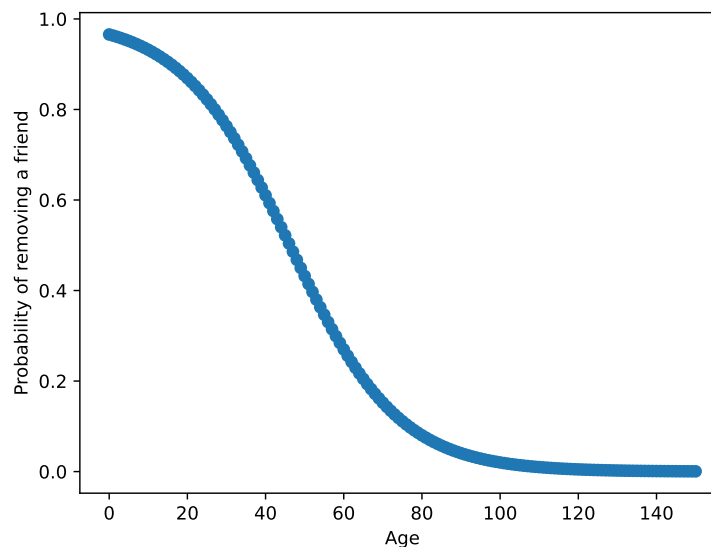


Figure 4.B.1: Probability of voluntarily removing a peer from one's peer network by age based on a logistic regression model fitted on empirical data as summarised in Table 4.B.1

Appendix 4.C Descriptive Results

4.C.1 Outcome Distributions

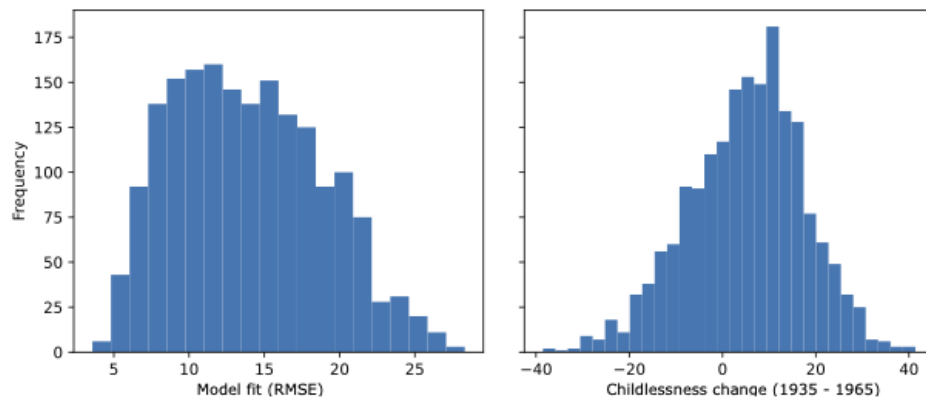


Figure 4.C.1: Histogram of ABSM outcome across simulation runs

4.C.2 Input-Output Correlations

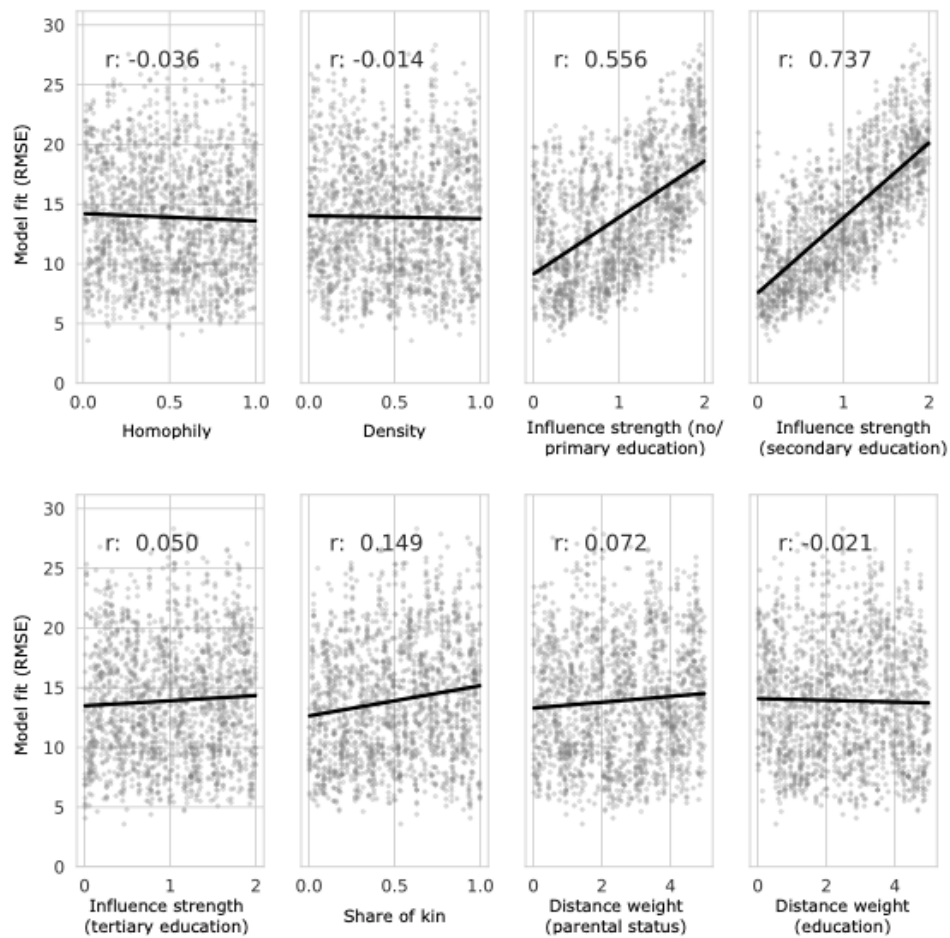


Figure 4.C.2: Input-output correlations per model parameter for the outcome of ABSM fit (RMSE)

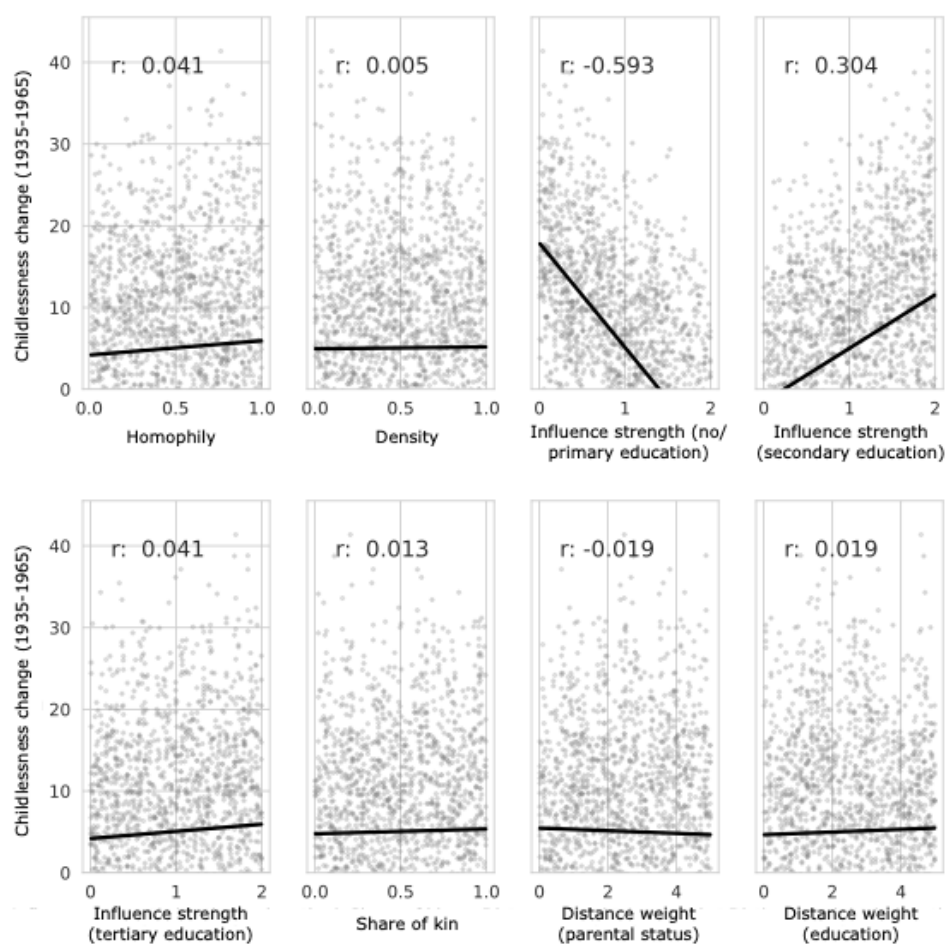


Figure 4.C.3: Input-output correlations per model parameter for the outcome of childlessness change between the 1935 and 1965 birth cohort

Appendix 4.D GBM Emulator Hyperparameters

Table 4.D.1: Optimal hyperparameters for the GBM emulator

Hyperparameter	ABSM fit (RMSE)	Childlessness change (1935-1965 birth cohorts)
Learning rate	0.016	0.012
Maximum depth	3	2
Maximum features	5	7
Minimum sample leafs	9	5
Minimum sample split	7	4
Number of estimators	1.200	500
Subsample	0.699	0.103

Appendix 4.E Emulator Prediction Performance

Table 4.E.1: Cross-validated emulator performance measures

Emulator	Outcome	MSE	RMSE	NRMSE	R^2	Adj. R^2	Var. Expl.
RMM	Model fit (RMSE)	1.019	1.009	−0.075	0.962	0.959	0.962
	Childlessness change	55.607	7.456	−1.477	0.573	0.540	0.574
GBM	Model fit (RMSE)	0.939	0.971	−0.072	0.964	0.965	0.965
	Childlessness change	55.699	7.461	−1.475	0.572	0.570	0.573

Appendix 4.F Sobol Sensitivity Indices

Tables 4.F.1 and 4.F.2 show the raw Sobol indices and their errors as visualised in Figures 4.10a respectively 4.10b. Note that ST, S1 and S2 represent the total, first-order and second-order indices, respectively, of which the sum can exceed one if the parameters are interdependent (Li et al., 2010). Only the parameter (interactions) with a non-null index are shown in these tables.

