STUDIES IN HISTORICAL LIVING STANDARDS AND HEALTH: INTEGRATING THE HOUSEHOLD AND CHILDREN INTO HISTORICAL MEASURES OF LIVING STANDARDS AND HEALTH

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Short Abstract (300 words)

This dissertation attempts to integrate the household and children more fluidly into measures of well-being in the past. In part one, I develop a Monte Carlo simulation to test some of the assumptions of Allen's welfare ratio methodology. These included his assumptions that family size was constant over time, that there were no female-headed households and that women and children did not participate in the labour force. After all of the adjustments, it appears that Allen's welfare ratios underestimate the welfare ratios of a demographically representative group of families, especially if women and children's labour force participation is included. However, the predicted distributions also highlight the struggles of agricultural labourers, who are given separate consideration. Even the average agricultural labourers' family with women and children working would have had to rely of self-provisioning, gleaning, poor relief or the extension of the working year to make ends meet at the poorest point in their family life cycle. Part two adjusts Floud *et al.*'s estimates of calorie availability in the English economy from 1700 to 1909 for the costs of digestion, pregnancy and lactation. Taken together, these three additional costs reduced the amount calories available by around 15 per cent in 1700 but only by 5 per cent in 1909 because of the changing composition of the English diet. Part three presents a new adaptive framework for studying changes in children's growth patterns over time and a new methodology, longitudinal growth studies, for measuring gender disparities in health in the past. An adaptive framework for understanding growth provides a more parsimonious explanation for the vast catch-up growth achieved by slave children in the antebellum American South. The slave children were only able to achieve this catch-up growth because they were programmed for a tall height trajectory by relatively good conditions *in utero*. Finally, impoverished girls experienced greater catch-up growth than boys in two schools in late-nineteenth century Boston, USA and early-twentieth century London, suggesting that girls were deprived relative to boys before entering these institutions.

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Extended Abstract (2,500 words)

This dissertation attempts to improve the theoretical and methodological basis for studying how labour opportunities and decisions made at the household level affected the living standards of the household as a group and individuals within it, especially children.

The dissertation is broken into three parts consisting of five chapters total. The first part develops a Monte Carlo simulation based on early modern English demographic data to tackle three problems. First, it tests some of the simplifying assumptions of Allen's real wage methodology, namely his estimate of average family size, which is held constant over time, his exclusion of women and children's income from his calculations, and his exclusion of female-headed households. Second, because each family's welfare ratios (real wages) are measured across the family life cycle, the family's welfare ratios can be recorded for the median or the minimum point in the family life cycle. Thus, we can know how families were doing at an average point in their life cycle and how they were doing at the hardest point in their life cycle when they were supporting the largest number of children. Third, the simulation allows a distribution of families to be predicted, so it is possible to measure the adequacy of the male breadwinner wage by considering the number of families below a certain welfare ratio threshold and the inequality in real income that is determined by family size and composition. The Monte Carlo simulation focuses on two periods, 1650-1700 and 1750-1800, limiting the arguments that can be made about the nineteenth century.

Both chapters in part one use demographic data drawn from Wrigley *et al.*'s family reconstitutions of 26 English parishes to adjust Allen's real wages to the

changing demography of early modern England.[1] Using parity progression ratios (a fertility measure) and age specific mortality for children and parents, model families are predicted in two reference periods 1650-1700 and 1750-1800. These models yield two levels of interesting results. At the individual family level, we can measure how different families' real wages changed over the family life cycle as additional children were born. At the aggregate level, we can predict thousands of families using Monte Carlo simulation, creating a realistic distribution of median family real wages in the economy. There are two main findings. First, pregnancy and lactation do not create cyclical effects in the family's income because the consumption of children is slowly added to the household's from pregnancy to nursing to weaning. Instead, most families' welfare ratios decline steadily across the family life cycle until children begin to leave the household, increasing the welfare ratios. Second, Allen's real wages understate or match the median of the predicted demography-adjusted welfare ratio distributions.

Chapter two complicates the model developed in chapter one to better understand the way households earned their living. Poor households in eighteenth-century England used a number of strategies to combat poverty and increase their income formally in the labour market and informally outside it. These strategies included sending women and children into the labour market, allocating resources unequally within the household, self-provisioning on garden plots of land, appealing to the poor law for aid, and expanding the number of days worked by household members. These strategies constituted an economy of makeshifts, which allowed the poor to at least scrape by and even reach respectable levels of consumption for the period. While social and economic historians have studied these individual strategies for eighteenth-century England, few historians have been able to integrate them all to determine how these strategies influenced the income of the average family and how large a gap had to be filled by the economy of makeshifts for the poor to reach target consumption levels. This chapter seeks to integrate these strategies in such a way.

Thus, the original Monte Carlo simulation is expanded to incorporate women and children's labour force participation and the unequal distribution of resources within the household. I then use Monte Carlo simulation to predict a distribution of 30,000 realistic families and their corresponding welfare ratios for the period 1750-1800. Using the predicted distributions, I measure the influence of women and children's labour force participation and unequal household distribution on the family's welfare ratios and their implied information about the availability of energy for work. Finally, for each level of women and children's labour force participation and each household resource distribution assumption, I calculate the level of self-provisioning, poor law support, or additional days of work necessary for the family to reach a certain target consumption level.

The results suggest that at the median welfare ratio in the life cycle, agricultural labourers' families could get by at a low consumption level through either self-provisioning or working a few more days. However, at the minimum welfare ratio in the life cycle, this was much more difficult, and the poor law likely had to play a strong role in keeping these families afloat. Women and children's labour force participation increased the average family welfare ratios by 31 to 48 per cent

[1] Wrigley *et al.*, *English Population History*; Allen, 'Great Divergence'; Allen, *British Industrial Revolution*.

depending on the specification used, and could even put agricultural labourer families within stabbing distance of Allen's respectability level of consumption. However, even with women and children's labour force participation, families still struggled to make ends meet at the low point in the welfare ratio curve. Thus, the results highlight the precarious position of agricultural labourers in the late eighteenth century, the importance of women and children's labour participation in keeping poor families afloat, and the importance of life-cycle poverty, which is ignored when real wages are only measured for the average family at the average point in the life cycle. Thus, the results from part one suggest that Allen's real wage estimates are approximately correct when measuring the welfare of the average family at the average point in the life cycle, but his figures hide the difficulties of the same average family when it was at its largest.

Part two of the dissertation consists of one chapter. The chapter provides a critical review of some of the methods used for calculating the number of calories available in the British economy from 1700 to 1909. All of the authors working with this method have made judicious use of agricultural output data and trade statistics, and their results provide an interesting additional welfare measure with which to compare trends in real wages, nutritional status (stature) and mortality rates. However, the figures are biased somewhat because they do not account for the costs of digestion on the one hand and the costs of lactation and pregnancy on the other. Focusing primarily on Floud *et al.*'s figures, with a brief robustness check from Muldrew's figures, I systematically adapt Floud *et al.*'s figures to measure the influence of these factors on the overall supply of calories in the economy.[2] Digestion costs arise because the body has more difficulty breaking down certain components of food (dietary fibre and protein) than others. These additional costs are not incorporated in the Atwater factors Floud *et al.* and Muldrew used to convert food production into calories. Thus, their figures overestimate the amount of calories that people could absorb from their food. Adjusting for these digestion costs is complicated by the fact that digestion costs directly relate to the diet being consumed, which changed over time. The average bread and other cereals consumed in the early eighteenth century contained much more dietary fibre than the average bread consumed in the early twentieth century. Thus, it is not possible to merely adjust Floud *et al.*'s figures downward by a fixed percentage. After making estimates of digestion costs in each benchmark year, digestion costs reduce the average calories available per capita by 12.7 per cent in 1700 but only by 4.9 per cent in 1909 again because of the changing composition of the diet.

The energy costs of pregnancy and lactation could have also been substantial since women require an additional 475 calories per day during the final trimester of pregnancy and 675 calories per day during the first six months of nursing. These costs were measured for the population of England by calculating the number of pregnant women in each benchmark year from the crude birth rate and the number of children needing to be nursed from infant and early childhood mortality rates. These costs were lower than the digestion costs only reducing average per capita calorie consumption by 2.5 per cent. Taken together the digestion, pregnancy and lactation adjusted figures suggest a more pessimistic level of calorie availability than Floud *et al.* and Muldrew's argue.

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2 Floud *et al.*, *Changing Body*; Muldrew, *Food*.

Part three of the dissertation attempts to advance the theoretical framework and introduce a new methodological strategy for studying children's growth in historical populations, hopefully making some interesting points about the growth pattern of antebellum American slaves and gender differences in health in late-nineteenth and early-twentieth century Britain and America.

Chapter four presents a new adaptive framework for understanding children's growth in the past. Drawing upon the recent work of Gluckman and Hanson and their co-authors on adaptive responses in relation to growth, I present four adaptive mechanisms that affected the growth patterns of children.[3] First, acute poor prenatal conditions can trigger an immediate adaptive response where the foetus slows its growth until conditions improve. Second, the general or average conditions *in utero* lead to a predictive adaptive response where the foetus develops assuming that the postnatal environment will closely match prenatal conditions. Thus, the metabolism and growth trajectory of a child is programmed during the prenatal period: children experiencing good conditions *in utero* would have a higher metabolism and growth trajectory than their counterparts facing poor conditions. Third, a nutritional or disease shock in childhood or adolescence can lead to an immediate adaptive response where growth is temporarily slowed until the child has enough energy to continue growing. Finally, poor conditions before the pubertal growth spurt can prompt the child to delay his/her growth spurt until conditions improve. All of these responses are adaptive because they increase the probability that a child will survive to reproductive age and produce viable offspring, but this does not mean that there are no costs involved. These stunting events have negative consequences for the long-run mortality risk of the child.

Having discussed the framework in great detail, I then use it to reinterpret the growth pattern of American slaves.[4] I argue that the mismatch between relatively good conditions *in utero* and absolutely appalling conditions in infancy and early childhood led slave children to become incredibly stunted by age three or four. However, this age, slave children experienced rapid catch-up growth, first because their immune systems had become more developed and had adapted to the poor disease environment and later because their diet improved tremendously when they entered the labour force around age ten. Thus, American slave children were able to experience rapid catch-up growth because they were prenatally programmed for a higher metabolism and growth trajectory. The chapter concludes by setting out some stylized facts about children's growth in the past and pointing toward areas of future research.

Chapter five measures the relative deprivation of children admitted to the Marcella Street Home in Boston, MA (1889-1898) and the Ashford School in London, UK (1908-1917) by studying their longitudinal growth, a first for a historical study. By comparing the catch-up growth of boys and girls, a proxy for health and nutritional conditions before entering the institutions, I find that in both the Marcella Street Home and the Ashford School girls experienced faster height gain relative to modern standards than boys. There are three potential explanations for this result. First, girls could have been treated better than boys in the schools, but this does not

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[3] Gluckman and Hanson, 'Evolution'; Gluckman and Hanson, 'Consequences'; Gluckman *et al.*, 'Environmental Influences'.

[4] Steckel, 'Peculiar Population'.

seem to have been the case. Second, girls might have a greater natural propensity for catch-up growth; however, there is no scientific consensus on this question, so we can tentatively reject this explanation. Therefore, it seems likely that girls were relatively worse off when compared to boys. The most parsimonious explanation for girls' relative poor health is that girls may have been discriminated against in the allocation of household resources before entering these institutions. This finding is contradictory to household budget studies, which found no gender discrimination in household resources.[5] Female deprivation could have played a role in slowing the progression of improvements in health across the late nineteenth and early twentieth centuries, at least for a portion of the population. Thus, it was only when resources became incredibly abundant in the twentieth century and female deprivation disappeared that the biological living standards of the population could increase substantially.

[5] Horrell and Oxley, 'Crust and Crumb'; Logan, 'Family'; Harris, 'Gender', (1998).

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My primary debt of gratitude upon completing this project goes to my two supervisors: Bob Allen and Deborah Oxley. Both placed a lot of trust in me when I chose to pursue a completely different project in my DPhil than what I had studied before. Their support as the project changed and took shape was invaluable. They formed a good team, which provided expertise in different aspects of the dissertation. Bob introduced me to real wages as his research assistant and then generously asked me to co-author a paper with him. One could not have asked for a better guide in how to research, write and publish an academic journal article. Deborah started me down the path of this dissertation when she encouraged me to write a short-essay on measurements of living standards in history in my first year in Oxford. I have benefited from her support and constructive criticism ever since, especially as I navigated the complexities of studying children's growth in history. I should also note that chapter three would have just been an afterthought of reading *The Changing Body* if Deborah had not encouraged me to develop the ideas further.

I am also grateful to those people and organizations that helped fund my graduate studies at Oxford. My parents, Mark and Deana Schneider, and grandparents, Dorothy and Rudy Schneider, partially helped me fund my MPhil, making graduate study possible without crippling amounts of debt. In my DPhil, I was funded by the Clarendon Scholarship and by Nuffield College. Money for research travel was provided by the Economic History Society, Santander and Nuffield College. I also benefitted both professionally and financially from the teaching experience I gained at Oxford and am very grateful to those who made these opportunities available to me: Deborah Oxley, Bob Allen and Kevin O'Rourke.

I am also appreciative of the wonderful scholarly community of economic and social historians in Oxford. I learned a lot from discussions with colleagues, and Friday drinks certainly made my graduate career more exciting and relaxed than it otherwise might have been. I am also grateful to the members and fellows of Nuffield College who provided me with an office, interesting discussions at lunch and enough social activity to keep me sane.

This dissertation benefitted tremendously from the comments of a wide variety of people in a number of different venues. Chapter one was improved based on the comments of participants in the Household Decision Making in History Workshop at All Souls College, Oxford and seminar participants at Lund University and the HPSS group at the University of Cambridge. Special thanks are due to Jane Humphries who encouraged the project and provided a copy of her forthcoming paper 'Lure of Aggregates' in the *Economic History Review*. Chapter two was greatly improved through presentations at the London FRESH meeting (2012) and at the Institute for Historical Research in London. Chapter three benefitted from comments from Jane Humphries, Francisco Beltran, Arthur Downing, Hans-Joachim Voth, two anonymous referees for the *European Review of Economic History*, and participants at the 2012 *EREH* Fast-Track Meeting in London. Chapter four was greatly improved through a series of discussions with Deborah Oxley initially even before she became my supervisor. Chapter five was strengthened by comments from Christiaan Monden, seminar participants in Tübingen and Utrecht and at Nuffield College, Oxford and the LSE as well as conference participants at the EHA Conference in Vancouver, the Institutions and the History of Health and Healing Workshop in Dublin and the EHS meeting in York. Of course any mistakes are entirely my own.

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ABBREVIATIONS

BMI	Body mass index
BMR	Basal metabolic rate
CBA	City of Boston Archives
CBR	Crude birth rate
CDC	United States Center for Disease Control
CHA	Chartres, Holderness and Allen
FAO	Food and Agriculture Organization of the United Nations
g Ag	Prices converted into grams of silver
GDP	Gross domestic product
GH	Growth hormone
HDI	Human development index
IGF-I	Insulin-like growth factor I
LBW	Low birth weight
LMA	London Metropolitan Archives
ME	Metabolizable energy
MGRS	Multicentre Growth Reference Study
MSH	Marcella Street Home
NCHS	United States National Center for Health Statistics
NME	Net metabolizable energy
OLS	Ordinary least squares regression
PAL	Physical activity level
PPR	Parity progression ratio
SMBM	Signed Minutes of the Board of Management
TBA	Turner, Beckett and Afton
UN	United Nations
WHO	World Health Organization
WLSD	West London School District
WR	Welfare Ratio

INTRODUCTION

There is a very long tradition of attempts to measure the well-being of individuals and populations in the past. Many different methods have been developed to determine living standards. Many historians have painstakingly reconstructed GDP per capita for historical periods: the work of Deane and Cole, Crafts, Harley, and Broadberry *et al*. stands out in this regard.[1] However, GDP per capita is a problematic measure of living standards because it does not value leisure, health, unpaid employment, or 'improvements in the quality of goods and services unless they were reflected in prices'.[2] Thus, other economic historians such as Phelps Brown and Hopkins, Feinstein, Allen and Clark estimated real wages for different groups within society such as agricultural labourers, building labourers, and craftsmen, or for

[1] Deane and Cole, *British Economic Growth*; Crafts, *British Economic Growth*; Harley, 'Reassessing the Industrial Revolution'; Broadberry *et al.*, 'British Economic Growth'.
[2] Floud *et al.*, *Changing Body*, p. 9.

indices of wages across the entire economy.[3] Finally, studies of income inequality have shown how the changing distribution of income in society over time affected the living standards of different groups.[4] These methods provide a very interesting glimpse at how the purchasing power of various groups in society changed over time, but they have been criticized for focussing solely on monetary factors and ignoring other fundamental elements of the standard of living such as health.[5]

In response to these criticisms, other historians began to develop new methodologies for measuring living standards and these expanded over the years. The work of the Cambridge Group and other historical demographers greatly increased our understanding of mortality change in history and around the world.[6] Likewise, Fogel, Steckel, Floud and Komlos pioneered the use of adult stature as a proxy for the nutritional status of a population.[7] The field of anthropometric history has expanded greatly since this early work to incorporate women's stature, children, body mass index and even the relationship between height and mortality.[8] Although controversial at first, the mean stature of a population has now been generally accepted as a useful proxy for health, though it is a complicated measure influenced by nutrition, disease and work and is sometimes difficult to interpret. Finally, in the past ten years, Floud *et al.*, Muldrew, Allen and Broadberry *et al.* have all produced estimates of the amount of calories available to the English population per capita in certain benchmark years. These estimates, which unfortunately vary substantially both in level and in

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[3] Phelps Brown and Hopkins, 'Seven Centuries'; Feinstein, 'Pessimism Perpetuated'; Allen, 'Great Divergence'; Allen *et al.*, 'Wages'; Allen *et al.*, 'Colonial Origins'; Clark, 'Long March'; Clark, 'Condition'.

[4] Milanovic *et al.*, 'Pre-Industrial Inequality'; Lindert and Williamson, 'Revising'; Allen, 'Engels' Pause'.

[5] Floud *et al.*, *Changing Body*, p. 7-8.

[6] Wrigley and Schofield, *Population History*; Wrigley *et al.*, *English Population History*; Bengtsson *et al.*, *Life under Pressure*; Woods, *Demography*; Humphries, 'Bread and a Pennyworth'; McNay *et al.*, 'Excess Female Mortality'.

[7] Floud *et al.*, *Height*; Steckel, 'Slave Height'; Fogel, 'New Sources'; Komlos, 'Stature'.

[8] Nicholas and Oxley, 'Living Standards'; Harris, *Health*; Horell *et al.*, 'Measuring Misery'; Cuff, 'Body Mass Index'; Fogel, *Escape from Hunger*.

trend, provide a general view of changes in energy availability over time.[9] Others have also measured the caloric value of workhouse diets and measured the importance of the micro-nutrient content of representative diets to see how this element of the standard of living changed.[10] Clearly, the historical study of living standards has expanded far beyond traditional income measures.

In recent years there have also been attempts to incorporate Sen's insights into measures of historical living standards. Sen essentially argued that instead of focusing on the 'functionings' or the outcomes of measurements of well-being such as mortality and literacy rates, GDP per capita, etc., economists (and economic historians) should measure people's capabilities, or the opportunities that they have to achieve certain outcomes.[11] Sen's ideas led to the formulation of the human development index, which combines life expectancy, educational attainment, and income and has been calculated historically for developed countries and Africa since the late nineteenth century by Crafts and Prados de la Escosura.[12] In addition, de Moor and van Zanden have argued that women's empowerment in the late medieval and early modern periods led to the development of the European Marriage Pattern, which assured lower fertility, higher wages, and more rapid human capital formation in Northwest Europe where it was most common.[13] Van Zanden is currently expanding the project in order to better incorporate a capabilities approach to historical living standards.[14]

Each new method for measuring living standards and its subsequent employment in historical research has brought economic historians closer to capturing

[9] Floud *et al.*, *Changing Body*; Muldrew, *Food*; Allen, 'English'; Broadberry *et al.*, 'British Economic Growth'.
[10] Shammas, 'Food Expenditures'; Gazeley and Horrell, 'Nutrition'; Horrell and Oxley, 'Bringing'.
[11] Sen, *Development as Freedom*; Sen, *Standard of Living*, p. 16.
[12] Crafts, 'Human Development Index'; Prados de la Escosura, 'Human Development'.
[13] de Moor and van Zanden, 'Girl Power'.
[14] van Zanden, 'In Good Company'.

a very broad understanding of well-being in the past. This dissertation continues in this long tradition by attempting to integrate the household and children into our methods and theoretical understanding of living standards.

These elements have not been ignored in the literature. A few of the highlights of the literature on the household would include the following. In response to the real wage literature, which had exclusively focused on male wages, Horrell and Humphries measured the household income of families from household budgets from 1787 to 1865, finding that household income grew at lower rates than male income across the Industrial Revolution.[15] Humphries has also recently objected to Allen's characterization of a high-wage economy based on male earnings, arguing that assumed historical family sizes were too small, it did not allow enough calories for the family's minimum consumption requirements including women's additional consumption requirements during pregnancy and lactation, and it did not allow for female headed households, who were in many ways the most vulnerable households in the population.[16] Horrell and Oxley have also challenged historians to consider how resources are allocated in the household rather than assuming that the household is an equal, unitary structure. They have found evidence that in Britain household members bargained for resources with those members that had access to employment outside the household having a stronger position than those who did not.[17] All of these insights are very important, but it has not always been possible to incorporate the complications these ideas raise within current methodological frameworks. This is especially true for time periods when the types of evidence that the authors above relied upon are not available. Part one of the dissertation attempts to measure how the household considerations presented above would affect the real wages calculated for

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[15] Horrell and Humphries, 'Old Questions'.
[16] Humphries, 'Lure'.
[17] Horrell and Oxley, 'Bargaining'.

England in the early modern period. Part two also deals with some of these issues by calculating the global energy costs of digestion, pregnancy and lactation in the British economy between 1700 and 1909 and adjusting the calories available per capita estimated by authors using the energy cost accounting methodology to reflect these additional energy costs.

There is also a long history of studying children's anthropometric measures to understand children's growth pattern and health. Early in the anthropometric movement in history, Steckel studied the 'peculiar' growth pattern of slaves in the antebellum American South, who experienced massive catch-up growth over their growing years.[18] Later, Floud *et al.* examined the growth of British boys in the Marine Society and at the Sandhurst Military Academy from the mid-eighteenth to mid-nineteenth centuries, and Harris used the aggregate statistics provided by school medical officers to construct changes in child stature across the first half of the twentieth century.[19] Hatton and his co-authors have also recently written several papers about child stature, arguing that differing infant mortality rates around Britain left children significantly stunted and that children from larger families were more stunted in the first half of the twentieth century.[20] Again, these studies have presented interesting and useful results. It will be argued here, in part three, that these results can perhaps be better understood within an adaptive framework for growth and with the insights of a longitudinal analysis of children's growth developed in part three.

Thus, the seemingly disparate parts of the dissertation are in the end unified by a desire to improve the theoretical and methodological basis for studying how labour opportunities and decisions made at the household level affected the living standards of the household as a group and individuals within it, especially children.

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[18] Steckel, 'Peculiar Population'.
[19] Floud *et al.*, *Height*, pp. 163-182; Harris, *Health*, pp. 84-89; Harris, 'Gender', (1998).
[20] Hatton, 'Infant Mortality'; Hatton and Martin, 'Effects'; Hatton and Martin, 'Fertility Decline'.

As mentioned above, the dissertation is broken into three parts consisting of five chapters total. The first part develops a Monte Carlo simulation based on early modern English demographic data to tackle three problems. First, it tests some of the simplifying assumptions of Allen's real wage methodology, namely his estimate of average family size, which is held constant over time, his exclusion of women and children's income from his calculations, and his exclusion of female-headed households. Second, because each family's welfare ratios (real wages) are measured across the family life cycle, the family's welfare ratios can be recorded for the median or the minimum point in the family life cycle. Thus, we can know how families were doing at an average point in their life cycle and how they were doing at the hardest point in their life cycle when they were supporting the largest number of children. Third, the simulation allows a distribution of families to be predicted, so it is possible to measure the adequacy of the male breadwinner wage by considering the number of families below a certain welfare ratio threshold and the inequality in real income that is determined by family size and composition. The Monte Carlo simulation focuses on two periods, 1650-1700 and 1750-1800, limiting the arguments that can be made about the nineteenth century.

Both chapters in part one use demographic data drawn from Wrigley *et al.*'s family reconstitutions of 26 English parishes to adjust Allen's real wages to the changing demography of early modern England.[21] Using parity progression ratios (a fertility measure) and age specific mortality for children and parents, model families are predicted in two reference periods 1650-1700 and 1750-1800. These models yield two levels of interesting results. At the individual family level, we can measure how different families' real wages changed over the family life cycle as additional children

[21] Wrigley *et al.*, *English Population History*; Allen, 'Great Divergence'; Allen, *British Industrial Revolution*.

were born. At the aggregate level, we can predict thousands of families using Monte Carlo simulation, creating a realistic distribution of median family real wages in the economy. There are two main findings. First, pregnancy and lactation do not create cyclical effects in the family's income because the consumption of children is slowly added to the household's from pregnancy to nursing to weaning. Instead, most families' welfare ratios decline steadily across the family life cycle until children begin to leave the household, increasing the welfare ratios. Second, Allen's real wages understate or match the median of the predicted demography-adjusted welfare ratio distributions.

Chapter two complicates the model developed in chapter one to better understand the way households earned their living. Poor households in eighteenth-century England used a number of strategies to combat poverty and increase their income formally in the labour market and informally outside it. These strategies included sending women and children into the labour market, allocating resources unequally within the household, self-provisioning on garden plots of land, appealing to the poor law for aid, and expanding the number of days worked by household members. These strategies constituted an economy of makeshifts, which allowed the poor to at least scrape by and even reach respectable levels of consumption for the period. While social and economic historians have studied these individual strategies for eighteenth-century England, few historians have been able to integrate them all to determine how these strategies influenced the income of the average family and how large a gap had to be filled by the economy of makeshifts for the poor to reach target consumption levels. This chapter seeks to integrate these strategies in such a way.

Thus, the original Monte Carlo simulation is expanded to incorporate women and children's labour force participation and the unequal distribution of resources within the household. I then use Monte Carlo simulation to predict a distribution of 30,000 realistic families and their corresponding welfare ratios for the period 1750-1800. Using the predicted distributions, I measure the influence of women and children's labour force participation and unequal household distribution on the family's welfare ratios and their implied information about the availability of energy for work. Finally, for each level of women and children's labour force participation and each household resource distribution assumption, I calculate the level of self-provisioning, poor law support, or additional days of work necessary for the family to reach a certain target consumption level.

The results suggest that at the median welfare ratio in the life cycle, agricultural labourers' families could get by at a low consumption level through either self-provisioning or working a few more days. However, at the minimum welfare ratio in the life cycle, this was much more difficult, and the poor law likely had to play a strong role in keeping these families afloat. Women and children's labour force participation increased the average family welfare ratios by 31 to 48 per cent depending on the specification used, and could even put agricultural labourer families within stabbing distance of Allen's respectability level of consumption. However, even with women and children's labour force participation, families still struggled to make ends meet at the low point in the welfare ratio curve. Thus, the results highlight the precarious position of agricultural labourers in the late eighteenth century, the importance of women and children's labour participation in keeping poor families afloat, and the importance of life-cycle poverty, which is ignored when real wages are only measured for the average family at the average point in the life cycle. Thus, the results from part one suggest that Allen's real wage estimates are approximately correct when measuring the welfare of the average family at the average point in the life cycle, but his figures hide the difficulties of the same average family when it was at its largest.

Part two of the dissertation consists of one chapter. The chapter provides a critical review of some of the methods used for calculating the number of calories available in the British economy from 1700 to 1909. All of the authors working with this method have made judicious use of agricultural output data and trade statistics, and their results provide an interesting additional welfare measure with which to compare trends in real wages, nutritional status (stature) and mortality rates. However, the figures are biased somewhat because they do not account for the costs of digestion on the one hand and the costs of lactation and pregnancy on the other. Focusing primarily on Floud *et al.*'s figures, with a brief robustness check from Muldrew's figures, I systematically adapt Floud *et al.*'s figures to measure the influence of these factors on the overall supply of calories in the economy.[22] Digestion costs arise because the body has more difficulty breaking down certain components of food (dietary fibre and protein) than others. These additional costs are not incorporated in the Atwater factors Floud *et al.* and Muldrew used to convert food production into calories. Thus, their figures overestimate the amount of calories that people could absorb from their food. Adjusting for these digestion costs is complicated by the fact that digestion costs directly relate to the diet being consumed, which changed over time. The average bread and other cereals consumed in the early eighteenth century contained much more dietary fibre than the average bread consumed in the early twentieth century. Thus, it is not possible to merely adjust Floud *et al.*'s figures downward by a fixed percentage. After making estimates of digestion costs in each benchmark year, digestion costs reduce the average calories

[22] Floud *et al.*, *Changing Body*; Muldrew, *Food*.

available per capita by 12.7 per cent in 1700 but only by 4.9 per cent in 1909 again because of the changing composition of the diet.

The energy costs of pregnancy and lactation could have also been substantial since women require an additional 475 calories per day during the final trimester of pregnancy and 675 calories per day during the first six months of nursing. These costs were measured for the population of England by calculating the number of pregnant women in each benchmark year from the crude birth rate and the number of children needing to be nursed from infant and early childhood mortality rates. These costs were lower than the digestion costs only reducing average per capita calorie consumption by 2.5 per cent. Taken together the digestion, pregnancy and lactation adjusted figures suggest a more pessimistic level of calorie availability than Floud *et al.* and Muldrew's argue.

Part three of the dissertation attempts to advance the theoretical framework and introduce a new methodological strategy for studying children's growth in historical populations, hopefully making some interesting points about the growth pattern of antebellum American slaves and gender differences in health in late-nineteenth and early-twentieth century Britain and America.

Chapter four presents a new adaptive framework for understanding children's growth in the past. Drawing upon the recent work of Gluckman and Hanson and their co-authors on adaptive responses in relation to growth, I present four adaptive mechanisms that affected the growth patterns of children.[23] First, acute poor prenatal conditions can trigger an immediate adaptive response where the foetus slows its growth until conditions improve. Second, the general or average conditions *in utero* lead to a predictive adaptive response where the foetus develops assuming that the

[23] Gluckman and Hanson, 'Evolution'; Gluckman and Hanson, 'Consequences'; Gluckman *et al.*, 'Environmental Influences'.

postnatal environment will closely match prenatal conditions. Thus, the metabolism and growth trajectory of a child is programmed during the prenatal period: children experiencing good conditions *in utero* would have a higher metabolism and growth trajectory than their counterparts facing poor conditions. Third, a nutritional or disease shock in childhood or adolescence can lead to an immediate adaptive response where growth is temporarily slowed until the child has enough energy to continue growing. Finally, poor conditions before the pubertal growth spurt can prompt the child to delay his/her growth spurt until conditions improve. All of these responses are adaptive because they increase the probability that a child will survive to reproductive age and produce viable offspring, but this does not mean that there are no costs involved. These stunting events have negative consequences for the long-run mortality risk of the child.

Having discussed the framework in great detail, I then use it to reinterpret the growth pattern of American slaves.[24] I argue that the mismatch between relatively good conditions *in utero* and absolutely appalling conditions in infancy and early childhood led slave children to become incredibly stunted by age three or four. However, this age, slave children experienced rapid catch-up growth, first because their immune systems had become more developed and had adapted to the poor disease environment and later because their diet improved tremendously when they entered the labour force around age ten. Thus, American slave children were able to experience rapid catch-up growth because they were prenatally programmed for a higher metabolism and growth trajectory. The chapter concludes by setting out some stylized facts about children's growth in the past and pointing toward areas of future research.

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[24] Steckel, 'Peculiar Population'.

Chapter five measures the relative deprivation of children admitted to the Marcella Street Home in Boston, MA (1889-1898) and the Ashford School in London, UK (1908-1917) by studying their longitudinal growth, a first for a historical study. By comparing the catch-up growth of boys and girls, a proxy for health and nutritional conditions before entering the institutions, I find that in both the Marcella Street Home and the Ashford School girls experienced faster height gain relative to modern standards than boys. There are three potential explanations for this result. First, girls could have been treated better than boys in the schools, but this does not seem to have been the case. Second, girls might have a greater natural propensity for catch-up growth; however, there is no scientific consensus on this question, so we can tentatively reject this explanation. Therefore, it seems likely that girls were relatively worse off when compared to boys. The most parsimonious explanation for girls' relative poor health is that girls may have been discriminated against in the allocation of household resources before entering these institutions. This finding is contradictory to household budget studies, which found no gender discrimination in household resources.[25] Female deprivation could have played a role in slowing the progression of improvements in health across the late nineteenth and early twentieth centuries, at least for a portion of the population. Thus, it was only when resources became incredibly abundant in the twentieth century and female deprivation disappeared that the biological living standards of the population could increase substantially.

As a final remark, I should note that a version chapter one was published in the January 2013 issue of *Explorations in Economic History*.[26] The paper version is slightly shorter with fewer figures and without the illegitimacy robustness check.

[25] Horrell and Oxley, 'Crust and Crumb'; Logan, 'Family'; Harris, 'Gender', (1998).
[26] Schneider, 'Real Wages and the Family'.

Chapter three is also forthcoming in the *European Review of Economic History* and will likely be published in the summer of 2013.[27]

[27] Schneider, 'Inescapable Hunger'.

Part I:

Testing the Assumptions of Real Wages with Monte Carlo Simulation

Chapter One:

Real Wages and the Family: Adjusting Real Wages to Changing Demography in Pre-modern England

The flurry of scholarship in the last decade reconstructing historical real wages around the world has fundamentally changed the way economic historians understand the Great Divergence debate. By comparing nearly identical consumer price baskets and labourers' wages, first Allen and then his collaborators were able to construct comparable real wages for most parts of the world including North America, Latin America, Europe, Africa, India, and China.[1] These papers have generally refuted the California school position that parts of China and India were just as developed as Europe in the eighteenth century. Real wages were quite low around the world from the sixteenth century onwards with notable exceptions in Britain and the Netherlands.