Table 4.F.1: Sobol sensitivity indices for the ABSM fit (RMSE)

Parameter combination	Total effect		First-order effect		Second-order effect	
	Coef.	Conf.	Coef.	Conf.	Coef.	Conf.
<u>Total and first order effects</u>						
β	0.06	0.02	0.02	0.06		
γ	0.06	0.02	0.04	0.07		
ρ_p	0.39	0.10	0.40	0.18		
ρ_s	0.57	0.14	0.58	0.19		
ρ_t	0.05	0.02	0.03	0.06		
ζ	0.10	0.03	0.06	0.09		
θ_p	0.06	0.03	-0.02	0.06		
θ_e	0.05	0.02	-0.03	0.05		
<u>Second order effects</u>						
$\beta * \gamma$					0.02	0.11
$\beta * \rho_p$					0.04	0.11
$\beta * \rho_s$					-0.07	0.11
$\beta * \rho_t$					0.03	0.10
$\beta * \zeta$					0.03	0.10
$\beta * \theta_p$					0.02	0.11
$\beta * \theta_e$					0.02	0.10
$\gamma * \rho_p$					-0.02	0.10
$\gamma * \rho_s$					-0.07	0.09
$\gamma * \rho_t$					-0.00	0.09
$\gamma * \zeta$					-0.03	0.09
$\gamma * \theta_p$					0.01	0.09
$\gamma * \theta_e$					-0.01	0.09
$\rho_p * \rho_s$					-0.08	0.31
$\rho_p * \rho_t$					-0.02	0.24
$\rho_p * \zeta$					-0.05	0.24
$\rho_p * \theta_p$					-0.00	0.24
$\rho_p * \theta_e$					-0.02	0.22
$\rho_s * \rho_t$					-0.14	0.23
$\rho_s * \zeta$					-0.12	0.22
$\rho_s * \theta_p$					-0.13	0.24
$\rho_s * \theta_e$					-0.12	0.21
$\rho_t * \zeta$					-0.04	0.09
$\rho_t * \theta_p$					-0.00	0.09
$\rho_t * \theta_e$					-0.02	0.09
$\zeta * \theta_p$					0.01	0.12
$\zeta * \theta_e$					-0.01	0.12
$\theta_p * \theta_e$					0.05	0.09

Note: γ = Density; ζ = Share of kin; β = Homophily; θ_p = Distance weight (parental status); θ_e = Distance weight (education); ρ_p = Influence strength (no/primary education); ρ_s = Influence strength (secondary education); ρ_t = Influence strength (tertiary education)

Table 4.F.2: Sobol sensitivity indices for the change in childlessness between the 1935 and 1965 birth cohorts

Parameter combination	Total effect		First-order effect		Second-order effect	
	Coef.	Conf.	Coef.	Conf.	Coef.	Conf.
<u>Total and first order effects</u>						
β	0.66	0.21	0.06	0.20		
γ	0.61	0.18	-0.16	0.18		
ρ_p	1.09	0.28	0.42	0.23		
ρ_s	0.66	0.23	0.09	0.19		
ρ_t	0.52	0.14	-0.01	0.18		
ζ	0.56	0.14	-0.12	0.22		
θ_p	0.50	0.12	-0.03	0.17		
θ_e	0.66	0.20	-0.15	0.21		
<u>Second order effects</u>						
$\beta * \gamma$					0.07	0.32
$\beta * \rho_p$					-0.06	0.29
$\beta * \rho_s$					0.02	0.34
$\beta * \rho_t$					-0.07	0.31
$\beta * \zeta$					-0.02	0.36
$\beta * \theta_p$					-0.04	0.29
$\beta * \theta_e$					0.04	0.34
$\gamma * \rho_p$					0.33	0.36
$\gamma * \rho_s$					0.10	0.29
$\gamma * \rho_t$					0.00	0.29
$\gamma * \zeta$					0.23	0.34
$\gamma * \theta_p$					0.07	0.28
$\gamma * \theta_e$					0.27	0.38
$\rho_p * \rho_s$					-0.01	0.33
$\rho_p * \rho_t$					-0.13	0.24
$\rho_p * \zeta$					-0.05	0.30
$\rho_p * \theta_p$					0.06	0.28
$\rho_p * \theta_e$					0.12	0.34
$\rho_s * \rho_t$					-0.05	0.27
$\rho_s * \zeta$					0.20	0.28
$\rho_s * \theta_p$					0.03	0.26
$\rho_s * \theta_e$					0.16	0.27
$\rho_t * \zeta$					-0.00	0.35
$\rho_t * \theta_p$					0.08	0.25
$\rho_t * \theta_e$					0.23	0.32
$\zeta * \theta_p$					0.13	0.27
$\zeta * \theta_e$					0.23	0.29
$\theta_p * \theta_e$					0.10	0.29

Note: γ = Density; ζ = Share of kin; β = Homophily; θ_p = Distance weight (parental status); θ_e = Distance weight (education); ρ_p = Influence strength (no/primary education); ρ_s = Influence strength (secondary education); ρ_t = Influence strength (tertiary education)

Chapter 5

Conclusion

This thesis has investigated macro-level childlessness patterns across time and socio-economic development as well as its pathways and consequences in micro-level life courses, and the role meso-level social network influences play in connecting the two. As such, it has provided a better understanding of how childlessness may come about in and affect people's lives, and how these pathways and consequences interact with individuals' social environment and the societal context they are embedded in more broadly. In this concluding section, I summarise the main findings presented in this thesis and embed these in the broader literature to highlight its scientific contributions. Hereafter, I discuss the implications of these findings for society and policy makers. I also consider limitations of the perspectives and analyses presented in this thesis, and give suggestions for promising avenues of future research. I conclude this thesis with some final remarks and finishing thoughts.

5.1 Summary

Throughout a series of three standalone but related contributions, I have i) examined the relationship between childlessness and socio-economic development on the (sub-)national level for sub-Saharan Africa; ii) assessed the accumulation of socio-economic (dis)advantage throughout the life courses of those who have eventually remained childless compared to those who have become parents; and iii) investigated the role of structural and compositional characteristics of social networks in the interaction between individual-level childbearing outcomes and aggregate trends in childlessness.

The first contribution of this thesis has provided, to the best of my knowledge, the first comprehensive overview of macro-level childlessness in sub-Saharan Africa. This region has developed substantially over the past decades but was long ignored in the childlessness literature because of its high fertility rates ([The World Bank, 2018](#)), even though the majority of childlessness in the region tends to be stigmatised

and driven by poverty (Baudin et al., 2020; Inhorn and Patrizio, 2015). Much of the relevant research instead has focused on (female) infertility, because of a common but unjustified assumption that other types of childlessness do not prevail in sub-Saharan Africa, given there is a strong desire for children and childbearing has been nearly universal (Bongaarts and Casterline, 2013). As such, an overview of levels of and trends in childlessness had been lacking for the region, particularly when it comes to the different types of childlessness. Further, while a U-shaped relationship between childlessness and development was hypothesised long ago (Poston et al., 1985; Poston and El-Badry, 1987; Poston and Trent, 1982), and was more recently (re-)investigated by some scholars (Baudin et al., 2020, 2015), Chapter 2 of this thesis presented an overview of this association at unprecedented levels of detail and variation. That is, it distinguished between involuntary, voluntary and circumstantial childlessness; between the education, income and health components of development; between men and women; and between subnational regions within a variety of countries.

Consequently, we¹ were able to examine childlessness in the broader sociological context of modernisation, and investigate how childlessness levels behave as societies become increasingly developed. More specifically, we used 291 Demographic and Health Surveys between 1986 and 2018 from 38 countries and 384 regions to assess the relationship between (different types of) childlessness and (different components of) development. Using hierarchical polynomial models, we found that the share of women who will never have children decreases with socio-economic advancements at lower levels of development, but increases with such advancements at higher levels of development. Male childlessness, on the other hand, tends to increase with socio-economic advancements across all of the levels of development considered. Whilst the prevalence of both men and women remaining permanently childless by voluntary choice or because of lacking a mating partner increases as regional levels of education and income rise, improvements in life expectancy and education are related to declines in infertility-related childlessness merely amongst women. The chapter also showed that childlessness tends to be more common in regions where low rates in marriage and polygyny prevail. The findings of this chapter have implications for how we might expect rates of different types of childlessness to evolve with future levels of development, also in comparison to more developed regions.

Second, I have proposed the usage of Bayesian hierarchical growth curve models (HGCMs) to provide a first comprehensive and holistic overview of the micro-level dynamic interplay between childlessness and socio-economic well-being over individuals' life courses. This work expands on the extensive literature considering socio-economic pathways into and consequences of childlessness,² connecting the two by assessing socio-economic differentials between childless adults and parents before, during and after

¹Chapter 2 was co-authored with Christiaan Monden.

²For pathways into childlessness, see for example Hagestad and Call (2007); Keizer et al. (2008); Raab and Struffolino (2020). For consequences of childlessness, see for example Cwikel et al. (2006); Koropecj-Cox and Call (2007); Tanturri et al. (2008).

the transition from temporary to permanent childlessness. Empirical investigation of this relationship had been challenging because of its substantive complexity, mainly stemming from childlessness often being a product of a complex life course process which is not clearly marked (Abbott, 2005; Giele and Elder Jr, 1998); might not be definitive at the time of measurement (Keizer et al., 2009); may have different reasons (Buhr and Huinink, 2017; Raab and Struffolino, 2020); and may associate with multiple life domains simultaneously and contemporaneously (Heinz, 2003; Kok, 2007; Nomaguchi and Milkie, 2020). Given that commonly used methodologies in the field are unable to synchronously incorporate and model these substantive complexities altogether, the resulting disconnected or even contradictory findings in the literature had hampered a holistic overview of the relationship between childlessness and socio-economic inequalities across the life course.

By transferring Bayesian inference for HGCMs from statistics to sociology, I have been able to incorporate and model the relevant substantive complexities of the question at hand, and as such provide a holistic substantive overview of the relationship between cumulative socio-economic (dis)advantage and childlessness over the life course. Methodologically, by applying Bayesian HGCMs to sociological questions of cumulative (dis)advantage, I have demonstrated the use of Bayesian approaches, and of Bayesian HGCMs for the investigation of cumulative (dis)advantage more specifically, to a wider audience beyond statisticians. Using the 1970 British Cohort Study, Chapter 3 dealt with constructing prospective interdependent life course trajectories of socio-economic well-being for eventual parents and permanently childless adults. Hereby, it distinguished between voluntary, involuntary, circumstantial and indecisive childlessness. As such, I found that parents are equally satisfied with life as those who have made an active choice not to have children, while individuals who have remained childless because of their health or personal circumstances are least satisfied with life. These observed differentials, as well as their growth across the life course amongst men, can largely although not fully be explained by group differences in relationship status. In terms of earnings, mothers report the lowest wages whilst women who have remained childless because of an active choice or some circumstance earn most. On the contrary, fathers tend to have higher wages than childless men, regardless of these childless men's reasons for never having had any children. Amongst both women and men, these economic inequalities tend to increase across the life course, which mainly has to do with differences in employment status across the groups. These findings have implications for policies addressing socio-economic inequalities not only by childbearing behaviours but also by gender. Furthermore, the proposed approach provides a valuable tool for assessing cumulative (dis)advantage in interrelated life domains via an unclearly marked, heterogeneous process, not only in the context of childlessness but also other life course topics.

Third, I have been amongst the first to quantitatively examine whether and how macro-level female childlessness patterns emerge from micro-level childbearing decisions, and what role the structure and

composition of meso-level social networks play in connecting the two. The literature on explanations of low fertility has increasingly recognised the importance of investigating social network influences on childbearing (for a review, see [Bernardi and Klärner, 2014](#)). Nevertheless, quantitative evidence for theories about the influence of social networks, as well as changes in their structural and compositional characteristics, on the increasing prevalence of childlessness had been lacking. This is mainly because social network influences on childbearing are often assumed to be less relevant in secular and individualistic post-industrial societies ([Bernardi and Klärner, 2014](#)), and because large-scale longitudinal data on social networks and fertility behaviour are limited ([Balbo et al., 2013](#)). Additionally, commonly used statistical regression methods generally struggle to explicitly model the real-life human interactions, more specifically amongst heterogeneous humans who form social networks endogenously, that underlie macro-level patterns in childlessness ([Gilbert, 2008](#); [Wilensky and Rand, 2015](#)).

Hence, the third contribution of this thesis presented a micro-level agent-based simulation model (ABSM) in conjunction with statistical and machine learning emulators to overcome these limitations. Calibrating the ABSM for the Dutch female birth cohorts between 1935 and 1965, I showed that the observed childlessness patterns seem to have emerged from individual-level childbearing behaviour. The results further suggested that social influence may have played a role in the observed steep increase in childlessness, especially amongst the 1945 to 1955 birth cohorts. Amongst the female population studied, social networks tended to be rather traditional and family-centered, with childbearing being the prevalent norm. However, the results provide evidence for the hypothesis that individuals' social networks have become increasingly sparse and heterogeneous over time, which might have decreased encouragement to abide to the prevailing childbearing norm and remain childless instead. This study has highlighted the importance of future endeavours to collect and analyse quantitative data, in particular when it comes to educational gradients in social influence as well as endogenous social network formation, to help further develop and test theories of social networks and fertility. Simultaneously, it has also demonstrated how ABSMs provide a valuable tool for doing so in the absence of such data.

5.2 Contributions

Beyond the standalone contributions made by each of its chapters, this thesis as a whole has made several contributions to the scientific literature on childlessness. First, this thesis specifically examined the phenomenon of childlessness rather than focusing on fertility. While the literature on childlessness has largely expanded over the past few decades (see for example [Kreyenfeld and Konietzka, 2017](#)), most relevant studies still tend to focus on fertility while viewing childlessness as its counter-factual ([Keizer,](#)

2010). However, research has shown that, at least at the macro level, high fertility rates need not necessarily equate to low childlessness rates and vice versa (Billari, 2005; Sobotka, 2017). Furthermore, even at the micro level it is important to acknowledge that permanent childlessness should not necessarily be viewed as the concomitant counter-factual of transitioning to parenthood. That is, while temporary childlessness could be defined as the counter-factual of having a child *at the same time* as parents, permanent childlessness is the counter-factual of *ever* having had a child (Tanturri and Mencarini, 2008). In other words, when observing a set of individuals during a period preceding their completed fertility, it is problematic to assume that not transitioning into parenthood during this period equates to permanent childlessness. Similarly, research has shown that experiences of childlessness, for example in terms of postponement, are different from those who do eventually transition to parenthood (Keizer, 2010). For this broad range of reasons, this thesis acknowledged that focusing on childlessness in itself is at least as interesting as focusing on (counter-factuals of) fertility. As such, it has been able to produce results valuable for mitigating unwanted experiences and promoting desired experiences of childlessness, as elaborated on further in section 5.3.

Second, the relevant literature has been increasingly emphasising the importance and inclusion of social network effects (e.g. Bernardi and Klärner, 2014), and calling for an understanding of how macro-level childlessness trends emerge from micro-level childbearing behaviour to better explain the growth of childlessness observed over the past decades (Billari, 2015). This thesis responded to this stream of research by assessing childlessness from the micro-, meso- and macro-level perspectives. As such, it provided a holistic overview of the phenomenon as well as a better understanding of how experiences at these three different levels are linked. That is, I found that macro-level childlessness levels seem to emerge from micro-level childbearing behaviours, which in turn are influenced by macro-level prevalences in childlessness – a feedback loop that is facilitated and supported by meso-level social influences in terms of following normative behaviours (Billari, 2015). These findings demonstrate the importance of explaining how the (inter)action of individuals generates population-level discoveries, and therefore calls for increased efforts to do so in future research endeavours as well.

Third, while some previous studies have shown that the group of childless individuals is heterogeneous (e.g. Allen and Wiles, 2013; Hagestad and Call, 2007; Raab and Struffolino, 2020), this heterogeneity has largely been neglected in relevant studies as a consequence of dichotomising the childlessness experience (Vikström et al., 2011). Even in cases where this dichotomisation is not applied, a variety of family trajectories and pathways into childlessness is considered rather than that different reasons for childlessness are explicitly distinguished (e.g. Comolli et al., 2021; Jalovaara and Fasang, 2020; Kahn et al., 2014; Mynarska et al., 2015; Van Winkle and Fasang, 2020), albeit with some exceptions (e.g. Buhr and Huinink, 2017; Tanturri and Mencarini, 2008). I have acknowledged this heterogeneity by

making use of rich data to distinguish between those who remain childless because of a voluntary choice, because of health or infertility issues, or because of for example economic or relationship circumstances. As a result, this thesis has shown that the relationship between childlessness and various socio-economic factors strongly depends on reasons for and pathways into childlessness, both at the micro and macro levels. For instance, Chapter 2 showed that at the macro level, involuntary childlessness may decline as life expectancy improves (at least for women), while circumstantial and voluntary childlessness tend to increase especially as income and education advance. At the micro level, voluntarily childless individuals generally fare better socially and economically than undesirably childless individuals, especially involuntarily childless women and circumstantially childless men (Chapter 3). Hence, by distinguishing between reasons for childlessness, I have been able to connect different strands of seemingly unconnected or even contradictory literature into a holistic and complementary overview. Future research on childlessness should therefore continue to acknowledge the heterogeneity of the group of childless individuals in terms of their reasons for and experiences of childlessness.

Fourth, recent studies of childlessness have followed calls for increased efforts to investigate males as well (e.g. [Keizer et al., 2008](#)). While the majority of studies that have included men have shown that female and male experiences of childlessness are different ([Kreyenfeld and Konietzka, 2017](#)), childbearing-related behaviours are still often seen as mainly female experiences ([Keizer, 2010](#)). This thesis has taken a gendered perspective and has examined trends, drivers and outcomes of childlessness for both women and men. As such, it has been able to show that male and female experiences of childlessness are indeed different. For instance, compared to those who have remained childless because of other reasons, childless men who have remained without children because of lacking a mating partner may be particularly disadvantaged socio-economically, which similarly goes for involuntarily childless women who suffer from infertility. Further, I have shown that male childlessness is actually substantial in both developing and developed regions of the world, and is –contrary to popular beliefs– not merely a female experience. These findings further signify existing calls in the literature to continue to include men in analyses of childlessness.

Fifth, while scholars' ability to collect and analyse large-scale data has substantially improved over the past years ([Salganik, 2019](#)), traditional surveys about family trajectories still tend to be limited in sample size and information. For example, calls have been made in the relevant literature to expand data when it comes to social network influences on fertility ([Balbo et al., 2013](#)) or couple-level experiences regarding childbearing ([Berrington, 2017](#)). In this respect, the findings presented in this thesis have helped bring forth suggestions for future data collections. For instance, Chapter 3 implied that increased data collection efforts regarding detailed and longitudinal childbearing intentions and outcomes would be helpful for improving our understanding of socio-economic polarisation across different groups in

society. Similarly, Chapter 4 highlighted the importance of future endeavours to collect and analyse quantitative data, in particular when it comes to educational gradients in social influence as well as endogenous social network formation, to help further develop and test theories of social networks and fertility. These suggestions for future data collection might guide scholars to collect and analyse novel data that help develop the scientific literature on and narrative of childlessness further. Nevertheless, there are some challenges to collecting large-scale survey data, including low response rates and the need for substantial resources in terms of money and time. Therefore, in sections 5.4 and 5.5 I speculate about how increasingly common digital (trace) data, which generally offer higher recency and coverage and are often easier and cheaper to collect, might provide a promising source of data in overcoming these limitations.

Sixth, the necessity to use more advanced data and methods for answering novel and complex social science questions has become increasingly recognised (e.g. Lynch and Bartlett, 2019). This shows, for example, from the increasing popularity and emergence of novel fields such as ‘computational social science’ (Salganik, 2019). Acknowledging this necessity, the chapters in this thesis have made use of rich longitudinal data and advanced methodologies to overcome current limitations in the analyses and understanding of childlessness. As such, I have been able to provide comprehensive overviews of childlessness not only across its emergence from micro-level behaviour, but also across a large number of spatial regions and across individual life course trajectories. Beyond these applied contributions, I have demonstrated how methodological approaches originated in disciplines other than the social sciences can be leveraged to investigate human behaviour and interactions at an elevated level of realism and complexity. With societies becoming increasingly digitised, it is crucial that social scientists of the future have the methodological toolkit to analyse and interpret data of unprecedented structure and scale (Salganik, 2019). Therefore, the computational perspective of this thesis should not only encourage fellow scholars to apply the proposed methods in their own work; it should also promote advances in the methodological training of future generations of social scientists to come.