This scholarship has been tremendously helpful in reconstructing the economic history of the world, but in order to make international comparisons, Allen and his co-authors made certain assumptions about family size and composition over

[1] Allen, 'Great Divergence'; Allen, *et al*., 'Wages'; Allen, *et al*., 'Colonial'.

time and across countries. Allen based his family size assumptions on an English gardener from Ealing, who had a wife and four small children, described by Sir Frederick Eden in *The State of the Poor* in the 1790s. Therefore, Allen assumed that the average family size and composition around the world was similar and consisted of the equivalent energy needs of three adult males.[2] Humphries has recently criticized Allen's constant family size as being too low for England, thus making his English real wage estimates too high.[3] There is therefore room in the literature for a careful reworking of the relationship between family size and real wages.

In general Allen's family size assumption may be justifiable because of the paucity of detailed demographic information that would allow historians to precisely vary family size over time for many countries. Family size is also difficult to proxy with other demographic variables because it depends not only on fertility measures but also on the mortality of children. However, there is good demographic data for England from which we can attempt to understand how changing family size influenced real wages over time. This chapter will use demographic data drawn from Wrigley *et al.*'s family reconstitutions of 26 English parishes to adjust Allen's real wages to the changing demography of early modern England.[4] Using parity progression ratios (a fertility measure explained later) and age specific mortality for children and parents, model families are predicted for two reference periods, 1650-1700 and 1750-1800. We can then study how the changing size and composition of an individual family affected its 'welfare ratio'[5] over the family life cycle. The welfare ratio is the wage earned by the father divided by the consumption requirements of the

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[2] Allen, *British Industrial Revolution*, p. 29.
[3] Humphries, 'Lure'.
[4] Wrigley, *et al.*, *English Population History*.
[5] Throughout the chapter, real wage will be used to refer to inflation adjusted male wages. Welfare ratio will be used to denote the family size and inflation adjusted male wage, i.e. the purchasing power of a family with certain demographic characteristics.

family in any given year. In addition, Monte Carlo simulation can be employed to predict thousands of families in each reference period, providing a realistic distribution of welfare ratios based on the different families possible. These distributions can then be compared with Allen's original figures to measure the influence of changing family size and structure on real wages.

1.1 Previous Attempts

There have been two previous attempts to account for family size in real wage calculations. First, in their paper on real wages and the industrious revolution, Allen and Weisdorf attempted to account for fluctuations in family size by using the net reproduction rate and the dependency ratio of the population to recalculate the size of the household in different years. The net reproduction rate is the average number of daughters surviving to reproductive age that would be born to a female if she conformed to the age-specific fertility and mortality rates throughout her lifetime. The dependency ratio is the number of people aged 15 and under and aged 60 and older divided by the people in the population aged 16-59. To calculate family size from these proxies, Allen and Weisdorf held that family size would be equal to two adults plus the net reproductive rate, and they used the dependency ratio as an index to calculate family size.[6]

Allen and Weisdorf's use of these proxies was a good first attempt to understand the effect of changing family size on household consumption requirements, but it is insufficient for several reasons. First, they did not adjust the net reproduction rate to account for males that might have been born in the household. Two adults plus the net reproduction rate would be the father, mother, and the

[6] Allen and Weisdorf, 'Industrious Revolution', pp. 723-26.

daughters born to the household but would not include sons. Therefore, a better measure might have been two plus the net reproduction rate times two, assuming that the same number of sons and daughters were born. They also do not allow children at different ages to influence the family's consumption differently. Teens needed many more calories than new-borns, and counting them the same clearly would influence their results. In addition, the dependency ratio is not a very good proxy because it is a measure of the cost of those not of working age on those of working age; it thus spreads the burden of those not working across the entire population instead of measuring the burden of dependents on families in society. These problems clearly limit the usefulness of the adjustment in the Allen-Weisdorf paper.

Jane Humphries has also attempted to account for changing family sizes on real wages in her paper criticizing Allen's method. She argued that the Ealing gardener's family was not representative of the English population, where larger family sizes were more common. To support this argument, she presented completed family size and sibling group size figures computed from the Cambridge group reconstitutions, which were much larger than Allen's model family.[7] However, these figures are also problematic. In the context of the Wrigley *et al.* family reconstitutions, a completed family is one where the mother survived to age 50. Thus, using these figures alone would overestimate family size since many women died before the age of 50. Likewise, with high infant and childhood mortality rates, many children would have died before adding substantially to the household's consumption requirements. Finally, although women may have had many children, it is doubtful that all of them were a burden on the household at the same time because birth spacing was quite wide. Clearly, previous attempts to understand how family size

[7] Humphries, 'Lure', p. 18.

influenced real wages have provided an interesting starting point for discussion, but a more complex method that incorporates both fertility and mortality is necessary to truly understand what the influence might be.

1.2 Real Wages, Consumption and Family Income

Before describing the predictive model in detail, it is first necessary to describe how family consumption and the family's welfare ratio over the family life cycle has been calculated in this chapter. The family's consumption was determined by the number of people needing to be fed, clothed and housed and by the additional consumption requirements of pregnancy and lactation. In order to measure this level of consumption uniformly, it was necessary to convert the consumption of children and adults of both sexes and at different ages into consuming units, the equivalent consumption of an adult male.[8] Fortunately, the Food and Agriculture Organization (FAO) has published recommended guidelines of caloric consumption for male and female children and adults, which allow these conversions to be calculated.

I have followed Floud *et al.*'s conventions for converting older men and adult women to consuming units.[9] However, Floud *et al.*'s categorization of children into five-year age groups is too broad to usefully capture the increasing burden of a child on a family as it grows. Therefore, I have used the FAO recommended calorie requirements of male and female children and adolescents, provided in Table 1.1 above. These energy requirements are based on the average weight of children at each age and on their estimated PAL given the typical activity level and the rate of growth at each age. These figures have been updated between the 1985 FAO report that

[8] Allen, 'Great Divergence'; Floud, *et al.*, *Changing Body*, pp. 43-6.
[9] Floud, *et al.*, *Changing Body*, pp. 46, 166.

Floud, *et al.* used and the 2004 FAO report, so it is worth reporting them here.[10] The calorie requirements of children at each age were divided by the 2900 calories required by an adult male aged 18-29.9 to produce the relevant consuming unit equivalent.[11] These calorie requirements are based on modern populations with modern body sizes, which were different than those in the past. However, the calorie requirements of men relative to women and children were likely similar if not identical in the past, and there is little evidence from before the nineteenth century upon which to base historical estimates anyway, especially for female adult heights and weights and children's growth.

Table 1.1: Energy requirements of male and female children.

	Males				Females			
Age (years)	Total Energy Expenditure (kcal/day)	Energy Deposited for Growth (kcal/day)	Daily Energy Requirement (kcal/day)	Consuming Unit Equivalent	Total Energy Expenditure (kcal/day)	Energy Deposited for Growth (kcal/day)	Daily Energy Requirement (kcal/day)	Consuming Unit Equivalent
			(1) + (2)	(3) / 2900			(5) + (6)	(7) / 2900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1-2	934	14	948	0.3269	851	14	865	0.2983
2-3	1,117	11	1,129	0.3893	1,035	12	1,047	0.3610
3-4	1,240	12	1,252	0.4317	1,145	11	1,156	0.3986
4-5	1,349	11	1,360	0.4690	1,231	10	1,241	0.4279
5-6	1,456	11	1,467	0.5059	1,320	10	1,330	0.4586
6-7	1,561	12	1,573	0.5424	1,415	13	1,428	0.4924
7-8	1,679	14	1,692	0.5834	1,537	17	1,554	0.5359
8-9	1,814	16	1,830	0.6310	1,678	21	1,698	0.5855
9-10	1,959	19	1,978	0.6821	1,831	23	1,854	0.6393
10-11	2,128	22	2,150	0.7414	1,981	25	2,006	0.6917
11-12	2,316	25	2,341	0.8072	2,123	25	2,149	0.7410
12-13	2,519	29	2,548	0.8786	2,250	26	2,276	0.7848
13-14	2,737	33	2,770	0.9552	2,355	24	2,379	0.8203
14-15	2,957	33	2,990	1.0310	2,430	19	2,449	0.8445
15-16	3,148	30	3,178	1.0959	2,478	12	2,491	0.8590
16-17	3,299	24	3,322	1.1455	2,499	5	2,503	0.8631
17-18	3,396	15	3,410	1.1759	2,503	0	2,503	0.8631

Notes: The baseline consuming unit energy requirement was held to be 2900 kcal/day, which was the recommended energy requirement for an adult male aged 18-29.9 with a BMI of 21 and a PAL of 1.75. Sometimes columns do not add precisely because of rounding in the original FAO report.

Sources: FAO, 'Human', pp. 26-27.

[10] FAO, 'Human', pp. 26-7.
[11] FAO, 'Human', p. 41.

In determining the costs of lactation and pregnancy, I have followed Humphries and the FAO guidelines.[12] Being pregnant raises a woman's daily energy requirements differently in each trimester of pregnancy: 85 kcal in the first, 285 kcal in the second, and 475 kcal in the third.[13] This averages to 282 additional kcal/day throughout the pregnancy and 211.25 kcal/day on an annual basis. A woman needs an additional 675 kcal/day in the first six months of breast-feeding and 460 kcal/day after the first six months until weaning, which is assumed to take place at 18 months.[14]

Using the calorie requirements for adults and children at various ages and for pregnancy and lactation, it is possible to precisely calculate a family's consumption needs throughout the family life cycle. This method provides a more dynamic picture of household consumption than Allen's original construction of real wages, where he assumed a constant family size.

Both of Allen's consumer price baskets, the subsistence and respectability baskets, will be employed in this chapter (Table 1.2). The subsistence basket was designed as a theoretical basket of goods with only enough food and non-food items for survival (1,938 calories per consuming unit). Thus, if a family could only afford to buy the subsistence basket – a subsistence welfare ratio of one – they had enough food to survive in the short term. It should be noted that Allen's subsistence basket truly marks the subsistence level. It would be very difficult for an active adult male to survive on less than 1,938 calories per day. The respectability basket, on the other hand, was based on the Eden household budgets providing a higher level of calories and protein and a more historically representative basket of goods. Allen used it to

[12] Humphries, 'Lure', p. 13.
[13] FAO, 'Human', p. 59.
[14] Wrigley *et al.* found evidence that average age of weaning was 19 months in the reconstitution parishes. Wrigley *et al.*, *English Population History*, pp. 489-92; FAO, 'Human', p. 65.

demarcate a respectable living standard with nice foods such as bread, beer, cheese and eggs, which British people and especially Londoners had come to expect by the end of the eighteenth century. If a family could purchase the respectability basket – a respectability welfare ratio of one – then they could afford to feed everyone in the family 2500 calories per consuming unit of this fancier food.

Table 1.2: Allen's Respectability and Subsistence Basket of Goods

	Panel A: Respectability Basket of Goods			Panel B: Subsistence Basket of Goods		
	Quantity per Consuming Unit per Year	Nutrients per Day		Quantity per Consuming Unit per Year	Nutrients per Day	
Good		Calories	Grams of Protein		Calories	Grams of Protein
Bread	234 kg	1,571	64	—	—	—
Oatmeal	—	—	—	155 kg	1,657	72
Beans/peas	52 L	370	28	20 kg	187	14
Meat	26 kg	178	14	5 kg	34	3
Butter	5.2 kg	104	0	3 kg	60	0
Cheese	5.2 kg	54	3	—	—	—
Eggs	52 each	11	1	—	—	—
Beer	182 L	212	2	—	—	—
Soap	2.6 kg	—	—	1.3 kg	—	—
Linen	5 m	—	—	3 m	—	—
Candles	2.6 kg	—	—	1.3 kg	—	—
Lamp oil	2.6 L	—	—	1.3 L	—	—
Fuel	5.0 M BTU	—	—	2.0 M BTU	—	—
Rent	5% allowance	—	—	5% allowance	—	—
Total		2,500	112		1,938	89

Sources: Allen, *British Industrial Revolution*, pp. 36-7.

Allen's building labourer and agricultural labour wage series for southern England will be used to calculate welfare ratios in the simulations.[15] These two wage series best reflect the demographic information available in the family reconstitution parishes, which were made up of rural and small town parishes and did not include any parishes from London. They also reflect two large groups of the labouring poor whose wages followed different trajectories across the early modern period: building labourers' real wages improved whereas agricultural labourers' real wages stagnated

[15] Allen, 'London', spreadsheet.

or decreased. Because the focus of this study is the role of changes in family size and age structure on the family's welfare ratio, prices and wages were held constant at fifty-year average levels. The fifty-year average nominal prices and wages as well as welfare ratios are reported in table 1.3.

In order to calculate the family's welfare ratio, I assumed, following Allen, that the family's income came only from the day wages of the father, a building or agricultural labourer who worked 250 days per year. This income was divided by the cost of buying either the subsistence or respectability basket for a family based on the consumption requirements of the household (family size). The additional food costs required for pregnancy and lactation were priced in terms of the food component of the basket rather than the entire basket. Thus, it was possible to calculate the welfare ratio of a family in every year of the family life cycle as additional children were born, parents and children died, and children left the household

Table 1.3: Allen's nominal prices, wages and welfare ratios.

	Respectability Basket		Subsistence Basket	
	1650-1700	1750-1800	1650-1700	1750-1800
Food Cost of the Basket per Day (1 consuming unit)	1.59	1.89	0.46	0.58
Non-Food Cost of the Basket per Day (1 consuming unit)	0.25	0.29	0.14	0.16
Total Cost of the Basket per Day (1 consuming unit)	1.84	2.19	0.60	0.74
Southern England Agricultural Labourer's Day Wage	5.57	5.89	5.57	5.89
Southern England Building Labourer's Day Wage	5.63	8.36	5.63	8.36
Allen Agricultural Labourer's Welfare Ratio	0.66	0.59	2.02	1.73
Allen Building Labourer's Welfare Ratio	0.67	0.83	2.04	2.45

Notes: Prices and wages listed in grams of silver. See text for welfare ratio calculation method.

Sources: Allen, 'London', spreadsheet.

1.3 The Model

Models of all types are simplifications of a complex reality. This one is no different, so it is important to begin the discussion of the model by highlighting some key simplifying assumptions necessary to produce the model. First, welfare ratios, as

Allen designed them, were meant to capture the living standards of families, and therefore, welfare ratios are only calculated for families with children and at least one parent living. The family life cycle begins when a woman becomes pregnant and ends when the final child leaves the household. Thus, unmarried individuals, childless married couples, married couples whose children have left the household or died, and orphans (children who had lost both parents) are not included in the model. Second, all families start out with a married couple removing illegitimacy from the model. The fertility measures in Wrigley *et al.* pertain only to legitimate fertility, so it is better to limit the model in this way. Illegitimacy was relatively rare in the reference periods used in this chapter, and the mortality rates of illegitimate children were substantially higher than those for legitimate children, making the addition of illegitimate births particularly difficult to add into the model. Third, no remarriage is allowed. Historical information about remarriage is highly problematic and does not allow for the systematic incorporation of remarriage into the model. Thus, if one parent died, the family was forced to live on the other parent's income for the rest of the family life cycle. Fourth, resources are allocated equally in the household based on the calorie consumption requirements for individuals of each sex at specific ages. This includes giving women more calories when they are pregnant or lactating. This assumption is problematic because it is unclear whether calories were actually allocated within the household in this way. The male breadwinner could have taken more of the family resources for himself, leaving the rest of the members of the family with less.[16] Finally, average English demography is applied to the families of labourers that are targeted by Allen's real wages. Class targeted demographic figures do not exist for the early modern period, so this is an unfortunate but necessary assumption.

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[16] Horrell, *et al.*, 'Measuring Misery', p. 95.

Having discussed how a family's welfare ratio is calculated and highlighted some key assumptions of the model, it is now possible to describe the model used to predict families. The model can be broken into three main elements, fertility, mortality, and children leaving the household, which all strongly influenced family size. The model will be predicted for two reference periods: 1650-1700 and 1750-1800. Unfortunately the published demographic figures in Wrigley *et al.* do not allow for a more granular analysis at this point.

To begin with fertility, if a couple is married, it is possible to use parity progression ratios (PPRs) to predict whether children are born in a family. PPRs are simply the percentage of women who have *another* child after giving birth to *n* number of children (*n* becoming the 'parity'). For example, the PPR at parity one is the percentage of women who have a second child after their first child is born; the PPR at parity two is the percentage of women who go on to have a third child; and so on. PPRs are always less than unity because a certain percentage of the population is or becomes sterile. Thus, PPRs normally decrease with each additional child born and as the woman becomes older. Wrigley *et al.* provide non-age specific PPRs from bachelor/spinster completed marriages for hundred-year periods across early modern England.[17] PPRs from completed marriages were employed because they establish a baseline level of fertility for women who did not die prematurely, though the women will be given a probability of premature death below. Thus, the PPRs from 1650-1749 and from 1750-1837 were used to predict families in the two reference periods. In order to limit the families to those with children, the PPR at parity zero was assumed to be equal to unity, eliminating entry sterility (married couples who were not able to conceive from the beginning of their marriage). This means that all couples in the

[17] Wrigley, *et al.*, *English Population History*, p. 403.

model had at least one child. Finally, women were assumed to have completed reproduction and reached menopause by age 50, a common assumption in historical demography.[18]

Family size and the number of children being supported in the household at one time is also influenced by the birth spacing between each successive child. Wrigley *et al.* provide birth spacing estimates, which varied based on the age of the mother and the parity of the child.[19] It was impossible to account for all of this variation, so the mean birth spacing for all parities above 0 and all ages was used in the model: 32.59 months in 1650-99 and 30.80 months in 1750-99.[20] In addition, Monte Carlo simulation allows variables to fluctuate randomly based on distributions with certain characteristics. Therefore, the birth interval in the model was allowed to vary randomly within a lognormal distribution with a mean of Wrigley *et al.*'s value for each reference period and a standard deviation of one year. Wrigley *et al.* also found that the birth interval following an infant death was shorter than a normal interval, so the interval after an infant death was allowed to vary based on a lognormal distribution with a mean of 23.51 months for 1650-74 and 23.25 months for 1750-74 and with standard deviations of 0.5 years.[21] Lognormal distributions were used to model birth spacing because one would expect the distribution of birth intervals to be right skewed. The birth interval from marriage to the first birth, parity 0, was allowed to vary uniformly from 0.75 to 2 years.