5.3 Societal and Policy Implications

The findings presented in this thesis are important for predictions and explanations of childlessness and its correlates. On the one hand, the findings provide an enhanced understanding of how childlessness and its correlates might behave across individual-level life courses and societal-level developments. On the other hand, they help us understand the mechanisms behind these phenomena, which in turn guides thinking about how to mitigate undesired trajectories or promote desired ones. Given the strong dependency of

drivers, mediators and consequences of childlessness on macro-level contextual factors (e.g. [Brini, 2020](#); [Huijts et al., 2013](#)), the findings of this thesis have a number of societal and policy implications.

First, this thesis suggested that childlessness levels have increased over the past decades globally, and might continue to increase further in the future. On the one hand, these trends may be beneficial with respect to concerns about climate change and overpopulation ([Hintz and Haywood, 2021](#)). On the other hand, they are simultaneously concerning for the viability of the population and welfare systems in the context of ageing populations ([Keizer, 2010](#)), particularly in low-fertility settings. That is, increased levels of childlessness, and declining fertility more generally, contribute to the ageing of the population ([Coleman, 2001](#)). This may pose a threat to welfare systems, given that older populations are generally less healthy and require more spendings on welfare payment while having a smaller work force to produce revenue ([Coleman, 2001](#); [Parliament of the United Kingdom, 2015](#)). While a substantial share of governments globally have taken measures to increase childbearing by introducing support for family planning and balancing work and family ([United Nations Population Division, 2017](#)), these measures have not (yet) shown to be effective in decreasing childlessness ([Frejka et al., 2008](#); [Sobotka et al., 2020](#)). It is therefore crucial that more research continues to be executed to better understand how policies may affect childbearing timing and quantum differently. In addition, measures could be taken to encourage social cohesion and integration of childless individuals, and especially elderly, in society, such that these individuals have a support network that compensates for their lack of children. For example, encouraging personal investments in such networks through organized community building events might help in this respect. Nevertheless, welfare states might consider shifting from kin- or peer-dependent support systems to universal support systems to provide care in old age, also for those who will have never had any children.

Second, the findings from this thesis imply that childlessness is generally not an active choice independent of one's personal situation, but more often a chosen or unchosen consequence of life circumstances such as infertility, struggling to find a mating partner, or an unwillingness to have to sacrifice one's career (e.g. [Berrington, 2017](#); [Buhr and Huinink, 2017](#)). While this thesis has not made any causal inferences when it comes to causes and consequences of childlessness, the results presented seem to suggest that unintended childlessness and/or the factors having influenced selection into unintended childlessness may contribute to further socio-economic disadvantages in the future lives of undesirably childless individuals. That is, while employment differences between childless adults and parents largely explained (the growth of) economic differentials between the groups, life satisfaction differentials (and their growth amongst men) could only partially be explained by group differences in relationship status and other relevant factors. Future research would strongly benefit from more closely examining the direction and directness of the found associations from a causal inference point of view. Hereby, the

associations discovered in this thesis may be used to guide the formulation of intriguing questions for future research disentangling selection and causal effects (also see section 5.4). Nevertheless, preliminary policy improvements might gain from the findings presented in this thesis by mitigating the undesired circumstances that select individuals into childlessness, regardless of whether these circumstances directly or indirectly via childlessness affect socio-economic outcomes.

Regarding economic inequality, this thesis showed that economic activity differences across the groups of childless individuals and parents seem to explain the observed economic differentials between them. Therefore, it is important that efforts are taken to reduce these differences to prevent further economic polarisation in society. Given that previous research has found evidence for labour market discrimination of mothers and childless men in terms of capabilities and commitment (Correll et al., 2007; Killewald, 2013), employers' diversity and inclusion efforts should increasingly focus on parental status as a protected category. Another way to achieve fewer employment differences across the groups of childless adults and parents is to improve opportunities for women to reconcile work and family, and perhaps simultaneously ensure men of lower socio-economic status are not left behind on the marriage market. Female emancipation and educational attainment –in conjunction with persistent traditional norms about gender roles within families– may lead to higher shares of individuals postponing childbirth and remaining permanently childless, for example because of longer time spent in education, sex imbalance in largely hypergamous marriage markets, and family-work dilemmas (e.g. Bianchi, 2011; Burkimsher and Zeman, 2017; Keizer et al., 2008). Policies aimed at reducing circumstantial childlessness of this form could therefore perhaps focus on promoting marriage and childbearing, especially amongst highly educated women and lower-educated men. In this respect, it is essential that gender equality increases throughout a variety of domains, such as the economic, household and family domains (McDonald, 2000a,b, 2008). This could be done, for example, by increasingly providing support for those struggling to combine work with family, e.g. in the form of childcare; by incentivising women to build and maintain a career from young ages onwards; and by encouraging men to take on more housework and paternal leave. Such changes could contribute to diminishing gender differences not only in work experience but also in childcare skills (e.g. Rocha, 2021). As such, existing gender norms about mating and childbearing may be gradually replaced by more progressive norms that fit the needs and desires of today's women and men, perhaps such as highly educated women increasingly marrying lower-educated men and these men taking on more household and family chores.

Regarding social inequality, the findings of this thesis implied that group differences in relationship status explain much of the observed differentials between childless adults and parents. Hence, relevant policies could focus on promoting partnering through, for instance, financial benefits for partnered couples (Cherlin, 2003). Hereby, it is important that these policies take into consideration that the kind of

partnering they encourage is in line with contemporary generations' values of self-expression, freedom and autonomy (*ibid.*). Nevertheless, the results presented in this thesis showed that not all of the observed social differentials could be explained by the considered factors, suggesting that undesired childlessness may actually negatively affect subjective well-being. While more evidence for a causal effect should be provided by future research endeavours, this finding is in line with speculations from other studies as well (e.g. [Nomaguchi and Milkie, 2020](#)). Therefore, it is essential that measures are taken to mitigate the prevalence of involuntary and circumstantial childlessness as much as possible. Nevertheless, despite such measures it is unlikely that levels of undesired childlessness will reach zero ([Bongaarts and Potter, 1983](#)). Hence, it seems essential in any respect that more social and mental support is provided for those remaining childless undesirably.

In terms of mitigating involuntary childlessness, the findings presented in this thesis suggest that health status is linked to both involuntary childlessness as well as lower life satisfaction on the micro level. The macro-level results suggest that increasing investments in healthcare and technological advancements might help in achieving the goal of reducing involuntary childlessness. However, recent studies have shown that infertility has been rising in both developed and developing regions of the world, mainly as a consequence of unhealthy living patterns and behaviours ([Levine et al., 2017](#); [Sengupta et al., 2017](#)). Provided more causal evidence will continue to be brought forward in support of these claims, governments and policy-makers should therefore aim to discourage such behaviours (e.g. smoking, alcoholism) and instead promote more healthy behaviours (e.g. active lifestyle, healthy diet). Increasing and more equal opportunities in terms of access to infertility treatment might also be effective in this respect, for example through the provision of financial state support for the matter. Causal inference research could perhaps also focus on investigating the direction of the observed negative relationship between polygyny and childlessness: in the case of polygyny actually causing infertility via venereal diseases, restrictions on polygyny might help reduce the prevalence of involuntary childlessness particularly in developing regions.

In terms of mitigating circumstantial childlessness, beyond promoting partnering and improving opportunities to reconcile work and family, financial and economic limitations to having children could potentially be reduced. In this respect, economic shifts observed amongst younger cohorts might result in higher marriage and childbirth postponement rates ([Caltabiano et al., 2017](#); [Comolli and Bernardi, 2015](#)). To illustrate, those currently in their childbearing ages –also referred to as the ‘millennial’ generation born between 1981 and 1996 ([Fry, 2020](#))– experience lower pension contributions, wages (especially relative to student debts) and rates of home ownership compared to the generations preceding them ([United States Government Accountability Office, 2019](#)). Relevant policies could perhaps focus on improving these circumstances, or at least decreasing their relevance for childbearing intentions and behaviour. For

example, some employers have started offering financial benefits to promote childbearing amongst their employees, whether that be in overcoming subfecundity or monetary limitations (Beioley, 2021; Bishop, 2021). Other policies might be targeted towards programs that help repay or forgive student loans, or provide tax benefits and affordable mortgage programs for those buying a house for the first time (United States Government Accountability Office, 2019).

Third, while childlessness has become more common over the past decades, it remains an “ideologically charged” topic in the public debate (Kreyenfeld and Konietzka, 2017, p. 3). With more and more evidence of highly educated women prioritising their careers and socio-economically disadvantaged men struggling to find a mating partner, childless individuals tend to be portrayed as somehow impaired, lacking, egocentric or deviating (Berrington, 2017). However, as aforementioned, the research presented in this thesis shows that only a small share of the population actually has an active desire to remain childless; more often so, it is the outcome of a long-term interplay of different life circumstances. Even when a personal decision is made to remain childless, this need not be a straightforward one nor need it be an egocentric one. That is, other studies have shown that some childless individuals decided not to have children because they wanted to prevent them from contemporary issues like climate change, or because they were worried they could not provide them with the parenting their children might need (Park, 2005; Stegen et al., 2020). Additionally, as mentioned before, the boundary between individual agency and external constraints in deciding whether to have children might be blurry (Jeffries and Konnert, 2002; Kelly, 2009). For example, if individuals prioritise their career over children, this might not necessarily mean that children are not desired. Rather, it might mean that these individuals feel like a choice has to be made between two seemingly exclusive life paths. While in itself women should not have to choose between the two in the same way men generally have not had to, it is crucial for protecting the mental well-being of childless individuals that the public debate around childlessness changes. In this respect, the complexity of and heterogeneity in childbearing decisions and outcomes should be recognised in discussions of childlessness and portrayals of childless individuals.