A final variable often associated with fertility is the age at marriage of both parents, though in the current model it only affects the mortality risk that parents face year to year because the PPRs used to predict births are not age-specific. Again

[18] Wrigley, *et al.*, *English Population History*, p. 359.
[19] Wrigley, *et al.*, *English Population History*, pp. 410, 433.
[20] Wrigley, *et al.*, *English Population History*, p. 447.
[21] Wrigley, *et al.*, *English Population History*, pp. 438-9

lognormal distributions were used to predict the age at marriage of both parents because age at marriage was right skewed. The mean marriage ages of men and women were drawn from Wrigley *et al.* for both reference periods. Then lognormal distributions were defined in order to most closely match the cumulative frequency distributions of marriage ages described in Wrigley *et al.*[22] Although the distributions could not be replicated exactly, the mean, median, and first and ninth decile were matched to create a fairly similar distribution.

Mortality was also crucial in determining family size. Many births did not lead to a long-term increase in the consumption requirements of the household because the child died prematurely, and many births did not occur at all because one of the parents died before reaching menopause or sterility. To account for this, each child was given a probability of dying in every year until they left the household. These probabilities of dying were drawn from the Wrigley *et al.* reconstitutions, which had annual probabilities of death for the first five years and then five-year probabilities thereafter. The mortality rates apply only to legitimate births, so there is no conflict with the absence of illegitimate births mentioned above.[23] If the child died, the household no longer had to provide resources to the child and family consumption requirements decreased.

Likewise, each parent had an age and sex-specific mortality risk drawn from Wrigley *et al*. These age and sex-specific mortality risks are necessary because excess female mortality due to maternal mortality and other causes was a feature of historical populations.[24] Although Wrigley *et al.* do present some figures for maternal mortality, the age and sex-specific mortality rates employed already incorporated maternal mortality, so it was not possible to have a separate maternal mortality risk associated

[22] Wrigley, *et al.*, *English Population History*, pp. 146-7.
[23] Wrigley, *et al.*, *English Population History*, pp. 250-51.
[24] McNay, *et al.*, 'Excess Female Mortality'.

with each birth. In the model if the father dies, both his consumption and income leave the household and the wife is assumed to begin working, earning 50 per cent of the male wage.[25] If the mother dies, her consumption is removed from the household but her death does not affect household income because in the model women do not work unless their husband is dead. These are heroic assumptions because of women's important household, non-market, and waged work, and it may be possible to relax these assumptions in later analysis.

Finally, the age at which children leave the household was also critical to the family's welfare over the family life cycle. Older teenagers were a substantial drain on resources, requiring more calories than adults. Therefore, if children left the household later, they were a much larger burden on the family.[26] Children could leave the household in a number of ways: they could get an apprenticeship; become a servant in a different household; get married and form an independent household; or they could enter the workforce while remaining in the same household, earning at least their own consumption requirements and removing the household's need to support them. Mixing these four definitions is not ideal, but is perhaps the best method of dealing with this problem. The age at which children left the household was therefore allowed to vary based on a normal distribution with a mean age of leaving at 16 and a standard deviation of one year: this yielded a range of ages from 12 to 20. This age was assigned randomly to each child despite the sibling set size or the family's income. The net effect of these assumptions will be tested later in the chapter.

The model produces results that are interesting at two levels. We can observe the changing welfare of individual families across the family life cycle as additional

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[25] This is realistic when women's income from work is combined with poor relief.

[26] This is true only if older children were not working. See chapter two for differences when children's labour force participation is included.

children are born, grow up, leave, and die. We can also study the distribution of median welfare ratios from 20,000 predicted families in each reference period. The results for each of these levels of analysis are presented in the next two sections with an additional section afterwards that performs some robustness checks on the results.

1.4 Family Life Cycle Results

The family life cycle results are perhaps best explained by looking at the welfare ratios across the family life cycle for several families. These families were not chosen to be representative but instead to highlight the effect of certain demographic characteristics and events on family welfare. For the sake of simplicity, these examples are drawn from the 1750 reference period, but the general findings are the same across both periods. Figure 1.1 shows the subsistence welfare ratio (dark blue) for Family A, which consisted of two parents and nine children with no fatalities before the maturity of the final child (see also Table 1.4). Allen's constant three consuming unit real wages are also displayed (light blue). With a median welfare ratio of 1.69 across the life cycle, the family falls well below Allen's subsistence welfare ratio of 2.45 for building labourers in 1750-1800.[27] The first two children had already left the household by the time the final (ninth) child was born, and this pattern continued as the other children aged and eventually left the household as well. Thus, the median number of children supported at any given time was only four children despite the nine children born in the household. This finding suggests that only accounting for the number of children born and not whether they are in the household at the same time could significantly skew the welfare ratios calculated for the family. It is also interesting that there do not appear to have been cyclical effects in the

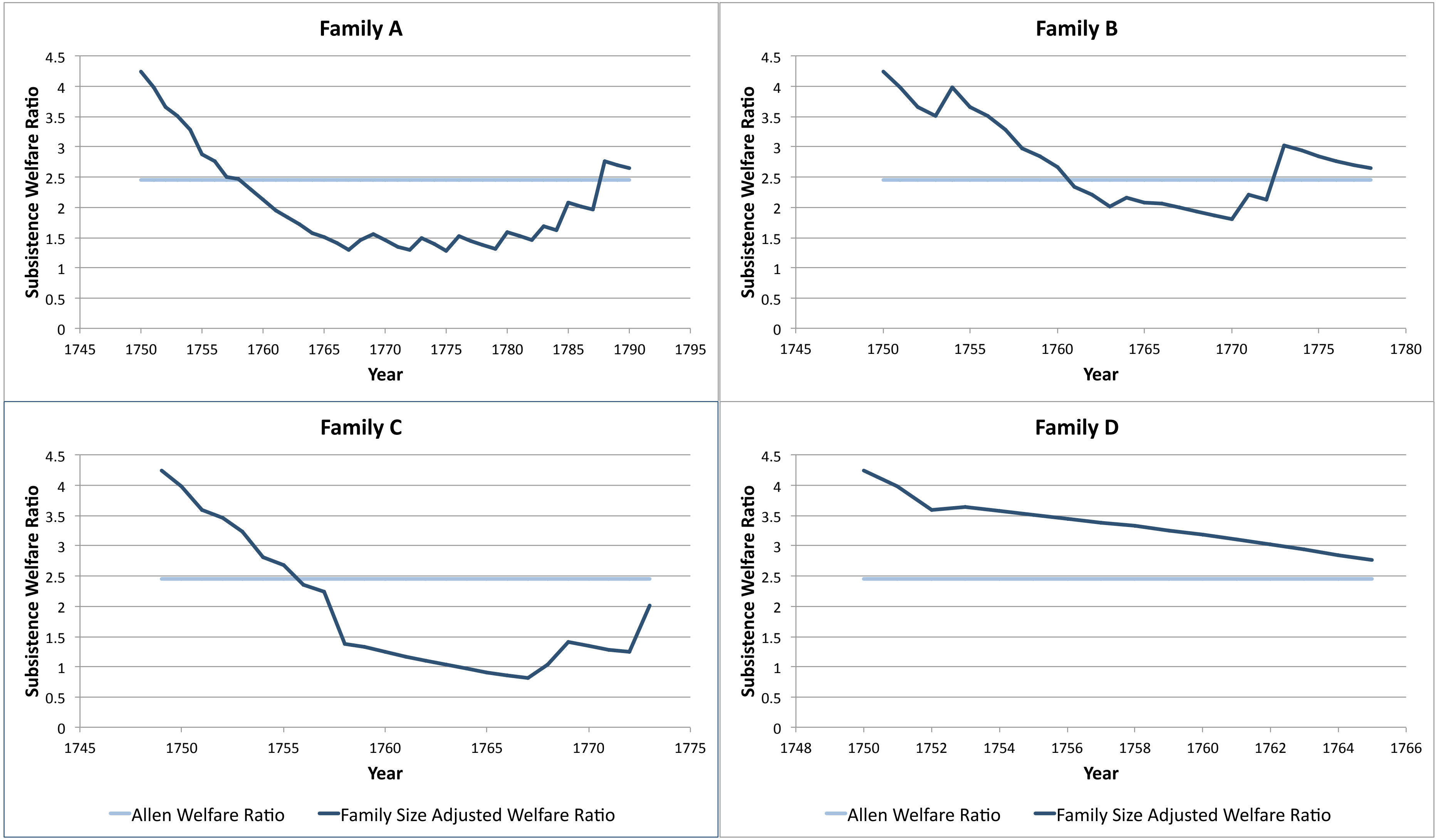
[27] The distributions of family welfare ratios and children supported at one time tend to be skewed, so the median will be used throughout the chapter as the best measure of central tendency for these variables.

family's income based on pregnancy and lactation. The cyclical effects in Family A's welfare ratios after 1768 are upward spikes in the family's welfare ratios caused by children leaving the household, not by additional births. Finally, the family's welfare ratio changes drastically across the family life cycle from 4.24 when the parents first married to a minimum of 1.28 in 1775 when the family reached its peak consumption. Thus Allen's spot welfare ratio estimate hides significant variation in family welfare ratios across the family life cycle.

Figure 1.1 also shows the welfare ratios for Family B, a family with six children born, three surviving to leave the household, and both parents surviving until the final child left the household. Family B's welfare ratio follow a similar pattern to those of Family A, but Family B is much better off with a median subsistence welfare ratio of 2.70, substantially above Allen's constant subsistence ratio for the period, 2.45. Family B highlights the importance of including childhood mortality in the calculations of family size and family welfare ratios. Despite the fact that six children were born in Family B, the median number of children being supported at any given time was two and the maximum number of children was only four. Likewise, child deaths could create sharp upward spikes in the family's welfare ratios because the family no longer had to feed the child: see the jump in the welfare ratio between 1753 and 1754 caused by the first child's death at age two. The effect of child deaths is smaller when the household is larger because the children made up a smaller percentage of the total family consumption requirements.

With a median welfare ratio of 1.34, Family C was one of the poorer families predicted from the 1750 Monte Carlo simulation, but it was not a particularly large family. It consisted of two parents and four children, all surviving to leave the household. The significant difference was that the father died eight years into the

Figure 1.1: Southern England building labourers subsistence welfare ratios (1750-1800) for four model families across the family life cycle.



Sources: Simulated results and table 1.3 for Allen's figure.

Table 1.4: Characteristics of example families in Figure 1.1 above.

	Family				
Characteristics	A	B	C	D	E
Total Children Born	9	6	4	1	1
Child Deaths	0	3	0	0	1
Death Year of Mother	––	––	––	––	––
Death Year of Father	––	––	1758	––	––
Median Welfare Ratio	1.69	2.70	1.34	3.36	4.24
Min Welfare Ratio	1.28	1.80	0.81	2.77	4.24
Median Number of Children Supported	4	2	3	1	1
Max Number of Children Supported	7	4	4	1	1
Length of Family Life Cycle (years)	41	29	25	16	2

Notes: Families were predicted using southern English building labourer's wages and the subsistence price basket from 1750-1800. Allen's welfare ratio is equal to 2.45 for the period.

Sources: Simulated results.

marriage, which removed both his consumption and his income from the family. This death is visible in Figure 1.1 from the sharp decline in the welfare ratios in 1758. As mentioned above the mother is assumed to have been able to earn half of the father's wage, but this still led to a substantial drop in the family's income: the father's death accounts for 25 per cent of the decline in the welfare ratio from peak to trough. The family's welfare ratio also remained low after the father's death until the first two children left the household. Family C therefore demonstrates the importance of including parental mortality when calculating the welfare ratios for families.

Families D and E represent the higher end of the distribution of median family welfare ratios. Family D was composed of two parents and one child who all survived the family life cycle. As shown in Figure 1.1, the family's welfare ratio declined steadily across the family life cycle, but it always remained above Allen's welfare ratio and yielded a high median welfare ratio of 3.36. Finally, Family E consists of a couple that were married and conceived a child, but the child died in infancy and the couple became sterile before the next birth. Thus, the family is only observed and measured as a family for two years and the median welfare ratios are very high. The proportion of families falling into this category could significantly alter the shape and central tendency of the income distributions.

In conclusion, the family life cycle results show a somewhat U-shaped pattern in welfare ratios over time for families. This is as expected because as a family grows and the children age, the resources needed to feed the family increase. Likewise, as children leave the household, their consumption needs are removed increasing the family's welfare ratio. The model, however, does not predict cyclical welfare shocks created by pregnancy and lactation because each child is added *gradually* to the family's consumption through pregnancy, breastfeeding, and thence independence.[28] Women needed very few additional calories (85 extra calories per day) in the first trimester of pregnancy. This extra consumption gradually increased throughout pregnancy and nursing until weaning when the child's consumption ceased to be provided through the mother and was added directly to the family's consumption. Therefore, the additional costs of feeding the mother during pregnancy and lactation did not have a strong cyclical impact on family welfare ratios. However, there could have been other costs for new clothing, a midwife, and in lost productivity during pregnancy and nursing, which were not measured as a part of the model. The clear message from the results is that the cost of each new child drove the male breadwinner family closer to subsistence.

1.5 Monte Carlo Simulation Results

While the picture painted of individual family's welfare ratios over the family life cycle is instructive of the welfare consequences of certain demographic events, in

[28] Humphries, 'Lure', p. 13.

order to understand whether family size mattered more generally, it is necessary to understand how these demographic events affected the distribution of welfare ratios in society as a whole. Therefore, Monte Carlo simulation was used to predict 20,000 model families. This yielded realistic distributions of several variables that help to explain the complex interaction between fertility and mortality characteristics, family size, welfare ratios and, in the end, real wages.

Table 1.5: Demographic predictions of the Monte Carlo simulations.

	1650-1700	1750-1800
Mean of Predicted Distribution of Median Children Supported	2.01	2.29
Median of Predicted Distribution of Median Children Supported	2.00	2.00
Coefficient of Variation of Distribution of Median Children Supp.	0.4134	0.3868
Mean of Predicted Distribution of Max Children Supported	3.01	3.58
Median of Predicted Distribution of Max Children Supported	3.00	4.00
Max of Predicted Distribution of Max Children Supported	9.00	9.00
Mean Total Children Born per Family	3.89	4.66
Completed Family Size (Humphries)	––	5.46
Computed Sibling Group Size (Humphries)	––	7.48

Sources: Simulated results and Humphries, 'Lure', p. 18. See also Humphries, *Childhood*, p. 57.

The first thing to note is that family size was generally much lower than historians have thought, especially if family size is only considered to be the number of children being supported by the household at the same time. Because the distribution of children being supported by an individual household was not always normal, the median provided the best measure of central tendency at the household level. Thus, the mean value for the distribution of median children being supported at one time was 2.01 in the period 1650-1700 and 2.29 in the period 1750-1800 (Table 1.5). These figures are similar to the number of resident children found in population listings, which were also quite low.[29] The mean value was lower in the first reference period because the parity progression ratios (PPRs) were lower, more women were becoming sterile; parents got married later giving them less time to have children; and birth spacing of children was slightly longer. The lower number of children born per family in the period 1650-1700 corroborates the importance of these fertility differences. Mortality also played a role though; mortality rates were higher for both children and adults in the seventeenth century. Birth spacing was not only important in limiting the number of children women could have before reaching menopause, but it also had the effect of spreading the burden of additional children over a number of years, which further reduced the number of children being supported at any one time.