Fourth, the findings of this thesis suggest that social network influences may be relevant for explaining the observed increases in childlessness, and that both the endogeneity of social network formation as well as the homogeneity of social networks have an impact on the extent to and direction in which social network influences operate. In the relevant literature, it has been hypothesised that social networks have become decreasingly traditional over the past decades, with the focus shifting from low-mobility, long-term, activity-based and kin-centered networks to high-mobility, short-term, interest-based friend-centered networks (Keim, 2011; Wellman, 1979). With increasing globalisation and availability of social media platforms, one might expect social networks to continue to become more ‘individualised’ and

centralised, although with increasingly homogeneous and dense clusters of people within these otherwise ‘individualised’ overall social networks (Himmelboim et al., 2017). That is, online social networks and dating platforms more easily allow individuals to connect to like-minded people based on a set of individual characteristics and interests, and the algorithms behind these platforms might reinforce this behaviour by suggesting potential matches of interest based on observed similarities (Chitra and Musco, 2020). Hence, homogeneous ‘bubbles’ of like-minded people may be formed, in which childbearing may either be strongly encouraged or discouraged depending on the social norms around fertility within these ‘echo chambers’, and particularly amongst the central people (‘influencers’) within these groups (Bail, 2021). Eventually, this process may result in a polarised society when it comes to childbearing norms and behaviour, which –as the results from this thesis have implied– might in turn lead to increasing inequalities between different groups in society. To prevent or mitigate such polarisation as much as possible, ideas from the extensive literature on political polarisation may be used as guideposts. Some of these suggested solutions include adjusting algorithms behind social media platforms such that they suggest information and people contradicting rather than confirming one’s own beliefs, with the goal of increasing ‘intergroup contact’ and ‘perspective taking’ (Pettigrew and Tropp, 2006). Yet another solution that has been proposed entails decentralising social networks by increasing egalitarianism and equity in terms of influence within these networks (Bail, 2021).

5.4 Limitations

There are a number of limitations to this thesis which call for extensions in future research. First, while this thesis has assessed childlessness from the micro-, meso- and macro-level perspectives, one missing but important perspective on childlessness is that of the couple. Although the qualitative literature on childlessness, and infertility more specifically, has put more focus on the couple (e.g. Onat and Beji, 2012; Tabong and Adongo, 2013), couple-level analyses of childlessness remain limited when it comes to quantitative studies, albeit with some exceptions (e.g. Berrington, 2004; McAllister and Clarke, 2000). The main reason for this is because large-scale couple-level data on fertility decisions and their consequences are still rare (Berrington, 2017). By neglecting the couple-level perspective, this thesis has not been able to assess, for example, how within-couple gender differences are affected by inter-partner interactions (Keizer, 2010); how both partners’ individual circumstances, desires and intentions interact in influencing the decision (not) to have children (Berrington, 2004; McAllister and Clarke, 2000; Rijken, 2009); or how life experiences affected by (not) having children, such as relationship satisfaction or career progression, might be experienced differently by both partners within a couple (e.g. Ganth et al., 2013; Keizer, 2010; Keizer and Schenk, 2012). Therefore, future research on childlessness would benefit

from taking the perspective of couples in addition to individuals when researching gender dynamics in pathways into and experiences of childlessness (Keizer, 2010). Developing a better understanding of these partner dynamics therefore also calls for increased efforts to collect large-scale couple-level data on intentions and outcomes of childlessness. As aforementioned, given the limitations of collecting large-scale survey data (i.e. resources, response rates, recency), increasingly common digital (trace) data may provide a promising source of information in this respect. To illustrate, profile and/or interaction data from online dating platforms could be exploited, in a similar way as for example Bruch and Newman (2018) have done, to examine potential partner dynamics in matching and dating in the case of certain fertility or childlessness intentions.

Second, a challenge that remains is determining or inferring when childlessness has transferred from being a temporary to a permanent state, and how it came about in people's lives. In terms of the former, in each chapter of this thesis I have considered data constraints, relevant literature and national-level contextual factors in making a sensible choice for the cut-off age at which permanent childlessness can be concluded. However, doing so is more simplistic for women than men, as females have a rather clearly marked start and end to the fecund period (Buhr and Huinink, 2017; Fiori et al., 2017). On the other hand, men usually remain fertile until higher ages and do not have such a clearly marked end to their fecund period, although most men within a couple consider their female partner's fecund period when planning for children (*ibid.*). Therefore, with the cut-off ages used in each chapter, I cannot guarantee that some of the individuals classified as permanently childless will have had children after having reached this cut-off age. As a result, I might have overestimated the prevalence of permanent childlessness, particularly amongst men. Nevertheless, given that empirical data generally show that men in practice hardly have children after the cut-off ages considered in each of the chapters, the impact of such biases on the findings presented in this thesis is likely limited.

Related, this thesis has not aimed at making causal inferences when it comes to causes and consequences of childlessness. The main reason for this is because it is generally difficult to infer when childlessness has become definitive because it often does not entail a clearly marked event, but rather the eventual absence of the event of having a child (De Rose, 1996; Tanturri et al., 2015). This conceptual feature of childlessness has complicated the examination of causes, selection into and consequences of childlessness even in longitudinal studies, because scholars cannot always be certain when an individual has decided or realised they have remained childless, or if they are still intending or planning to have children in the future (Bijlsma and Wilson, 2020; Keizer et al., 2009; Plotnick, 2009; Umberson et al., 2010). Nevertheless, to develop effective policies that help mitigate negative experiences directly and indirectly related to childlessness, there is substantial necessity and room for assessing the earlier-life causes and later-life consequences of childlessness from a causal inference point of view, both on the

micro and macro levels. Some recent studies of fertility have been going in this direction already (e.g. [Bijlsma and Wilson, 2020](#)), although similar studies with a focus of childlessness are still rare (for an exception, see [Comolli and Bernardi, 2015](#)).

To overcome the challenges related to causal inference, future research might benefit from collecting and using rich and longitudinal data about childbearing desires and intentions as well as reasons for outcomes in analyses of childlessness to be able to try and more clearly ‘mark’ the phenomenon (e.g. [Nomaguchi and Milkie, 2020](#); [Umberson et al., 2010](#)). Hereby, relatively novel sources of digital trace data might be promising for overcoming the aforementioned limitations of survey data collection. For example, one could monitor individuals’ childbearing intentions at an unprecedentedly high number of different times throughout the life course by tracking their online search behaviour and/or their likes and interests for certain social media pages. Google searches, for instance, have “shown to capture information-seeking behaviours that might not be readily measured in surveys” ([Kashyap, 2021](#), p. S62), and hence might be used to examine such behaviours for parenthood-related topics. Similarly, likes to Facebook pages about parenthood and babies, downloads of fertility-related phone apps, or even purchases of fertility-related products, in combination with someone’s online behaviour more generally, might give an indication of their childbearing intentions and how these might change across the life course.

In terms of inferring how childlessness came about in people’s lives, it remains challenging to acknowledge the heterogeneity of pathways into and reasons for childlessness. This thesis has made a worthwhile and best-of-effort attempt within the given constraints and challenges to classify types of childlessness directly and indirectly. As such, it has not only been able to connect seemingly competing views of childlessness in the literature, but has also brought forward results that support calls from the literature to increasingly acknowledge the heterogeneity in the group of childless individuals. Nevertheless, the used classifications of childlessness types might not have been perfectly accurate, for example because of uncertainty in indirect responses to childlessness questions (e.g. [Berrington, 2017](#)); discrepancies between reports of earlier childbearing intentions and later childlessness reasons as a consequence of ex-post rationalisation ([Berrington, 2017](#); [Jeffries and Konnert, 2002](#)); lack of a level of detail in direct responses to childlessness questions; and blurriness between personal choice and circumstances when it comes to reasons for childlessness ([Tanturri and Mencarini, 2008](#)). Therefore, future research might benefit from collecting larger-scale data on more specific fertility intentions, reasons and outcomes across longer lifespans of individuals. One suggestion in this respect would be to combine such survey responses with actual human behaviour, not only to more accurately pin down the reason for childlessness but also to investigate the magnitude of some of the aforementioned biases and uncertainties in survey responses. Such behaviours could be offline, for example when seeking infertility treatment in hospital, or could be

online, for instance when web-searching for more information about infertility or benefits for working parents.

Third, this thesis has provided evidence for the notion that childlessness often is a complex process outcome, and a broad range of factors play a role in this outcome. Many of these factors, such as partnerships, network influences, education and health, have been studied in this thesis, both on the micro and macro levels. However, there might be other relevant factors influencing reasons for and experiences of childlessness that have not been included in this thesis. For example, previous research has shown that certain personality traits are associated with remaining childless (e.g. [Avison and Furnham, 2015](#)), and that both individual as well as societal values and norms directly influence decisions about childbearing (e.g. [Collins, 2019](#)). Nevertheless, it was not possible to include such factors in the chapters of this thesis because of data limitations, i.e. them not being sufficiently and/or accurately available in the data sets used. As a consequence, I have not been able to make inferences about such factors, and hence the explanations of childlessness suggested in this thesis should be considered as potentially partial explanations merely. In this respect, it would be interesting for future research to further explore the role of such factors to provide an increasingly comprehensive overview of the pathways into and consequences of childlessness.

Fourth, as is the case for most analytical studies, the research on childlessness presented in this thesis may suffer from misreporting issues. Particularly for the high-fertility regions considered, the presented estimates of childlessness may have been downwardly biased as a consequence of over-reporting fertility due to the stigma attached to childlessness ([Larsen, 1989](#); [van Balen and Bos, 2009](#)). Similarly, voluntary childlessness may have been overestimated as a consequence of ex-post rationalisation ([Jeffries and Konnert, 2002](#); [Pritchett, 1994](#)). Although men may equally over-report fertility, they may also under-report fertility if they are not aware of having produced children ([Rendall et al., 1999](#); [Schoumaker, 2017](#)). Under-reporting may also have occurred when parents do not include the birth of a child which has passed away, while overestimations of childlessness may have occurred due to the exclusion of women who deceased during pregnancy or delivery. In this thesis, I have limited the effect of such biases on the conclusions drawn by using established accurate measures of childlessness; executing extensive sensitivity analyses; and transparently reflecting on how potential biases, if any, could have influenced the results. Nevertheless, it is not possible to completely rule out the impact of misreporting biases on the produced estimates of childlessness and its correlates, and these effects may or may not have cancelled each other out. In this respect, to mitigate this issue in future research, data collection efforts might benefit from more thoroughly and transparently investigating and producing statistics on such misreporting biases. In addition, scholars may want to complement traditional survey data with more novel ‘non-reactive’ digital data sources that do not suffer from the so-called ‘Hawthorne effect’, because they implicitly observe

individuals whose behaviours therefore do not change as a consequence of knowingly being observed (Salganik, 2019).