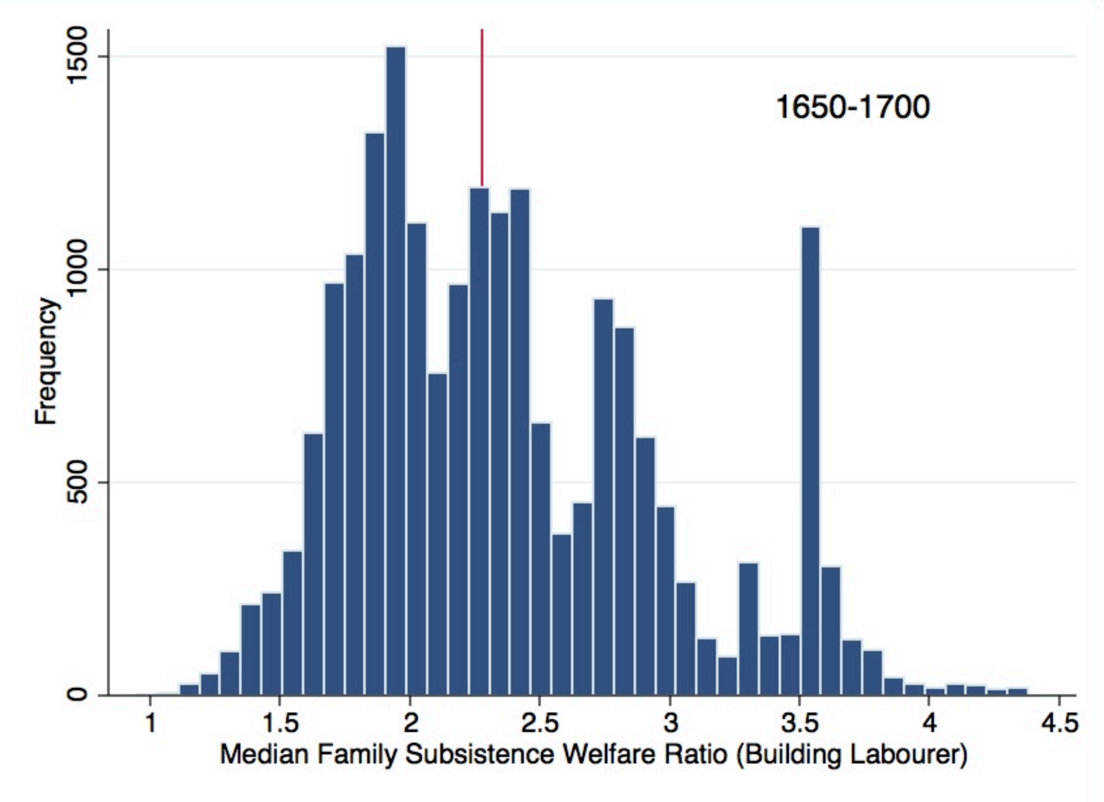
The maximum number of children being supported by the family at one time also provides insight into the distribution of family size. Even these figures are substantially lower for both periods than might be expected: the mean of the predicted distribution of maximum children supported was 3.01 for 1650-1700 and 3.58 for 1750-1800. While up to nine children could be cared for in a single household at one time, the average figures were much lower, showing how strong the birth spacing and mortality effects could be. Thus, the number of children being supported at any time was substantially smaller than the completed family size or sibling group size measures used by Humphries to criticize Allen's method. However, the number of children being supported is also a somewhat misleading characteristic because as described above, some children required more of the household's resources than others. Thus, the consuming unit weighted welfare ratio is the best measure of the family's well being.

[29] Baker, *The Inhabitants of Cardington*, pp. 37-42; Wall, 'Leaving Home and the Process of Household Formation', p. 80.

Before discussing the summary statistics of the distributions, it is first necessary to understand the shape and composition of the distribution of median welfare ratios (Figures 1.2 and 1.3). The distributions appear to be right skewed and multimodal. The various modes are associated with certain types of families that are more likely to exist than others. The spike at a median welfare ratio just above 3.5 in 1650-1700 and around 4.25 in 1750-1800 is associated with two types of families. One type of family had one child that survived to maturity but the mother died shortly after the child's birth. The other type, similar to family D above, had one child or a number of children who died in infancy after which the couple became sterile. These types of families were more common in the first reference period because mortality rates of mothers and children were higher and because the PPR at parity one was lower, creating higher rates of subsequent sterility.

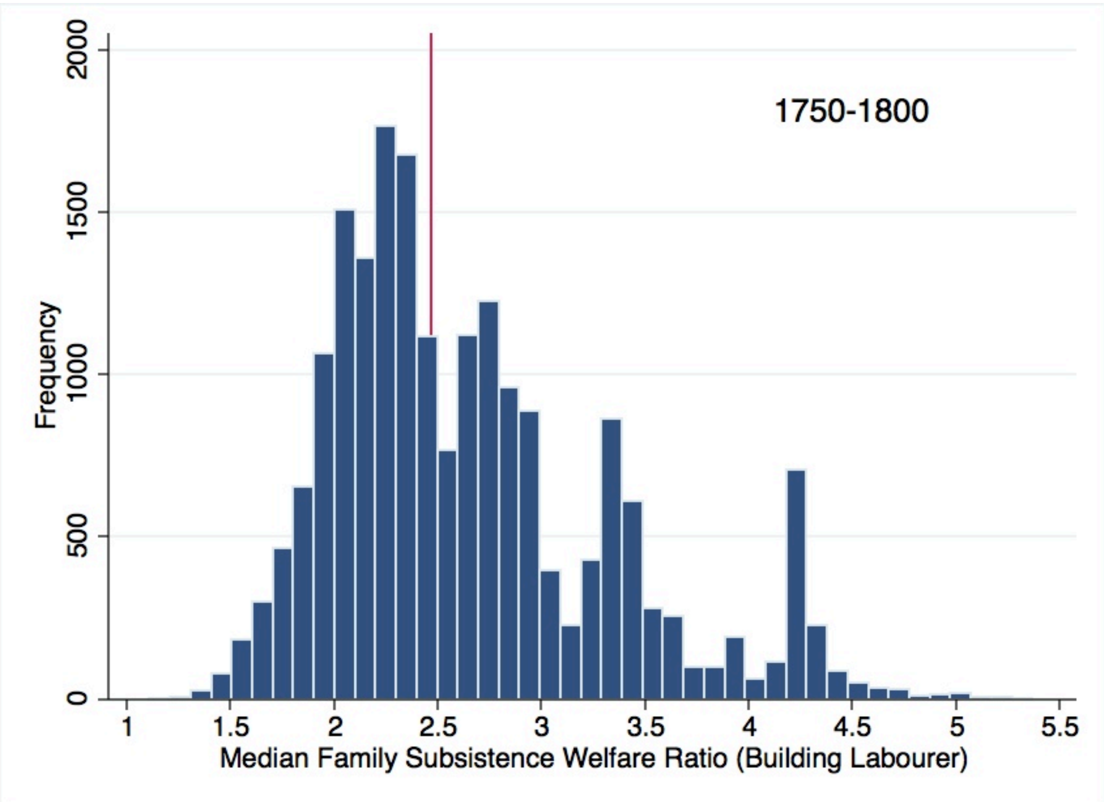
The cluster of median welfare ratios around 2.75 in 1650-1700 and around 3.25 in 1750-1800 is associated with families supporting one child at a time where both parents survive or a father supporting two children at a time. Again this cluster is larger in the period 1650-1700 because of lower fertility and higher mortality rates. The next modal cluster around a welfare ratio of 2.35 in 1650-1700 and around 2.75 in 1750-1800 is associated with families with a median of two children being supported at a time, mothers supporting one child alone, or fathers supporting three children alone. The final cluster just above two in 1650-1700 and around 2.25 in 1750-1800 consists of families supporting a median of three children at any given time, mothers supporting two children, and fathers supporting four children. This cluster was much larger in 1750-1800 than before because fertility had increased and mortality had decreased creating larger families. The left tail mainly consisted of

Figure 1.2: Distribution of Median Family Subsistence Welfare Ratios for Southern English Building Labourers in 1650-1700 (median displayed as red line).



Sources: Simulated results.

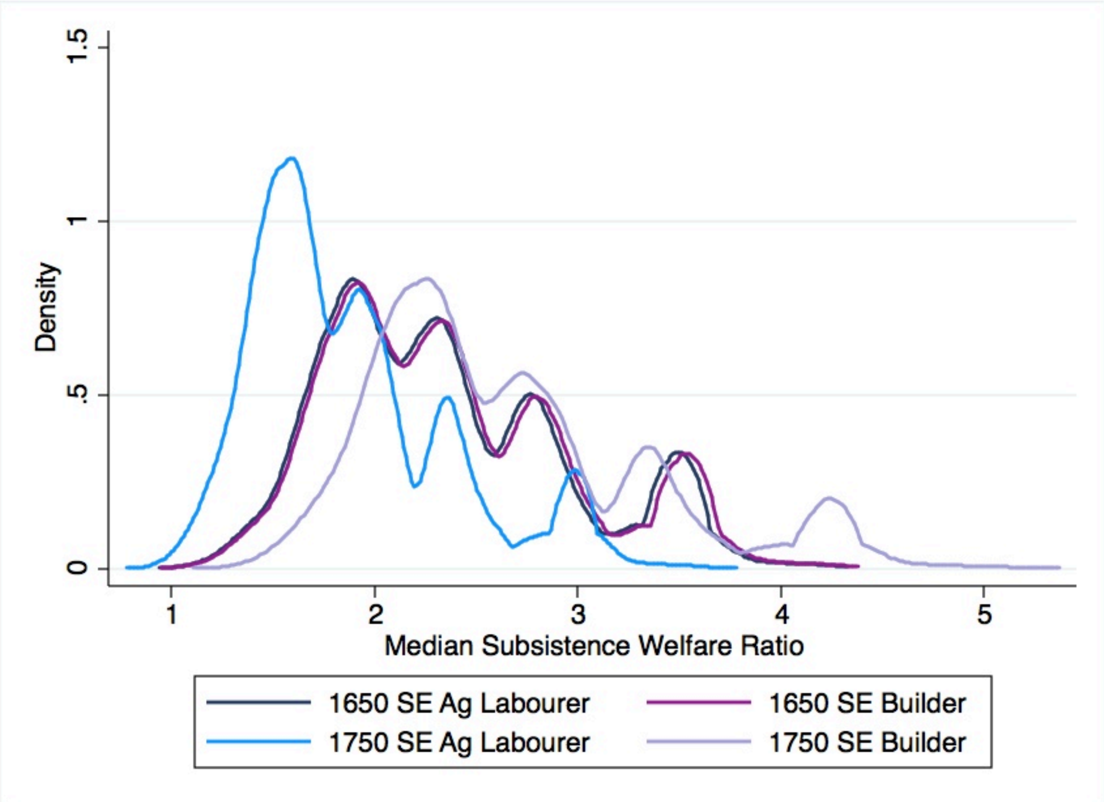
Figure 1.3: Distribution of Median Family Subsistence Welfare Ratios for Southern English Building Labourers in 1750-1800 (median displayed as red line).



Sources: Simulated results.

widows supporting a median of three or four children, but there were also families with two parents supporting five children at a time with a maximum of nine in the household at the same time. The right tail was associated with widowers supporting one child.

Figure 1.4: Predicted distributions of median family subsistence welfare ratios of agricultural labourers and building labourers in southern England.



Sources: Simulated results.

The discussion above has focused on southern English building labourers' subsistence welfare ratios in both reference periods, but the distributions are the same, although condensed somewhat, for the southern England agricultural labourers' subsistence welfare ratios and the respectability welfare ratios. Figure 1.4 shows several overlapping kernel density plots that compare the distribution of welfare ratios for agricultural and building labourers in both reference periods. Figure 1.5 does the same for the respectability welfare ratio distributions. In the period 1650-1700, the agricultural and building labourers' wage distributions were nearly identical, but they diverged significantly over the following hundred years with building labourers doing substantially better than agricultural labourers.

There was also change in the centres and dispersions of the distributions over time (Table 1.6). Because the distributions of median family welfare ratios are not normally distributed and are multi-modal, the median is the best measure of central tendency. The median of the median agricultural labourer's family subsistence welfare ratio was 2.02 in 1650-1700 but declined to 1.73 by 1750-1800. Agricultural labourers' welfare ratios declined substantially because their wages increased only by 5.72 per cent between the two periods which was not enough to keep pace with the increasing cost of the subsistence basket (23.68 per cent) and increasing family sizes (14.01 per cent). In addition, the percentage of total family years lived below the subsistence level – a subsistence welfare ratio of one – increased from 1.92 per cent in 1650-1700 to 6.09 per cent in 1750-1800. This evidence thus suggests that increases in family size exacerbated the low wage growth experienced by English agricultural labourers across the early modern period to the point that six per cent of the population was starving.

The median of the median building labourer family subsistence welfare ratios was 2.28 in 1650-1700 and increased to 2.47 by 1750-1800. This increase was caused by an upward shift in the distribution: nominal day wages of building labourers in southern England increased by 48.38 per cent between the two periods (Table 1.3). Unlike agricultural labourers, the increase in building labourer's wages in southern England was large enough to overcome the rising cost of the subsistence basket (23.68 per cent) and the increase in the number of children supported in the household (14.01 per cent). Building labourers were also largely able to avoid subsistence crises with only 1.80 per cent of family years lived by all predicted families falling below unity in 1650-1700. This figure fell with improving conditions in the eighteenth century. In addition, the changing demographic characteristics between the two periods did not significantly alter income inequality ; the Gini coefficient was around 0.14 in both periods.

Table 1.6: Descriptive statistics for distributions of predicted median family subsistence welfare ratios of agricultural labourers and building labourers in southern England.

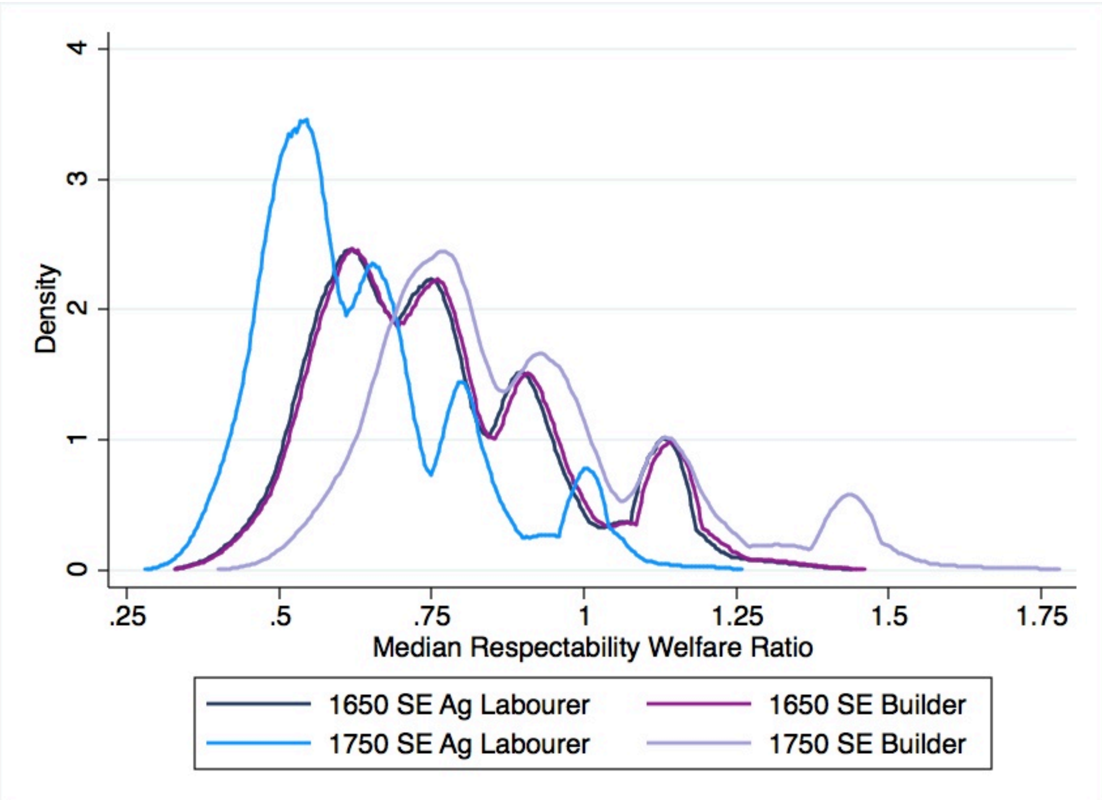
	Southern England Agricultural Labourers		Southern England Building Labourers	
	1650-1700	1750-1800	1650-1700	1750-1800
Allen Subsistence Welfare Ratio (WRs)	2.02	1.73	2.04	2.45
Median of Predicted Distribution of Median WRs	2.25	1.74	2.28	2.47
Mean of Predicted Distribution of Median WRs	2.35	1.86	2.37	2.65
Min of Predicted Distribution of Median WRs	0.94	0.78	0.95	1.11
% of Total Family Years Below Subsistence	1.92%	6.09%	1.80%	0.77%
Gini Coefficient	0.1422	0.1410		

Sources: Simulated results.

The median family respectability welfare ratios paint a largely complementary picture to the subsistence distributions already described. Again the distributions of building labourer and agricultural labourers' welfare ratios were similar in 1650-1700 but diverged in the eighteenth century. The median agricultural labourer respectability welfare ratio declined from 0.66 in the late seventeenth century to 0.59 in the late eighteenth century (Table 1.7). This decline was caused by both a downward shift in the distribution and the changing shape of the distribution. The sluggish, 5.72 per cent increase in agricultural labourers' nominal day wages was far short of the 18.74 per cent increase in the cost of the respectability basket and the 14.01 per cent increase in the number of children being supported. The percentage of total family years lived by the predicted families under the respectability value of one also increased from 83.42

per cent to 92.75 per cent between the two periods highlighting the changing shape of the distribution. The median building labourer respectability ratio increased across the two periods from 0.67 to 0.84. The buoyant increase in southern English building labourers' nominal day wages of 48.38 per cent again exceeded the 18.74 per cent increase in the cost of the respectability basket and the 14.01 per cent increase in the number of children being supported. The percentage of family years spent below the respectability level also declined from 82.47 per cent to 63.31 per cent. Finally, inequality as measured by the Gini coefficient was remarkably stable despite the changes in the shape of the welfare ratio distribution between the two periods.

Figure 1.5: Predicted distributions of median family respectability welfare ratios of agricultural labourers and building labourers in southern England.



Sources: Simulated results.

These distributions can also be compared to Allen's original welfare ratios to see whether his welfare ratios overstate or understate the demography-adjusted ratios.

The distributions show that Allen's welfare ratios are nearly identical to the predicted medians in the period 1750-1800, but Allen's welfare ratios for 1650-1700 are lower than the demography-adjusted ratios because the average consuming unit burden on the family was less than the three consuming units that he assumed. This suggests that Allen's three consuming unit family was not a bad estimate and likely understates the median real wage of labourers rather than overstating it as Humphries has suggested.[30] It is possible that with the increase in fertility and decrease in mortality at older ages and in childhood across the nineteenth century, there could be a point where the median consuming units per family exceeded Allen's three consuming unit basket. However, at least for the preindustrial period, it is unlikely that Allen's welfare ratios would overestimate the demography-adjusted welfare ratios.

Table 1.7: Descriptive statistics for distributions of predicted median family respectability welfare ratios of agricultural labourers and building labourers in southern England.

	Southern England Agricultural Labourers		Southern England Building Labourers	
	1650-1700	1750-1800	1650-1700	1750-1800
Allen Respectability Welfare Ratio (WRs)	0.66	0.59	0.67	0.83
Median of Predicted Distribution of Median WRs	0.73	0.59	0.74	0.84
Mean of Predicted Distribution of Median WRs	0.76	0.63	0.77	0.90
Min of Predicted Distribution of Median WRs	0.33	0.28	0.33	0.40
% of Total Family Years Below Respectability	83.42%	92.75%	82.47%	63.31%
Gini Coefficient	0.1413	0.1404		

Sources: Simulated results.

1.6 Robustness Checks and Potential Biases

Modelling the full variation of family size and structure is inherently impossible, so it is important to understand how the simplifications and assumptions in the model affect the final outcomes. Therefore, a number of robustness checks have

30 Humphries, 'Lure'.

been carried out to test the assumptions. When robustness checks were not possible, the potential nature of the bias and its effect on the median of the welfare ratio distribution and on income inequality is explained so that the potential bias is clear. This section will treat four potential issues in turn: the age at leaving the household, remarriage, women and children's labour force participation, and illegitimacy.

Table 1.8: The influence of changing the age at which children left the household on the distribution of southern English building labourers' median respectability welfare ratios.

	Mean Age of Children Leaving		
	14	16	18
Allen Respectability Welfare Ratio (WRs)	0.83	0.83	0.83
Median of Predicted Distribution of Median WRs	0.89	0.84	0.80
Mean of Predicted Distribution of Median WRs	0.93	0.90	0.87
Min of Predicted Distribution of Median WRs	0.42	0.40	0.38
Mean of Dist. of Median Children Supported	2.19	2.29	2.38
% of Total Family Years Below Respectability	60.65%	63.31%	65.49%
Gini Coefficient	0.1282	0.1404	0.1504

Sources: Simulated results.

1.6.1 Age of leaving the household robustness check

Determining the age at which children should leave the household is a difficult proposition. Currently the leaving age is allowed to vary over a normal distribution with a mean of 16 and a standard deviation of one year, but small adjustments to this distribution could have a potentially large influence on the median welfare ratio distributions, especially since children in their late teens are especially burdensome on family resources. I have therefore re-simulated the model for the distribution of building labourers' respectability welfare ratios in 1750-1800 assuming the mean leaving age was 14 or 18. The results are presented in Table 1.8. Clearly, the age at which children left the household could have a large effect on the median welfare ratio, the years spent below the respectability level, and the income inequality created by differences in family size and structure. If children left the household later, the median welfare ratio decreased, the percentage of family years spent below the respectability level increased, and the income inequality also increased. Setting the appropriate level is difficult because there is very little representative evidence based on a large sample of households. Therefore, an average age of children leaving the household at 16 seems best.

It might also be desirable to partially endogenize the process through which children left. This would allow families with lower median welfare ratios to send their children to apprenticeships or out to work at younger ages than the children of their wealthier counterparts. This, however, is quite difficult. There is little evidence about the timing of children leaving the home upon which to draw. Humphries provides some evidence for when children started working or were apprenticed, but the relative frequency with which apprenticeships and employment were available is harder to establish.[31] Likewise, it is difficult to pick a threshold poverty line under which families would send their children out sooner. The respectability line might serve as a good point of reference, but with 63 to 82 per cent of southern English family years spent below the respectability threshold, it would not serve as a good demarcation point for that population. Although it is not possible to carry out a specific robustness check at this point, it is possible to understand how allowing children from poorer families to leave the household earlier would affect the distribution. If poorer children left earlier, then families at the lower end of the distribution would have smaller consumption requirements, raising their welfare ratio and moving them toward the

[31] Humphries, *Childhood*, pp. 203-7, 258-63.

right in the distribution. This would likely shift the median upwards and decrease income inequality in the population.

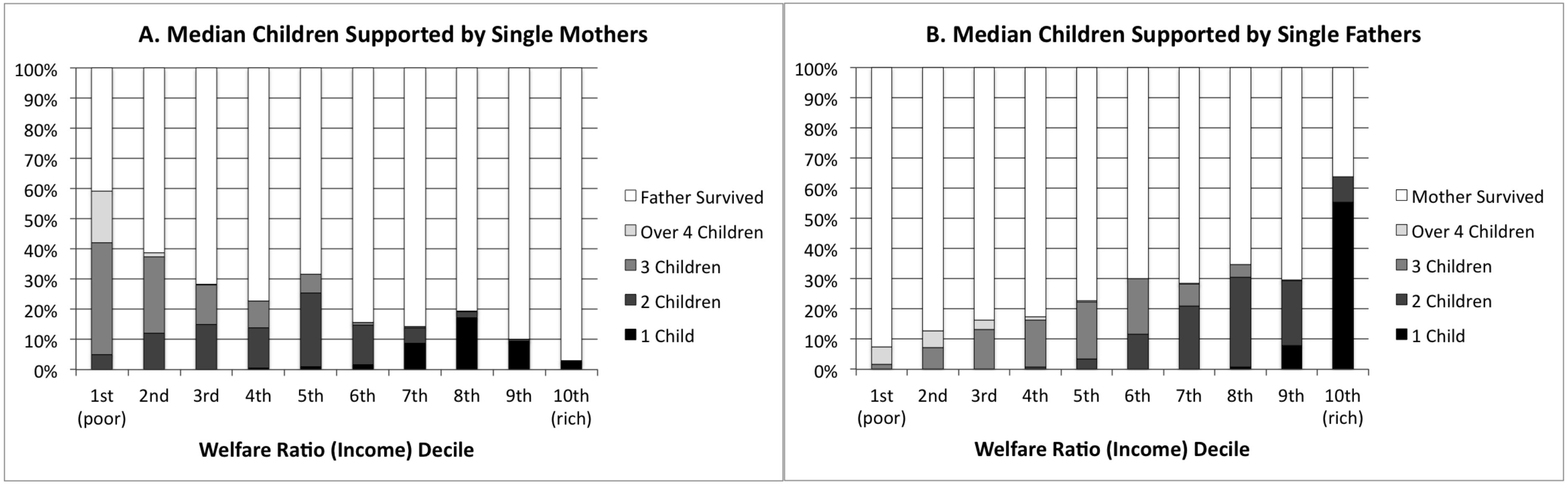
1.6.2 Remarriage robustness check

Not allowing remarriage is another potentially problematic assumption in the model. As it stands, single parent households are overrepresented in the distribution because some of the single parents would have remarried either bringing the higher income of a male earner back into a single mother's family or increasing the consumption requirements of a single father's family through the new wife's consumption and the birth of more children. This picture however oversimplifies the problem. Because women do not add to family income in the model and once they die no additional children can be added to the family, the mother's death is positively associated with the welfare ratio. Thus, in Figure 1.6B, single fathers are disproportionately represented in the upper deciles of the welfare ratio distribution. The opposite is true for single women (Figure 1.6A). Single mothers are disproportionately represented in the lower deciles of the welfare ratio distribution because they had to support their families on half of the male income.

Single father and single mother households were also different in another important respect. Most single fathers lost their wives early in their marriage when they had a smaller family. Single mothers lost their husbands well into their marriages when they had much larger families to support.[32] These women were poor because they had many children while their husbands were alive, and then their husbands died when the household was at its peak consumption requirement (see Family C above).

[32] This difference is likely a product of gendered mortality rates with women often experiencing higher mortality than men until age 40-45. Wrigley *et al.*, *English Population History*, p. 303.

Figure 1.6: Median children supported by families where one of the parents died across different welfare ratio deciles 1750-1800.



Notes: Single mothers and fathers refer to families where the mother or father died before the end of the family life cycle.

Sources: Simulated results.

This difference is important because it affected the desirability of the single parents when remarrying. Wrigley *et al*. found that controlling for period, age, and occupational type, widows with no dependents were usually remarried in 29.1 months whereas widows with four or more dependents were remarried in 63.1 months, over five years. This discrimination, however, was non-existent for widowers. The remarriage interval for widowers did not substantially differ across the number of dependents, and the effect was not statistically significant.[33] Thus, including remarriage in the model would likely shift the median downward. Widowers and widows with fewer dependents in the upper deciles would remarry and have additional children, lowering their welfare ratio. Introducing remarriage would decrease the income inequality in the distribution, though, because the dispersion of welfare ratios would decline.

As a preliminary estimate of what the net effect of adding remarriage would be, I have incorporated widower/spinster marriages into the model. These are the easiest marriages to model because according to the remarriage interval evidence, neither the widower's age nor the number of dependents in the household affected the remarriage intervals.[34] Thus, all widowers can be given an equal probability of being remarried, and the difficult remarriage selection issues surrounding widows can be avoided. In incorporating widower/spinster marriages into the model, most of the assumptions in the original model could be held the same: the second wife was subjected to the same annual probability of death based on her age as the first wife; child mortality rates were the same; and the method for estimating the age at which children left the household was the same. In addition, the consequences of child and parental mortality of both first and second wives were held the same.

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[33] Wrigley *et al.*, *English Population History*, p. 180.
[34] Wrigley *et al.*, *English Population History*, p. 180.

However, there were four additional modifications necessary. First, the age at marriage of the second wife was allowed to vary over a normal distribution with means at the average age of women in widower/spinster marriages from Wrigley *et al.* and a standard deviation of four years. The mean age at marriage of women in widower/spinster marriages, 29.5 in 1650-1700 and 28.5 in 1750-1800, was significantly higher than the mean age of women in bachelor/spinster marriages, so it was important to take this into account.[35] Second, it was necessary to make assumptions about the remarriage interval because remarriage was not instantaneous. Remarriage intervals were taken from Wrigley *et al.*'s regression analysis, so the intervals for the different periods are independent of the widower's age, number of dependants, and occupation. In 1650-1700 the remarriage interval was 27.9 months, and in 1750-1800 the interval was substantially longer at 35.8 months.[36] These intervals were allowed to fluctuate over normal distributions with standard deviations of 6 months in order to add variation to the model. Third, fertility, the parity progression ratios (PPRs), had to be lowered slightly. Because fertility declines strongly with age, fertility had to be lower for the older women in widower/spinster marriages than women in bachelor/spinster marriages.[37] In addition, the PPR at parity zero was set at the normal rate in order to introduce entry sterility into the model. A PPR of one at parity zero ensured that all bachelor/spinster married couples had children, but when incorporating remarriage into the model, it is no longer necessary to uphold this assumption. Thus, some women in widower/spinster marriages entered the marriage infertile.

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[35] Wrigley *et al.*, *English Population History*, p. 149.
[36] Wrigley *et al.*, *English Population History*, p. 180.
[37] Wrigley *et al.*, *English Population History*, p. 403. Holding the PPRs constant for both bachelor spinster and widower spinster marriages only led to a difference of around 0.02 in the final median welfare ratios.

Finally, if all widowers were remarried, the impact of remarriage would have been highly overstated in the robustness check. Determining the frequency of remarriage, however, is incredibly difficult. Wrigley *et al*. were very pessimistic about the reliability of their data on the relative frequency of bachelor/spinster, bachelor/widow, widower/spinster, and widower/widow marriages. Bachelor/spinster marriages were overrepresented in the reconstitution data, and the various other types of marriage were underrepresented in different ways. Their figures were also reliant on the number of connections that could be made in the reconstitution forms, which created substantial discrepancies between the relative frequencies calculated for men and women when they should have been equal. And even if these frequencies were taken to be reasonably reliable, they do not account for the relative desirability of different widowers and widows as described above. Fortunately, for widower/spinster marriages it seems that only the time period and the occupation of the widower were significant in explaining the remarriage interval.[38] Therefore, the average ratio of widower/spinster to bachelor/spinster marriages in the two reference periods can tentatively be applied to limit remarriage to a reasonable level: 14.47 per cent in 1650-1700 and 9.45 per cent in 1750-1800. Thus, all widowers were given a certain probability of remarriage, which limited widower/spinster marriages to the appropriate level.

Table 1.9 shows the effect of remarriage on distribution of building labourers' wages. In the period 1650-1700 female mortality rates were substantially higher, so a larger percentage of families lost the mother before the end of the family life cycle. The average ratio of widower/spinster to bachelor/spinster marriages was also higher at 14.47 per cent. Thus one would expect the impact of remarriage to be larger in the

[38] Wrigley, *et al.*, *English Population History*, pp. 164-6, 180.

first period. This is indeed the case, but the remarriage effect is quite small in both periods. In the first period remarriage reduced the median of the predicted distribution of welfare ratios by 0.06 from 2.28 to 2.22. This decreased welfare ratio is still much

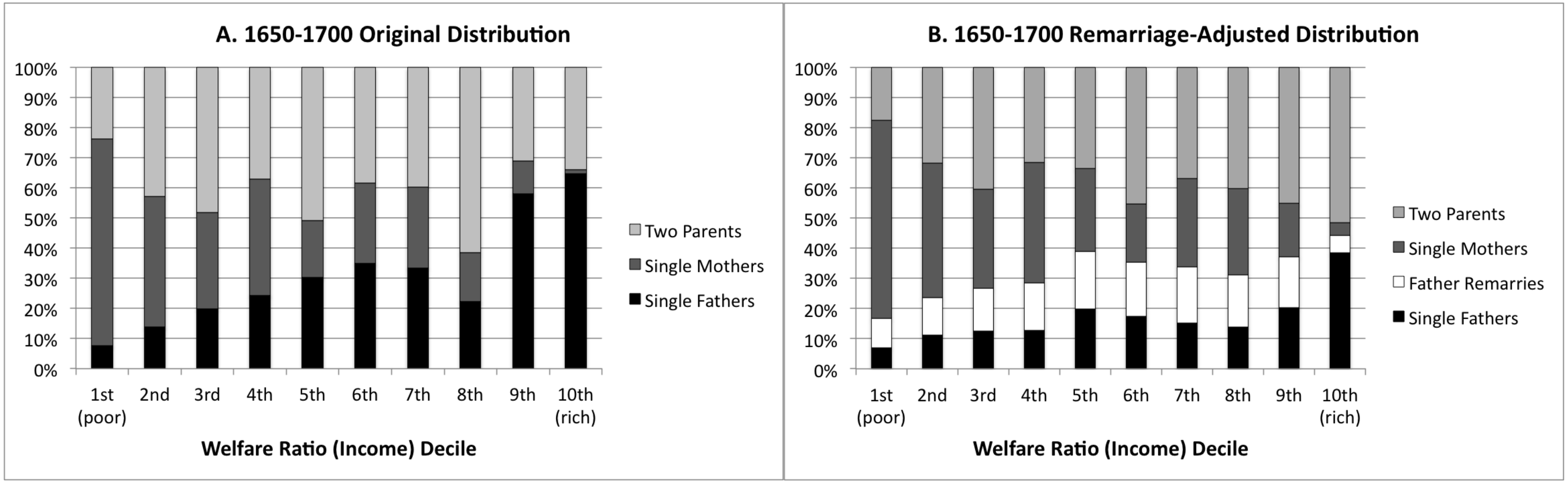
Table 1.9: Comparison between the descriptive statistics for the original distribution and remarriage adjusted distribution of predicted families.