5.5 Avenues for Future Research

Based on the findings from this thesis, a number of avenues for future research can be identified. First, it would be interesting to compare the findings of this thesis across different regions in the world and time spans in history. This thesis has explored childlessness in sub-Saharan Africa between 1986 and 2018; in the United Kingdom amongst the 1970 birth cohort between the ages of 26 and 46; and in the Netherlands amongst the 1935 to 1965 birth cohorts. It would be interesting to extend these contexts to countries and time spans beyond those considered in this thesis. While a number of cross-country comparisons have already been performed when it comes to determinants and consequences of childlessness, these have been limited largely to developed regions like the European Union (e.g. Brini, 2020; Huijts et al., 2013; Rijken and Merz, 2014). Further, although historical analyses of childlessness rates are available (Sobotka, 2017), studies regarding childlessness norms and acceptance throughout history are much more limited (for an exception, see e.g. Noordhuizen et al., 2010). Generally, existing cross-country and cross-time studies have shown that national and historical contexts play a significant role in levels and experiences of childlessness (e.g. Brini, 2020; Huijts et al., 2013; Rijken and Merz, 2014). Given the substantial variation across time, countries and regions in terms of levels of development, welfare systems and cultural norms and values, it would be interesting for scientists to further explore the impact of these different factors on the pathways into and experiences of childlessness throughout historical phases and across the world.

A second valuable avenue for future research would be to produce forecasts of childlessness trends across these contexts. While the results presented in this thesis might be used as a basis to speculate about future levels of childlessness, more formal forecasts predicting these levels might be helpful for researchers and policy makers. That is, formal forecasts of childlessness may help inform research efforts in understanding the micro-level and macro-level drivers of childlessness, and therefore also policy makers in how best to promote or mitigate these expected future levels of childlessness (Billari et al., 2014). Some of the methods used in this thesis provide a promising basis for doing so, given that both Bayesian approaches and ABSMs have shown effective in producing sensible forecasts of demographic trends, also when it comes to fertility-related topics. For instance, the Bayesian approach could be used to derive stochastic and expert-based forecasts of childlessness (Billari et al., 2014), while ABSMs could be particularly fruitful in investigating the consequences of different policy scenarios on forecasts of childlessness (Ciganda and Todd, 2021; Grow and van Bavel, 2017).

Third, childlessness can be defined from different perspectives, such as the biological or residential definitions. Throughout this thesis, childlessness has been defined in its demographic terms as the absence of ever having had at least one biological live-born child; stillbirths, miscarriages and other forms of terminated pregnancies were not included as live births. Previous research has shown that these definitions might affect the conclusions drawn. For example, differences between childless men and fathers tend to be conditioned by the residency status of fathers' children (Keizer et al., 2009). An interesting avenue for future research therefore would be to break down the findings presented in this thesis by these different definitions of childlessness. Not only would this help shed more light on how experiences of childlessness differ across often overlooked groups of individuals, such as adoptive and step-parents, but it might also enhance our ability to connect seemingly contradictory findings existing in the literature. Such studies could, for instance, investigate whether the socio-economic experiences of non-biological parents are more similar to those of biological parents or those of childless individuals instead.

Fourth, some contemporary topics in today's society are those of sexual orientation and gender identity. In 2011, United Nations Human Rights Council (2011) made a call to stop discrimination, violence and sanctions on the basis of gender identity and/or sexual orientation. During the past few years, same-sex marriages have been becoming increasingly common, as have expressions of gender identities beyond cisgender men and women as well as sexualities beyond the heterosexual one (Chamie and Mirkin, 2011). While the legalisation and acceptance of LGBTQ+³ families have sparked scholarly interest in researching experiences of parenthood within such families (for a review, see Reczek, 2020), research on experiences of childlessness amongst these couples has remained rather scarce. Therefore, it might be interesting for future research to focus more on these groups when examining experiences of childlessness. For example, what are common ways for such couples to overcome biological limitations to having children (e.g. adoption, surrogacy), and how do these couples experience such processes? Another interesting topic for future research would be to examine how these individuals and couples experience normative expectations from their social environment with respect to starting a family. While answering such questions, it could be particularly interesting to distinguish between different sexual orientations and gender identities to examine whether experiences of childlessness differ across these groups, especially in relation to societal norms for and acceptance of these various orientations and identities.

Fifth, an exciting avenue for further research is that of exploiting the technological improvements in computing power and digitisation observed during past decades by using computational methods and digital data in sociological and demographic research (Billari and Zagheni, 2017; Kashyap, 2021). This thesis has demonstrated the results and impact that can be achieved using more advanced methods like

³LGBTQ+ is a term often used to refer to all of the agender, ally, asexual, androgyne, aromantic, asexual, bigender, bisexual, cross-dresser, demisexual, gay, gender queer, gender variant, intersex, lesbian, pangender, pansexual, queer, questioning, transgender, transsexual and two-spirited communities (UC Davis Health, 2021).

Bayesian statistics and agent-based simulation modelling. Further continuing to do so might help social scientists answer novel questions, or existing questions in novel ways. Besides methodologically advanced methods, the increased prevalence of digital trace data nowadays, accumulated through the “adoption of internet and mobile technologies” (Kashyap, 2021, p. S58) as well as the “digitalization of data” (Kashyap, 2021, p. S59), also provides exciting opportunities for future research (Salganik, 2019). Nevertheless, these digital data sources might suffer from their own disadvantages, such as representation issues (i.e. some (groups of) individuals selecting themselves more than others into usage of big data systems); algorithmic confounding (i.e. human behaviour being influenced by how the big data system is built); incompleteness (i.e. missing some information because the data were not collected with the primary goal of doing research); drift (i.e. ongoing changes in big data systems); dirtiness (i.e. inclusion of information not of interest to researchers); inaccessibility (i.e. the data being protected because of legal and privacy issues) and sensitivity (i.e. information of highly personal nature) (Salganik, 2019).

Hence, some barriers will need to be overcome to benefit from the opportunities digital trace data offer. These barriers include for example the potential for data misuse and ethical issues; spatial inequality in data availability; integration of micro- and macro-level data; methodological approaches to analyse these data; and researcher access and reproducibility (Kashyap, 2021). Doing so will allow scholars to benefit from the advantages digital trace data have over traditional survey data, and exploit the seemingly endless opportunities to better understand populations in full (Independent Expert Advisory Group [IEAG], 2014; Kashyap, 2021). These advantages include ease, cheapness and speed of data collection; the scale (and therefore often global comparability) of the data; these data being ‘always on’ (i.e. big data systems automatically collecting data constantly); and these data being non-reactive (i.e. human responses and behaviours not being influenced by interview settings) (Salganik, 2019). These digital data sources, possibly in conjunction with computational methods, could be used to study a number of interesting questions when it comes to childlessness, and could complement traditional survey data mainly by providing insight into actual human behaviour and how this behaviour aligns with responses to survey questions. To give some examples of research questions that would be interesting to investigate, in addition to those already suggested, one could use Twitter data or online newspaper records to examine public opinions and sentiment about childlessness and childless individuals, perhaps in a similar way as what Mencarini et al. (2019) have done for parents. Another suggestion would be to examine long-term social influences on childbearing decisions through online social media networks, perhaps even in a quasi-experimental setting, for example when online friends post pictures of their newborn children or when sponsored pages show parenthood-related materials. Mechanisms behind social network effects on childbearing may also be further investigated using sensor data, for example when it comes to the role of spatial proximity and/or emotional contagion using geolocation respectively brain sensors.

5.6 Finishing Thoughts

In sum, this thesis has investigated the behaviour of macro-level childlessness patterns across time and socio-economic development as well as its pathways and consequences in micro-level life courses, and the role meso-level social network influences play in connecting the two. As such, it has provided a better understanding of how childlessness may come about in and affect people's lives, and how these pathways and consequences interact with individuals' social environment and the societal context they are embedded in more broadly. Not only has this thesis made a number of contributions to the scientific literature when it comes to variation in terms of level of analysis, type of childlessness and gender; its results are also important when it comes to notions of cultural norms, public perceptions, welfare systems and gender equality.

An open question that remains is that of how childlessness levels will develop in the future. On the one hand, we might expect that involuntary childlessness will continue to decrease, particularly in developing regions, as the quality of healthcare improves and so may opportunities for infertile couples to become pregnant despite their infecundity (e.g. through in-vitro fertilisation). On the other hand, it has been documented that infertility, especially amongst men, has been on the rise in developed regions instead due to environmental factors and lifestyle choices (e.g. [Levine et al., 2017](#)). At the same time, we might expect voluntary and circumstantial childlessness to increase over the next years. For instance, contemporary concerns about climate change and overpopulation might increasingly encourage individuals to abstain from childbearing ([Hintz and Haywood, 2021](#)). Further, ongoing efforts to achieve gender equity in for example educational attainment as well as economic participation and opportunity might result in higher shares of individuals, and women more specifically, following life paths that do not entail parenthood ([World Economic Forum, 2021](#)). Additionally, social media platforms increasingly facilitate the formation of homogeneous and dense clusters of people within otherwise rather 'individualised' overall social networks ([Himmelboim et al., 2017](#)). Hence, childlessness may be strongly endorsed in some of these most progressive clusters consisting largely of childless members, likewise resulting in a higher share of individuals remaining without children. The consequential increases in voluntary and circumstantial childlessness that might follow from these changes may be particularly relevant for developing regions, where substantial progress in emancipation, technology, individualisation and urbanisation has been made more recently ([Madsen et al., 2017](#)).

In more developed regions however, where such changes have already taken place to a larger extent, we might instead expect a reversal as a consequence of alternating norms as well as government responses to current trends. That is, the formation of homogeneous and dense online clusters of people emerging social media platforms facilitate ([Himmelboim et al., 2017](#)) might play a role in stimulating childbearing

amongst clusters consisting largely of parents (to be). Further, some governments have taken policy measures to increase fertility and decrease childlessness, and may be expected to keep doing so for the foreseeable future (United Nations Population Division, 2017). Hence, we might expect to observe increasingly progressive cultural norms about gender and childbearing, in conjunction with improved policies for especially women to reconcile work and family. In this respect, the ongoing COVID-19 pandemic might have an influence on future levels of gender equality and childlessness too: while women have been disadvantaged more than men in terms of occupational stress and risk, job loss and work disruption by children, work-from-home settings combined with telecommunication technologies have shown promising increases in men's participation in childcare and domestic responsibilities (Carli, 2020). With such developments altogether, voluntary and circumstantial childlessness may level off instead. However, as the analyses in this thesis show, there is substantial variation in family change within and across regions of the world as well as time spans in history, and so we should likely not expect some pattern of universal convergence in prevalences of childlessness.

References

- Abbott, A. (2005). Process and Temporality in Sociology: The Idea of Outcome in U.S. Sociology. In Steinmetz, G., editor, *The Politics of Method in the Human Sciences: Positivism and Its Epistemological Others*, pages 393–426. Durham, NC: Duke University Press.
- Allen, R. E. and Wiles, J. L. (2013). The utility of positioning theory to the study of ageing: Examples from research with childless older people. *Journal of Aging Studies*, 27(2):175–187.
- Avison, M. and Furnham, A. (2015). Personality and voluntary childlessness. *Journal of Population Research*, 32(1):45–67.
- Bail, C. (2021). *Breaking the Social Media Prism*. Princeton, NJ: Princeton University Press.
- Balbo, N., Billari, F. C., and Mills, M. (2013). Fertility in advanced societies: A review of research. *European Journal of Population*, 29(1):1–38.
- Baudin, T., De la Croix, D., and Gobbi, P. (2020). Endogenous childlessness and stages of development. *Journal of the European Economic Association*, 18(1):83–133.
- Baudin, T., De La Croix, D., and Gobbi, P. E. (2015). Fertility and childlessness in the United States. *American Economic Review*, 105(6):1852–1882.
- Beioley, K. (2021). Employers expand benefits to include cost of fertility treatment. Financial Times. Retrieved on 2021-12-09 from <https://www.ft.com/content/0f5d078a-662f-4943-a380-3881ce6f1114>.
- Bernardi, L. and Klärner, A. (2014). Social networks and fertility. *Demographic Research*, 30:641–670.
- Berrington, A. (2004). Perpetual postponers? women's, men's and couple's fertility intentions and subsequent fertility behaviour. *Population Trends*, 117:9–19.
- Berrington, A. (2017). Childlessness in the UK. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 57–76. Springer.
- Bianchi, S. M. (2011). Changing families, changing workplaces. *The Future of Children*, 21(2):15–36.
- Bijlsma, M. J. and Wilson, B. (2020). Modelling the socio-economic determinants of fertility: a mediation analysis using the parametric g-formula. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 183(2):493–513.
- Billari, F. (2005). Partnership, childbearing and parenting: Trends of the 1990s. In Macura, M., MacDonald, A., and Haug, W., editors, *The new demographic regime: Population challenges and policy responses*, pages 63–94. New York/Geneva: United Nations, Sales No. E.
- Billari, F. C. (2015). Integrating macro-and micro-level approaches in the explanation of population change. *Population Studies*, 69(sup1):S11–S20.
- Billari, F. C., Graziani, R., and Melilli, E. (2014). Stochastic population forecasting based on combinations of expert evaluations within the Bayesian paradigm. *Demography*, 51(5):1933–1954.
- Billari, F. C. and Zagheni, E. (2017). Big data and population processes: A revolution? In Petrucci, A. and Verde, R., editors, *SIS 2017. Statistics and Data Science: New challenges, new generations*, pages 167–178. Proceedings of the Conference of the Italian Statistical Society, Firenze University Press.
- Bishop, K. (2021). How fertility became a workplace perk. BBC. Retrieved on 2021-12-09 from <https://www.bbc.com/worklife/article/20211008-how-fertility-became-a-workplace-perk>.
- Bongaarts, J. and Casterline, J. (2013). Fertility transition: is sub-Saharan Africa different? *Population and Development Review*, 38:153–168.
- Bongaarts, J. and Potter, R. E. (1983). *Fertility, biology, and behavior: An analysis of the proximate determinants*. New York, NY: Academic Press.
- Brini, E. (2020). Childlessness and low fertility in context: evidence from a multilevel analysis on 20 European countries. *Genus*, 76(1):1–38.
- Bruch, E. E. and Newman, M. (2018). Aspirational pursuit of mates in online dating markets. *Science Advances*, 4(8):eaap9815: 1–6.
- Buhr, P. and Huinink, J. (2017). Why childless men and women give up on having children. *European Journal of Population*, 33(4):585–606.
- Burkimsher, M. and Zeman, K. (2017). Childlessness in Switzerland and Austria. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 115–137. Springer.
- Caltabiano, M., Comolli, C. L., and Rosina, A. (2017). The effect of the Great Recession on permanent childlessness in Italy. *Demographic Research*, 37:635–668.

- Carli, L. L. (2020). Women, Gender equality and COVID-19. *Gender in Management: An International Journal*, 35(7/8):647–655.
- Chamie, J. and Mirkin, B. (2011). Same-sex marriage: A new social phenomenon. *Population and Development Review*, 37(3):529–551.
- Cherlin, A. J. (2003). Should the government promote marriage? *Contexts*, 2(4):22–29.
- Chitra, U. and Musco, C. (2020). Analyzing the impact of filter bubbles on social network polarization. In *Proceedings of the 13th International Conference on Web Search and Data Mining*, pages 115–123.
- Ciganda, D. and Todd, N. (2021). Demographic models of the reproductive process: Past, interlude, and future. *Population Studies*, 6:1–19.
- Coleman, D. A. (2001). Population ageing: An unavoidable future. *Social Biology and Human Affairs*, 66:1–11.
- Collins, C. (2019). *Making motherhood work: How women manage careers and caregiving*. Princeton, NJ: Princeton University Press.
- Comolli, C., Bernardi, L., and Voorpostel, M. (2021). Joint family and work trajectories and multidimensional wellbeing. *European Journal of Population*, 37:643–696.
- Comolli, C. L. and Bernardi, F. (2015). The causal effect of the great recession on childlessness of white American women. *IZA Journal of Labor Economics*, 4(1):1–24.
- Correll, S. J., Benard, S., and Paik, I. (2007). Getting a job: Is there a motherhood penalty? *American Journal of Sociology*, 112(5):1297–1338.
- Cwikel, J., Gramotnev, H., and Lee, C. (2006). Never-married childless women in Australia: Health and social circumstances in older age. *Social Science & Medicine*, 62(8):1991–2001.
- De Rose, A. (1996). Scelte di fecondità e d'infecundità: i fattori determinanti individuali e di contesto. In Giorgi, P. and Strozza, S., editors, *Studi di popolazione. Temi di ricerca nuovi*. Rome, Italy: Department of Demographic Sciences, University of Rome “La Sapienza”.
- Fiori, F., Rinesi, F., and Graham, E. (2017). Choosing to Remain Childless? A Comparative Study of Fertility Intentions Among Women and Men in Italy and Britain. *European Journal of Population*, 33(3):319–350.
- Frejka, T., Sobotka, T., Hoem, J., and Toulemon, L. (2008). Childbearing trends and policies in Europe: Summary and general conclusions. *Demographic Research*, 19:5–13.
- Fry, R. (2020). Millennials overtake Baby Boomers as America's largest generation. Pew Research Center. Retrieved from: <https://www.pewresearch.org/fact-tank/2020/04/28/millennials-overtake-baby-boomers-as-americas-largest-generation/>.
- Ganth, D. B., Thiagarajan, S., and Kalorath, N. (2013). Role of infertility, emotional intelligence and resilience on marital satisfaction among Indian couples. *International Journal of Applied Psychology*, 3(3):31–37.
- Giele, J. and Elder Jr, G. (1998). *Methods of life course research: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications.
- Gilbert, N. (2008). *Agent-Based Models*. Sage Publications.
- Grow, A. and van Bavel, T. J. (2017). *Agent-Based Modelling in Population Studies*. Springer.
- Hagestad, G. O. and Call, V. R. (2007). Pathways to childlessness: A life course perspective. *Journal of Family Issues*, 28(10):1338–1361.
- Heinz, W. R. (2003). From work trajectories to negotiated careers. In Mortimer, J. and Shanahan, M., editors, *Handbook of the Life Course*, pages 185–204. Springer.
- Himmelboim, I., Smith, M. A., Rainie, L., Shneiderman, B., and Espina, C. (2017). Classifying Twitter topic-networks using social network analysis. *Social Media + Society*, 3(1):1–13.
- Hintz, E. A. and Haywood, A. (2021). Media Frames of Voluntary Childlessness in the United States from 1989 to 2018. *Sex Roles*, 84(11):747–764.
- Huijts, T., Kraaykamp, G., and Subramanian, S. V. (2013). Childlessness and psychological well-being in context: A multilevel study on 24 European countries. *European Sociological Review*, 29(1):32–47.
- Independent Expert Advisory Group [IEAG] (2014). A world that counts: Mobilising the data revolution for sustainable development. [Technical report]. Retrieved from: <https://www.undatarevolution.org/wp-content/uploads/2014/11/A-World-That-Counts.pdf>.
- Inhorn, M. C. and Patrizio, P. (2015). Infertility around the globe: New thinking on gender, reproductive technologies and global movements in the 21st century. *Human Reproduction Update*, 21(4):411–426.
- Jalovaara, M. and Fasang, A. E. (2020). Family life courses, gender, and mid-life earnings. *European Sociological Review*, 36(2):159–178.