	1650-1700 Building Labourers		1750-1800 Building Labourers	
	No Remarriage	Remarriage	No Remarriage	Remarriage
Allen Subsistence Welfare Ratio (WRs)	2.04	2.04	2.45	2.45
Median of Predicted Distribution of Median WRs	2.28	2.22	2.47	2.43
Mean of Predicted Distribution of Median WRs	2.37	2.30	2.65	2.59
% of Total Family Years Below Subsistence	1.80%	1.81%	0.77%	0.74%
Gini Coefficient	0.1422	0.1340	0.1410	0.1318
Mean of Dist. of Median Children Supported	2.01	2.03	2.29	2.31
Mean of Dist. of Max Children Supported	3.01	3.15	3.58	3.67
Mean Total Children Born per Family	3.89	4.15	4.66	4.89
% Single Father Families	30.95%	16.84%	26.64%	16.94%
% Single Mother Families	28.30%	30.99%	24.43%	25.81%
% Families where Father Remarried	—	14.79%	—	9.32%
% of Families where Both Parents Survived	40.76%	37.39%	48.94%	47.94%

Sources: Simulated results.

higher than the welfare ratio that Allen would have predicted, 2.04. In 1750-1800, the ratio of widower/spinster to bachelor/spinster marriages was lower, 9.45 per cent, and the decrease in the median welfare ratio due to remarriage was also smaller, a decrease 0.04 from 2.47 to 2.43. This decrease was not large enough to substantially shift the median below Allen's welfare ratio of 2.45 for the later period. Remarriage did not seem to affect the percentage of total years lived beneath subsistence either, but it did decrease the inequality by reducing the number of single father households at the top end of the distribution. This shift is especially clear when comparing the percentage of single father households in the upper welfare ratio deciles for the

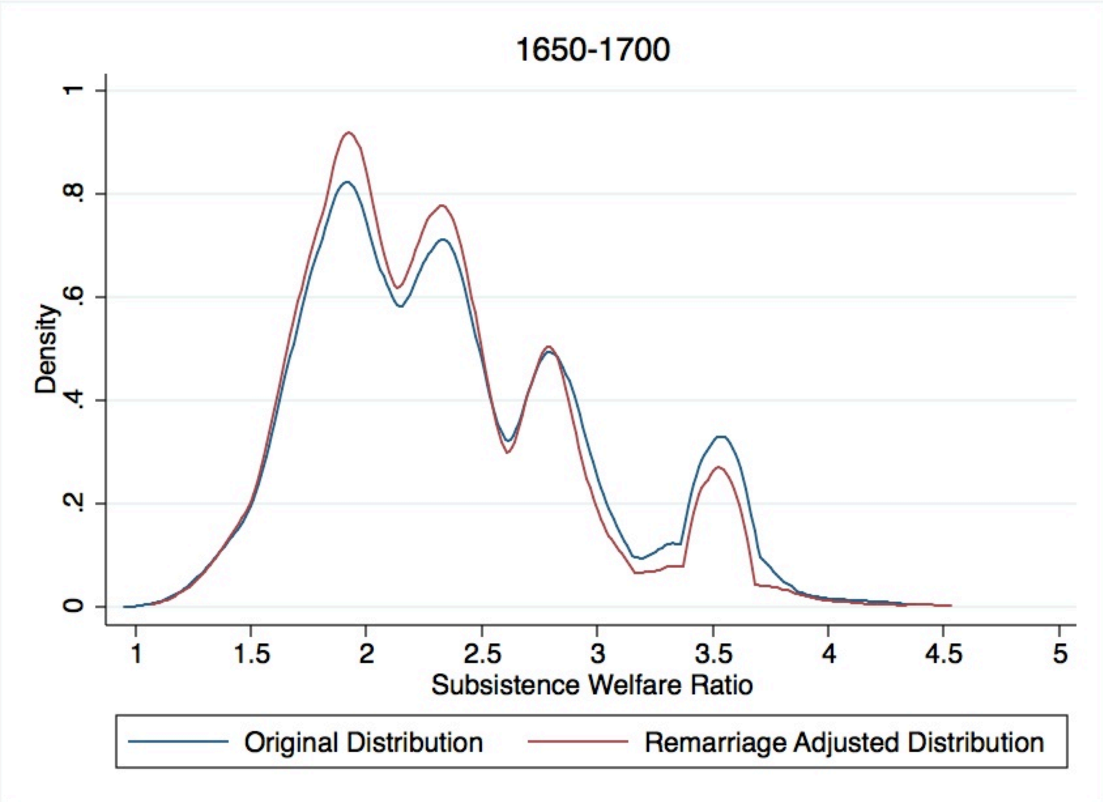
Figure 1.7: Comparison of the frequency of two parent and single parent families across welfare ratio deciles between the original predicted distribution and the remarriage-adjusted distribution.



Notes: Single mothers and fathers refer to families where the mother or father died before the end of the family life cycle.

Sources: Simulated results.

Figure 1.8: Comparison of the original and remarriage-adjusted distributions of median welfare ratios.



Sources: Simulated results.

original distribution 1650-1700 and the remarriage adjusted distribution (Figure 1.7). Figure 1.8 compares the 1650-1700 original and remarriage adjusted distributions on a kernel density plot showing that remarriage increased the relative frequency of larger families in the modal clusters around 1.75 and 2.25 and decreased the modal cluster around 3.5. In terms of family size, remarriage significantly increased the number of children born per family, counting both wives in the same family. It also increased the maximum number of children being supported at any given time. However, the effect on the median number of children supported was much smaller, a difference of two or three hundredths.

The effect of remarriage on the distribution of welfare ratios was relatively small for several reasons. First, remarriage took time, increasing the difference in age between the children of the first and second wives. Thus, the burden of children was spread out over a longer period of time, and the median number of children supported did not increase substantially. Second, many widowers did not get remarried. Only 46.75 per cent of widowers in 1650-1700 and 35.47 per cent of widowers in 1750-1800 were remarried. With such low rates of remarriage, there were still a lot of single father households in the upper deciles of the distribution. Finally, a small but important minority of the second wives entered the marriage infertile or died relatively young before they could have a number of children. These conclusions are very tentative because the precise nature of remarriage is unclear from the historical sources. In addition, this exercise did not incorporate bachelor/widow and widower/widow marriages. However, these other marriages, as far as we can tell, occurred much less frequently than widower/spinster marriages because the ratios of bachelor/widow and widower/widow to bachelor/spinster marriages were around three per cent. Thus incorporating these other marriages would be unlikely to lower the median welfare ratio substantially.

1.6.3 Women and children's labour force participation

Another potential source of bias in the model is that it does not allow for women or children's labour force participation. Women and children did work in the early modern period and their income could serve as a helpful smoothing mechanism as the family's consumption requirements grew. In fact, Horrell *et al.* found that families' incomes increased across the family life cycle by sending children to work, compensating somewhat for the increased consumption requirements of the household.[39] However, introducing children and women's work into the model is

[39] Horrell, *et al.*, 'Destined for Deprivation', p. 345.

incredibly difficult. Information about women's labour force participation before the 1850 census, which enumerated both men and women's work, is fragmentary and geographically specific. Horrell and Humphries found a labour force participation rate of 65.7 per cent based on 196 households surveyed in the period 1787-1815.[40] When aggregate or more census-like evidence is available, women's labour force participation rates were incredibly variable. Saito found that married female labour participation could be as high as 67.5 per cent in the late eighteenth century in the parish of Cardington, Bedfordshire, which had prevalent employment in cottage industries such as spinning and lace making. However, in the parish of Corfe Castle, Dorset, Saito found that married women's labour participation rate was only 8.7 per cent.[41] Even in 1851 female labour participation rates varied from 20 per cent to over 90 per cent in different parts of the country.[42] Therefore, at a national scale it is difficult to pick a level of women's labour force participation. Children's labour is equally as tricky because it varies based on age and gender. Saito generally found that male child labour participation was lower for the age groups 5-14 than female labour force participation, but this trend was not as clear for children age 15 and above. Saito's evidence from Cardington and Corfe Castle does clearly show that there was high labour force participation for children over 15 of both sexes averaging 82.15 per cent across the two parishes.[43] This suggests that it was not uncommon for children to work and that their income could have provided important additional resources to the household as their consumption reached a peak in their late teens.

Labour force participation, however, is only one part of incorporating the earnings of women and children into the model. There is also the problem of deciding

[40] Horell and Humphries, 'Women's Labour Force Participation', p. 98.
[41] Saito, 'Who Worked When', p. 221.
[42] Shaw-Taylor, 'Diverse Experiences', pp. 44-5.
[43] Saito, 'Who Worked When', p. 221.

which women and children should work. The easiest way forward would be to give every child and woman the same probability of being engaged in the labour force, but this is not entirely satisfactory since children from poorer families would likely have higher labour force participation rates than children from wealthier families. Likewise, one would have to decide when children went to work. Humphries has shed considerable light on the factors influencing the age at which male children started work. She found that there was a U-shaped trend over time with higher ages of starting work in the eighteenth and late nineteenth centuries than in the early nineteenth century. The father's occupational group also made a significant difference. Children from larger families, from families where the father was dead or absent, and from families receiving poor relief also started work earlier.[44] Finally, there is the issue of how much remuneration, as a percentage of the male wage, that women and children were able to earn. This changed over time, by occupation, and by sex of the child. Clearly, a proper robustness check for women and children's earnings would be very complicated and would require a paper in and of itself (see chapter two). Suffice it to say, then, that including women and children's labour would increase the welfare ratios of the lower deciles of the welfare ratio distribution because they were the poorest families and had the most children available to send into the labour force (Figure 1.9). The overall effect on the welfare ratio distribution would be to shift the mean and median upward and decrease income inequality.

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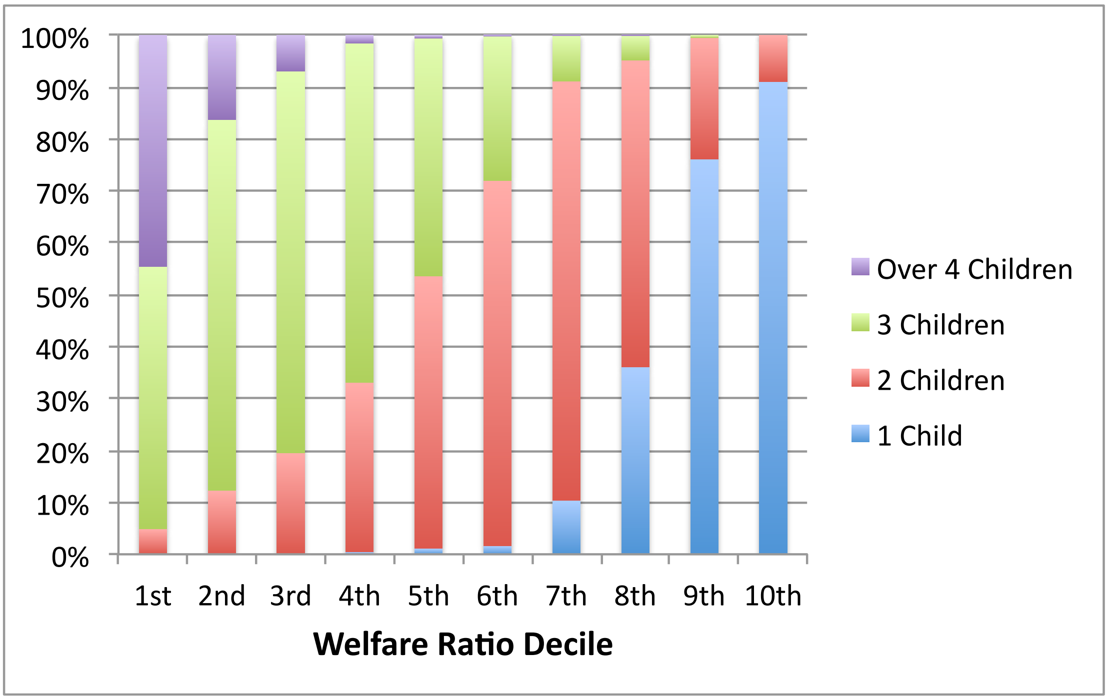
[44] Humphries, *Childhood*, pp. 203-7.

Figure 1.9: Median number of children supported at one time in 1750.



Sources: Simulated results.

1.6.4 Illegitimacy robustness check

The final source of bias in the model is that illegitimacy is not included. This is a necessary assumption because it underpins much of the fertility and mortality figures drawn from Wrigley *et al.*, but it also means that female-headed households are underrepresented in the final welfare ratio distributions. There is very little evidence about illegitimate fertility in the preindustrial period because family reconstitution itself focuses on legitimate fertility. However, Laslett and Adair have calculated the ratio of illegitimate births to total births for the early modern period finding great changes in the prevalence of illegitimacy across the centuries. Thus, illegitimacy ratios were quite low from 1650-1700 at 1.6 per cent and had increased substantially by 1750-1800 to 5.29 per cent.[45] It is therefore possible to calculate the

[45] Wrigley *et al.*, *English Population History*, pp. 219-25.

number of illegitimate births given the number of legitimate births predicted in the model. These figures are presented in Table 1.10.

Table 1.10: Calculation of illegitimate births from predicted legitimate births.

	1650-1700	1750-1800
Illegitimacy Ratio (50-year Average)	1.60%	5.29%
Illegitimate:Legitimate Ratio	1.62%	5.59%
Number of Legitimate Births Predicted	77,716	93,268
Number of Associated Illegitimate Births	1,260	5,212

Sources: Wrigley *et al.*, p. 224.

To account for these illegitimate births, the legitimate model presented above will be reconfigured to produce median welfare ratios for single mothers with illegitimate children, although there are some heroic assumptions involved that are clearly problematic. I will conduct this analysis for the later period, 1750-1800, because illegitimacy ratios were higher in that period, so illegitimacy was more likely to make a difference in the final distribution. In order to predict median welfare ratios for the illegitimate families, I made certain assumptions about the fertility and mortality of illegitimate mothers and children. For fertility, I assumed a parity progression ratio (PPR) of unity at parity zero, 0.5 at parities one and two, 0.25 at parity three, and 0.1 at subsequent parities. These numbers are pure guesses because there is very little evidence about the illegitimate fertility of single mothers. The PPRs are lower for illegitimate fertility because of the social stigma and economic consequences for a mother of having a child out of wedlock.[46] Thus, the low PPRs do not measure subsequent sterility per se but rather women who do not have an additional illegitimate child. These fertility measures yielded a mean of 1.64 children

[46] If illegitimate fertility is held equal to legitimate fertility in the model but the mortality and marriage assumptions described later are held constant, then the median welfare ratio of the illegitimate families falls from 3.37 to 2.92 assuming that mothers of illegitimate children earned 50 per cent of a male building labourer's wage. This difference would still put illegitimate mothers above the median of the legitimate distribution.

born per illegitimate mother but only a median of 1.17 children being supported at one time.

I also assumed that the mortality of illegitimate children was twice the legitimate rate, a common assumption among historical demographers.[47] This meant that levels of infant and childhood mortality were extremely high with 31.9 per cent of infants, 9.3 per cent of one-year-olds, and 5.7 per cent of two-year-olds dying. The assumption about when children left the household was kept the same with a mean age of leaving at 16. The distribution of mothers' ages at the birth of their first child was also changed to reflect earlier ages at first birth relative to the distribution of age of women at marriage, assuming that illegitimate mothers tended to be younger than married women. Again, the age at first birth did not affect fertility in the model but has an influence on maternal mortality risk. Finally, I have attempted to incorporate marriage of illegitimate mothers into the model, though again this is speculative. Illegitimate mothers were given a 5 per cent chance per year of getting married between ages 19 and 32, a 2.5 per cent change between the ages of 15 and 18 and between 33 and 39, and a 1 per cent chance of marriage per year after age 40. These probabilities of getting married were designed to somewhat match the frequency distribution of age at marriage for women in the period 1750-1800.[48]

The family life cycle of an illegitimate family is also different than the legitimate model in one respect. Similar to the legitimate model, the family life cycle for an illegitimate family begins when the mother becomes pregnant and ends with the single mother dying, all of the children dying, or the children leaving the household later in life. However, the illegitimate family life cycle also ended when the mother married. Including the years after remarriage in the model would have an

[47] Wrigley *et al.*, *English Population History*, p. 219.
[48] Holding the marriage probability constant at 0.05 rather than changing the probability with the mother's age had a very small influence on the final distribution predicted.

ambiguous effect because the family's income would be much higher despite the fact that more children could be born into the household. Since the purpose of the illegitimacy robustness check is to measure the effect of the underrepresented single mother households in the overall distribution, excluding illegitimate families after the mother married seemed reasonable. 71 per cent of families ended through normal means, the mother or children died or left the household, and 29 per cent of illegitimate family life cycles ended because the mother was married.

Table 1.11 presents the results of incorporating illegitimacy into the distributions. It is first important to note that the range of possible median illegitimate family welfare ratios was smaller than the range of the legitimate distribution. The median and range of the distribution was also strongly influenced by the wage that illegitimate mothers were assumed to be able to earn. If illegitimate mothers earned 50 per cent of the male wage, as single mothers did in the model, then the median illegitimate welfare ratio was 3.37, a very respectable standard of living indeed, higher than the median of the legitimate distribution. It seems unlikely, however, that mothers of illegitimate children would have been able to earn as much as other women because there was social stigma associated with illegitimacy, the Poor Law was less generous to illegitimate mothers especially after 1834, and the mothers had to care for their children.[49] But how much lower was their income? Table 1.11 presents three other income levels, one eighth, one quarter, and three-eighths the male wage, and there are very different affects on the overall distribution depending on which income level is picked. If mothers of illegitimate children earned 37.5 per cent of the male's wage, the effect of adding illegitimate families into the legitimate

[49] Laslett, 'Introduction', pp. 12-26.

Table 1.11: Subsistence welfare ratios for southern English building labourers (1750-1800) controlling for illegitimate families.

	Illegitimacy Adjusted (1750-1800): Percent of Male Wage Earned By Mother				Non-Adjusted (1750-1800)
	12.5	25	37.5	50	Two Parents
Median of Distribution of Predicted Median Illegitimate WRs	0.84	1.68	2.52	3.37	––
Mean of Distribution of Predicted Median Illegitimate WRs	0.87	1.74	2.61	3.47	––
Min of Distribution of Predicted Median Illegitimate WRs	0.32	0.65	0.97	1.30	––
Max of Distribution of Predicted Median Illegitimate WRs	1.15	2.30	3.45	4.60	––
Median of Combined Legitimate and Illegitimate Median WRs	2.36	2.36	2.49	2.62	2.47
Mean of Combined Legitimate and Illegitimate Median WRs	2.41	2.52	2.64	2.76	2.65
Gini Coefficient	0.2281	0.1713	0.1234	0.1512	0.1410

Sources: Simulated results.

distribution is negligible. The median actually increased slightly from the legitimate level and income inequality decreased. If the wage rate of illegitimate mothers was 12.5 or 25 per cent of the male wage, then including illegitimate families substantially decreases the medians and means of the combined distribution and increases income inequality.