- Jeffries, S. and Konnert, C. (2002). Regret and psychological well-being among voluntarily and involuntarily childless women and mothers. *The International Journal of Ageing and Human Development*, 54(2):89–106.
- Kahn, J. R., García-Mangano, J., and Bianchi, S. M. (2014). The motherhood penalty at midlife: Long-term effects of children on women's careers. *Journal of Marriage and Family*, 76(1):56–72.
- Kashyap, R. (2021). Has demography witnessed a data revolution? Promises and pitfalls of a changing data ecosystem. *Population Studies*, 75(sup1):47–75.
- Keim, S. (2011). *Social networks and family formation processes*. Springer.
- Keizer, R. (2010). *Remaining childless: Causes and consequences from a life course perspective*. PhD thesis, Utrecht University.
- Keizer, R., Dykstra, P. A., and Jansen, M. D. (2008). Pathways into childlessness: Evidence of gendered life course dynamics. *Journal of Biosocial Science*, 40(6):863–878.
- Keizer, R., Dykstra, P. A., and Poortman, A.-R. (2009). Life outcomes of childless men and fathers. *European Sociological Review*, 26(1):1–15.
- Keizer, R. and Schenk, N. (2012). Becoming a parent and relationship satisfaction: A longitudinal dyadic perspective. *Journal of Marriage and Family*, 74(4):759–773.
- Kelly, M. (2009). Women's voluntary childlessness: A radical rejection of motherhood? *Women's Studies Quarterly*, 37(2):157–172.
- Killewald, A. (2013). A reconsideration of the fatherhood premium: Marriage, coresidence, biology, and fathers' wages. *American Sociological Review*, 78(1):96–116.
- Kok, J. (2007). Principles and prospects of the life course paradigm. *Annales de Démographie Historique*, 1(113):203–230.
- Koropecj-Cox, T. and Call, V. R. (2007). Characteristics of older childless persons and parents: Cross-national comparisons. *Journal of Family Issues*, 28(10):1362–1414.
- Kreyenfeld, M. and Konietzka, D. (2017). *Childlessness in Europe: Contexts, Causes, and Consequences*. Springer.
- Larsen, U. (1989). A Comparative Study of the Levels and Differentials of Sterility in Cameroon, Kenya, and Sudan. In Lesthaeghe, R., editor, *Reproduction and Social Organization in sub-Saharan Africa*, pages 167–211. Berkeley, CA: University of California Press.
- Levine, H., Jørgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Mindlis, I., Pinotti, R., and Swan, S. H. (2017). Temporal trends in sperm count: a systematic review and meta-regression analysis. *Human Reproduction Update*, 23(6):646–659.
- Lynch, S. M. and Bartlett, B. (2019). Bayesian Statistics in Sociology: Past, Present, and Future. *Annual Review of Sociology*, 45.
- Madsen, J. B., Moslehi, S., and Wang, C. (2017). What Has Driven the Great Fertility Decline in Developing Countries Since 1960? *The Journal of Development Studies*, 54(4):738–757.
- McAllister, F. and Clarke, L. (2000). Voluntary childlessness: Trends and implications. In Bentley, G. R. & Mascie-Taylor, C. G., editor, *Infertility in the modern world. Present and future prospects*, pages 189–237. Cambridge, United Kingdom: Cambridge University Press.
- McDonald, P. (2000a). Gender equality, social institutions and the future of fertility. *Journal of Population Research*, 17(1):1–16.
- McDonald, P. (2000b). Gender equity in theories of fertility transition. *Population and Development Review*, 26(3):427–439.
- McDonald, P. (2008). Very low fertility: Consequences, causes and policy approaches. *Japanese Journal of Population*, 6:19–23.
- Mencarini, L., Hernández-Farías, D. I., Lai, M., Patti, V., Sulis, E., and Vignoli, D. (2019). Happy parents' tweets: An exploration of Italian Twitter data using sentiment analysis. *Demographic Research*, 40:693–724.
- Mynarska, M., Matysiak, A., Rybińska, A., Tocchioni, V., and Vignoli, D. (2015). Diverse paths into childlessness over the life course. *Advances in Life Course Research*, 25:35–48.
- Nomaguchi, K. and Milkie, M. A. (2020). Parenthood and well-being: A decade in review. *Journal of Marriage and Family*, 82(1):198–223.
- Noordhuizen, S., de Graaf, P., and Sieben, I. (2010). The public acceptance of voluntary childlessness in the Netherlands: From 20 to 90 per cent in 30 years. *Social Indicators Research*, 99(1):163–181.
- Onat, G. and Beji, N. K. (2012). Marital relationship and quality of life among couples with infertility. *Sexuality and Disability*, 30(1):39–52.

- Park, K. (2005). Choosing childlessness: Weber's typology of action and motives of the voluntarily childless. *Sociological Inquiry*, 75(3):372–402.
- Parliament of the United Kingdom (2015). Challenges of an ageing population. Retrieved from: <https://www.parliament.uk/business/publications/research/key-issues-parliament-2015/social-change/ageing-population/>.
- Pettigrew, T. F. and Tropp, L. R. (2006). A meta-analytic test of intergroup contact theory. *Journal of Personality and Social Psychology*, 90(5):751–783.
- Plotnick, R. D. (2009). Childlessness and the economic well-being of older Americans. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 64(6):767–776.
- Poston, Jr., D. L., Briody, E., Trent, K., and Browning, H. L. (1985). Modernization and Childlessness in the states of Mexico. *Economic Development and Cultural Change*, 33(3):503–519.
- Poston, Jr., D. L. and El-Badry, S. M. (1987). Modernization and childlessness among the governorates of the Arab Republic of Egypt, 1976. *Journal of Biosocial Science*, 19(2):181–193.
- Poston, Jr., D. L. and Trent, K. (1982). International variability in childlessness: A descriptive and analytical study. *Journal of Family Issues*, 3(4):473–491.
- Pritchett, L. H. (1994). Desired fertility and the impact of population policies. *Population and Development Review*, 20(1):1–55.
- Raab, M. and Struffolino, E. (2020). The heterogeneity of partnership trajectories to childlessness in Germany. *European Journal of Population*, 36(1):53–70.
- Reczek, C. (2020). Sexual-and gender-minority families: A 2010 to 2020 decade in review. *Journal of Marriage and Family*, 82(1):300–325.
- Rendall, M. S., Clarke, L., Peters, H. E., Ranjit, N., and Verropoulou, G. (1999). Incomplete reporting of men's fertility in the United States and Britain: A research note. *Demography*, 36(1):135–144.
- Rijken, A. J. (2009). *Happy families, high fertility? Childbearing choices in the context of family and partner relationships*. PhD thesis, Utrecht University.
- Rijken, A. J. and Merz, E.-M. (2014). Double standards: Differences in norms on voluntary childlessness for men and women. *European Sociological Review*, 30(4):470–482.
- Rocha, M. (2021). Promoting gender equality through regulation: the case of parental leave. *The Theory and Practice of Legislation*, 9(1):35–57.
- Salganik, M. J. (2019). *Bit by bit: Social research in the digital age*. Princeton, NJ: Princeton University Press.
- Schoumaker, B. (2017). Measuring male fertility rates in developing countries with Demographic and Health Surveys: An assessment of three methods. *Demographic Research*, 36:803–850.
- Sengupta, P., Nwagha, U., Dutta, S., Krajewska-Kulak, E., and Izuka, E. (2017). Evidence for decreasing sperm count in African population from 1965 to 2015. *African Health Sciences*, 17(2):418–427.
- Sobotka, T. (2017). Childlessness in Europe: Reconstructing long-term trends among women born in 1900–1972. In Kreyenfeld, M. and Konietzka, D., editors, *Childlessness in Europe: Contexts, Causes, and Consequences*, pages 17–53. Springer.
- Sobotka, T., Matysak, A., and Brzozowska, Z. (2020). Policy Responses to Low Fertility: How Effective Are They? New York, NY: UNFPA, Working Paper No. 1. Retrieved from: https://www.unfpa.org/sites/default/files/pub-pdf/Policy_responses_low_fertility_UNFPA_WP_Final_corrections_7Feb2020_CLEAN.pdf.
- Stegen, H., Switsers, L., and De Donder, L. (2020). Life stories of voluntarily childless older people: A retrospective view on their reasons and experiences. *Journal of Family Issues*, 42(7):1536–1558.
- Tabong, P. T.-N. and Adongo, P. B. (2013). Infertility and childlessness: a qualitative study of the experiences of infertile couples in Northern Ghana. *BMC Pregnancy and Childbirth*, 13(72):1–10.
- Tanturri, M., de Santis, G., and Seghieri, C. (2008). Economic well-being in old age in Italy: does having children make a difference? *Genus*, 64:75–99.
- Tanturri, M. L. and Mencarini, L. (2008). Childless or childfree? Paths to voluntary childlessness in Italy. *Population and Development Review*, 34(1):51–77.
- Tanturri, M. L., Mills, M., Rotkirch, A., Sobotka, T., Takács, J., Miettinen, A., Faludi, C., Kantsa, V., and Nasiri, D. (2015). State-of-the-art report: Childlessness in Europe. *Families and Societies*, 32:1–53.
- The World Bank (2018). Fertility rate, total (births per woman) - Sub-Saharan Africa. Retrieved from: <https://data.worldbank.org/indicator/SP.DYN.TFRT.IN?locations=ZG>.
- UC Davis Health (2021). LGBTQ+ Glossary. Office for Health Equity, Diversity and Inclusion. Retrieved from: <https://health.ucdavis.edu/diversity-inclusion/LGBTQI/LGBTQ-Plus.html>.

- Umberson, D., Pudrovska, T., and Reczek, C. (2010). Parenthood, childlessness, and well-being: A life course perspective. *Journal of Marriage and Family*, 72(3):612–629.
- United Nations Human Rights Council (2011). Human rights, sexual orientation and gender identity. A/HRC/17/L.9/Rev.1. Retrieved from: <https://documents-dds-ny.un.org/doc/UNDOC/LTD/G11/141/94/PDF/G1114194.pdf?OpenElement>.
- United Nations Population Division (2017). Government policies to raise or lower the fertility level. Retrieved from: https://www.un.org/en/development/desa/population/publications/pdf/popfacts/PopFacts_2017-10.pdf.
- United States Government Accountability Office (2019). Millennial Generation: Information on the Economic Status of Millennial Households Compared to Previous Generations. Report to the Ranking Member, Committee on the Budget, U.S. Senate. Retrieved from: <https://www.gao.gov/assets/gao-20-194.pdf>.
- van Balen, F. and Bos, H. M. (2009). The social and cultural consequences of being childless in poor-resource areas. *Facts, Views & Vision in ObGyn*, 1(2):106.
- Van Winkle, Z. and Fasang, A. E. (2020). Parenthood wage gaps across the life course: A comparison by gender and race. *Journal of Marriage and Family*, 82(5):1515–1533.
- Vikström, J., Bladh, M., Hammar, M., Marcusson, J., Wressle, E., and Sydsjö, G. (2011). The influences of childlessness on the psychological well-being and social network of the oldest old. *BMC Geriatrics*, 11(1):78.
- Wellman, B. (1979). The community question: The intimate networks of East Yorkers. *American Journal of Sociology*, 84(5):1201–1231.
- Wilensky, U. and Rand, W. (2015). *An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo*. Cambridge, MA: MIT Press.
- World Economic Forum (2021). Global Gender Gap Report 2021. Insight Report. Retrieved from: https://www3.weforum.org/docs/WEF_GGGR_2021.pdf.