Thus, the effect of incorporating illegitimacy into the distribution of median welfare ratios is somewhat ambiguous and depended strongly on the level of earnings of illegitimate mothers. However, the model for predicting the median welfare ratios of illegitimate families is problematic at best, making this robustness check of somewhat limited usefulness.

So what would the net effect of the various robustness checks and biases be? Incorporating illegitimacy is too problematic to come to any definitive conclusion about how it would shape the distribution. Allowing for remarriage shifts the distribution down a bit, but it seems unlikely that this affect would be larger than the upward shift created by incorporating women and children's participation in the labour force and by partially endogenizing the age at which children left the household. Thus, it seems that the median subsistence and respectability welfare ratios presented in Tables 1.6 and 1.7 are lower bounds for the actual demography-adjusted figures. Again, this suggests that Allen's original welfare ratios are either close to or slightly below the demography-adjusted figures.

1.7 Conclusion

This chapter has presented demography-adjusted welfare ratios for two broad reference periods, 1650-1700 and 1750-1800, showing that demography-adjusted welfare ratios are either higher than or match Allen's original real wage estimates.

These results are robust to the inclusion of remarriage and illegitimacy in the model, and any women and children's labour force participation would only increase the demography-adjusted figures further. The median family size in terms of consuming units was 2.69 in 1650-1700 and 2.98 in 1750-1800. Family size was much smaller than previous historians have argued for two reasons. First, relatively wide birth spacing ensured that not all children were present in the household at the same time and that the children each reached their peak consumption at different times. Second, mortality of children and adults significantly reduced the number of children born per family and the mouths that needed to be fed by the family. These factors kept family size at a relatively low level.

However, Allen's original real wage series stretch from 1264 to 1914. While these broader time periods cannot be incorporated into the model, it is possible to speculate about how changing fertility and mortality might have affected the distribution from the sixteenth century onwards. Fertility, measured by the net reproduction rate (NRR), was higher from 1550-1650 than from 1650-1700, and infant and childhood mortality was lower.[50] This suggests that family sizes were larger in the period 1550-1650 than in 1650-1700, but not quite as large as in 1750-1800 because fertility was not as high. Thus, Allen's real wages are probably close to the demography adjusted figures until the mid-seventeenth century when decreasing fertility and increasing mortality made family sizes smaller and drove the demography-adjusted welfare ratio above Allen's figure. By the mid-eighteenth century, however, family sizes had again grown because of increasing fertility and declining mortality of children and adults. Allen's real wage was probably again approximately equal to the demography-adjusted welfare ratio. Family sizes were

[50] Wrigley, *et al.*, *English Population History*, pp. 239, 250-1, 290, 614.

likely at their largest during the first half of the nineteenth century because fertility was unprecedentedly high and mortality had fallen. Thus, it is possible that the demography-adjusted welfare ratio could have fallen below Allen's real wage figure. In the second half of the nineteenth century, fertility fell to levels similar to those in 1650-1700, but childhood mortality rates also fell substantially.[51] The combined effects of these two processes likely kept family sizes at levels similar to those in 1750-1800, suggesting that Allen's real wages were close to the demography-adjusted welfare ratios.

It is also important to note that the scale of the adjustment for the demographic factors is really quite small. The largest gap between the demography adjusted welfare ratios and Allen's real wages was the difference in the period 1650-1700, but it only represented an 11.77 per cent increase in the welfare ratio. In order to halve the median building labourer welfare ratio in 1750-1800 to 1.225, the median family size would have to equal 6.02 consuming units. Families only reached this level of consumption in 2.55 per cent of the total family years lived 1750-1800. Thus, although adjusting for demography might raise or lower Allen's figures slightly, the demography adjustment is unlikely to change the general trend of the real wages Allen produced. Therefore, scholars wanting to improve upon Allen's method might find querying some of his other assumptions, for instance the constant 250-day work year, his rent assumptions and the reliance on male wages rather than household income, a more productive way of moving forward.

[51] Woods, *Demography*, pp. 6, 253.

CHAPTER TWO:

REAL WAGES AND THE HOUSEHOLD: QUANTIFYING THE ECONOMY OF MAKESHIFTS OF THE POOR IN EIGHTEENTH-CENTURY ENGLAND

Poor households in eighteenth-century England employed a number of strategies to increase their income formally in the labour market and informally outside it. These strategies included sending women and children into the labour market, allocating resources unequally within the household, self-provisioning on garden plots of land, gleaning, appealing to the poor law for aid, and expanding the number of days worked by household members. In addition, poor families could resort to a number of other strategies that are much more difficult to quantify such as theft, poaching, pawning, charity, etc. These strategies constituted an economy of makeshifts, which allowed the poor to at least scrape by and in other cases even reach respectable levels of consumption for the period.[1]

While social and economic historians have studied these strategies individually for eighteenth-century England, few have been able to integrate them to determine how they influenced the income of the average family. Likewise, few

[1] Hufton, *Poor* ; King and Tomkins (eds.), *Poor*.

historians have estimated how large a gap had to be filled by the economy of makeshifts for the poor to reach target consumption levels. This paper seeks to integrate the economy of makeshifts in such a way. In the previous chapter, I created a model that predicts welfare ratios (real wages) for families of agricultural labourers and building labourers over the family life cycle. In this chapter, the model is expanded to incorporate women and children's labour force participation and the unequal distribution of resources within the household. I then use Monte Carlo simulation to predict a distribution of 30,000 realistic families and their corresponding welfare ratios for the period 1750-1800. Focusing on the average (median) welfare ratio and the minimum welfare ratio across the family life cycle of the average family predicted by the simulations, I measure the influence of women and children's labour force participation and unequal household distribution on the family's welfare ratios. These welfare ratios are also converted to the amount of energy a family could purchase for work. Finally, for each level of women and children's labour force participation and each household resource distribution assumption, I calculate the level of self-provisioning, poor law support, or additional days of work necessary for the family to reach target consumption levels.

The results suggest that at the median welfare ratio in the family life cycle, agricultural labourers' families could get by at a low consumption level through either self-provisioning or working a few more days. However, at the minimum welfare ratio in the life cycle, this was much more difficult, and the poor law likely played a strong role in keeping these families afloat. Women and children's labour force participation increased the average family welfare ratios by 31 to 48 per cent depending on the specification used, and could even put agricultural labourer families within stabbing distance of Allen's respectability level of consumption. However, even with women and children's labour force participation, agricultural labourers' families still struggled to make ends meet at the low point in the welfare ratio curve during the life cycle. Building labourers were much better off because they started with a higher level of earnings. They likely used the six strategies mentioned above to target Allen's respectability level of consumption. I will first describe six strategies families used to combat poverty in eighteenth century; then explain how these strategies are incorporated into the existing Monte Carlo simulation; and finally present the results and conclude.

2.1 Six Elements of the Economy of Makeshifts

As mentioned above, six of the strategies that made up the economy of makeshifts will be tested in this paper: women and children's labour force participation, unequal distribution of household resources, self-provisioning through gardens and plots, income from common rights such as gleaning, poor relief and extension of the working year. Each has its own long and interesting literature, which I will attempt to briefly summarize here.

The nature and trajectory of women's employment from the second half of the eighteenth century through the nineteenth century has been subject to great debate. However, most of the controversy surrounded whether or not industrialization increased opportunities for women's labour participation, which is somewhat irrelevant to the mid-eighteenth century setting of this paper. In the mid-eighteenth century, the major employer of women was spinning. In fact, Muldrew has estimated that 75 per cent of women over the age of 14 were employed in spinning in 1770.[2] However, the spinning industry was drastically restructured after the invention and

[2] This is surely an overestimate: see the reworking of Muldrew's figures below. Muldrew, 'Th'ancient Distaff', p. 519-520.

implementation of the water frame, the spinning jenny and the spinning mule, each in succession after 1769. These technologies shifted spinning from cottage industry to factories.[3] The decline in spinning employment is evident in some of the figures of women's labour force participation rates in the eighteenth century. For example, 33.1 per cent of women and 8.5 per cent of female children in Cardington, Bedfordshire in 1782 were involved in spinning, but only 3.8 per cent of women and 13.5 per cent of female children were listed as spinners in the population listing taken for Corfe Castle, Dorset in 1790.[4] Comparing these two parishes across time is somewhat problematic because they had different economic structures to begin with (Cardington was always more dependent on cottage industries), but it highlights the decline in spinning nonetheless. The decline of spinning employment was slow at first, but certainly by 1800 the vast majority of wool and cotton yarn was produced in textile factories. The productivity gains achieved with the new technology also meant that many fewer women were required to produce an increasing amount of yarn.[5] There were some additional cottage industries that took off as spinning employment began to decline such as lace making, straw plaiting and handloom weaving. These industries helped to mitigate the loss of income and employment from spinning, but none could completely replace it. Lace-making and straw-plaiting were limited in geographic scope and handloom weaving did not become an important employer for women until the end of the eighteenth century.[6] Women's employment in agriculture was also on the decline at the same time.[7]

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[3] Burnette, *Gender*, pp. 39-40; Sharpe, *Adapting to Capitalism*, pp. 35-36, 69-70; Sharpe, 'Introduction', in Sharpe (ed.), *Women's Work*, pp. 6-10; Honeyman, *Women*, p. 31.
[4] Saito, 'Who worked when?', pp. 221-3.
[5] Burnette, *Gender*, p. 40.
[6] Burnette, *Gender*, pp. 42-48; Raven, 'A "Humbler, Industrious Class of Female" ';
[7] Snell, *Annals*, pp. 57-66; Honeyman, *Women*, pp. 28-30; but see also Verdon, 'A Diminishing Force', pp. 209-211.

Children's labour participation is similarly difficult to understand, especially for the eighteenth century, because historians' focus on and most of the sources come from the nineteenth century. There has been some debate about whether the widespread use of child labour in factories in the early stages of the Industrial Revolution was merely a continuation of the use of child labour in domestic and handicraft industries or a break from the past economic system. However, the current consensus appears to be that although there may have been an increase in children's labour participation during the late eighteenth and early nineteenth century as Humphries argues, child labour was in no way uncommon in the second half of the eighteenth century.[8] Saito's study of Corfe Castle (1790) and Cardington (1782) supports this claim with labour force participation rates around 35 per cent for children under the age of 15.[9]

Measuring the influence of women and children's labour on family income is again quite difficult. The only studies to provide convincing information on the contribution of women and children's income to family wages are the papers by Horrell and Humphries who collected a wide range of household budgets from 1787 to 1860. They found that in the earliest household budgets covering the period 1787-1815, women and children's income made up approximately 20 per cent of household income.[10] Thus, women and children's income could substantially increase family welfare. Aside from the size of their contribution, there is also the question of what factors pushed or pulled women and children into the labour market. Demand side factors were clearly important as Horrell and Humphries have shown: women and children's labour force participation was higher in areas with greater demand for

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[8] Humphries, *Childhood*, pp. 2-3, 203-207.
[9] Saito, 'Who worked when?', p. 221.
[10] Horrell and Humpries, 'Women's labour force participation', pp. 102-103; Horrell and Humphries, 'The exploitation of little children', p. 491.

women and children's labour.[11] However, in her study of working class autobiographies, Humphries was also able to highlight some of the supply side effects for children's labour. Children with a large number of siblings, the father absent, and on a poor law stipend started working at an earlier age than their counterparts. The mother's participation in the labour market also had a negative effect on the age of starting work, but it was not statistically significant. These results suggest that poorer families sent their children to work earlier than better off families.[12] These results are not entirely representative of the period studied here though because they are drawn from the entire sample of autobiographies with children born between 1627 and 1878 and the bulk of those in the nineteenth century. However, despite some uncertainty in the figures, women and children's labour participation was clearly an important way in which families combated poverty.

Another possible strategy for the family to avoid poverty would be to optimize the manner in which resources were distributed in the household. To a certain extent, this would be an obvious strategy and is not difficult to imagine happening. Men often had higher energy requirements than other family members because they performed strenuous labour, and therefore it would make sense to give them food resources commensurate with their energy requirements. However, unequal allocation of household resources could be more detrimental for two reasons. First, if the family was very poor, then the wife and children might have to sacrifice nutrients that they desperately needed so that the father could continue to work. Second, the father could have consumed well above his share of resources by, for instance, spending a lot of

[11] Horrell and Humpries, 'Women's labour force participation', p. 113; Humphries and Sarasúa, 'Off the record'.

[12] Humphries, *Childhood*, pp. 203-207.

time in the alehouse, and this could have negatively influenced women and children's health.[13]

There is some evidence that unequal household distribution affected women's health, though unfortunately most studies have been conducted for the nineteenth century. Nicholas and Oxley argue that the decline in women's labour opportunities at the end of the eighteenth and early nineteenth centuries changed the way that resources were allocated within the household to favour investment in males. Thus, women transported to Australia from the English countryside where women's employment declined the most were shorter than urban English women and Irish women, and English women experienced a sharper decline in height between 1795 and 1820 as well.[14] Later, Horrell, Meredith and Oxley found that women imprisoned in the Wandsworth House of Correction had substantially lower BMIs than their male counterparts, allowing them to gain weight on their prison diets rather than lose weight as the males did.[15] This mechanism, however, was not monolithic. In a follow-up study to the London one, Meredith and Oxley found that women in Paisley, near Glasgow, actually had higher BMIs than their male counterparts. They argue that women's strong labour market position in Paisley allowed them to bargain for resources within the household. Thus, there was a wage-earner bias in the allocation of household resources rather than a gender bias.[16] Excess female mortality was also higher in agricultural areas and was influenced by women's labour market prospects with some arguing that unequal household distribution was the cause.[17] Harris remains sceptical of this evidence, arguing that while there may have been evidence

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[13] Horrell and Oxley, 'Bargaining', pp. 149-153.
[14] Nicholas and Oxley, 'The living standards of women', pp. 746-747.
[15] Horrell *et al.*, 'Measuring misery'.
[16] Meredith and Oxley, 'Blood and Bone'; Horrell and Oxley, 'Bargaining'.
[17] McNay *et al.*, 'Excess Female Mortality', p. 670; Woods and Shelton, *Atlas*, pp. 134-135; Anderson, 'Social Implications', p. 19.

of discrimination in household resources against women, there is not strong evidence that there was discrimination against girls.[18] Thus, although the evidence is somewhat mixed and scepticism remains, unequal distribution of household resources is worth considering in the model.[19]

Self-provisioning has received the least amount of attention of the five strategies in part because it is so difficult to find quantitative information on self-provisioning. Floud *et al.* could only find information on output from garden plots for 1909-13 and then assumed that this self-provisioning was constant from 1700 to 1909 at 12 calories per person per day, not a particularly high number.[20] However, they accounted for the potato separately, which could have been an important part of garden plots. Salaman shows a map of locations where Arthur Young mentions the potato being grown in the 1760s and 1770s. The potato appears to have been most prevalent in enclosed areas in the Northwest and Southeast of England with relatively few farmers sowing potatoes in the South, the Midlands and the Northeast (at least as far north as the East Riding of Yorkshire). However, many of these potatoes were being grown for the market rather than self-provision. Young was disappointed that although many labourers had plots, few seemed to grow potatoes. Thus, although Salaman estimates that average daily consumption of potatoes in 1775 was a quarter pound per person (92 calories), it was not until the harvest failure of 1795 that potato consumption began to grow dramatically.[21]

Gazeley and Horrell provide the most reliable quantification of self-provisioning to date based on the Eden and Davies budgets from the 1780s and 1790s. They find that 35 per cent of households had a garden or were reported to be growing

[18] Harris, 'Anthropometric History', p. 71-73.
[19] This literature is covered more completely in chapter five section one.
[20] Floud *et al.*, *Changing Body*, pp. 156-157.
[21] Salaman, *History*, pp. 481-484, 495-496, 539, 613.

their own potatoes. In addition, 8 per cent of households were raising a pig. They find their estimates of people with access to plots convincing because as Shaw-Taylor has noted, few labourers had common rights before the parliamentary enclosures and because few parishes had attached common land by the late eighteenth century anyway.[22] In order to convert garden production into calories available for consumption, Gazeley and Horrell assume that the average garden produced 35 lbs. of potatoes and 3 lbs. of vegetables per week.[23] Taking Floud *et al.*'s assumptions in converting quantities of potatoes and vegetables into calories, this would yield 1,840 calories of potatoes and 53 calories of vegetables per day or 1,893 calories per day in total.[24] Gazeley and Horrell assume that a pig could produce 5 lbs. of meat and lard per week.[25] Using reasonable assumptions about the calorie content of different meats and lard and their relative makeup in the slaughter, we can assume that a family who slaughtered their pig would have 114 calories per day for a year.[26] Thus, although it is nearly impossible to determine the average amount of calories that the average labourer could produce in his garden, we at least know what the contribution to the family diet might have been if the labourer did have access to a garden or plot.

Common rights could have been another means for families to increase their income. Among the most important and widespread of these common rights was the right of the poor to glean the remaining crop on farmers' fields after the harvest. Peter King has suggested grain gleaned could be worth 3 to 14 per cent of a family's annual earnings depending on how many family members were participating in the labour

[22] Gazeley and Horrell, 'Nutrition', p. 6; Shaw-Taylor, 'Parliamentary enclosure', p. 658.
[23] Gazeley and Horrell, 'Nutrition: Online Appendix S1', p. 3.
[24] Floud *et al.*, *Changing Body*, pp. 219, 225. I assume the calorie conversion for potatoes was 23 calories/oz. and the conversion for vegetables was 7.74 calories/oz.
[25] Gazeley and Horrell, 'Nutrition: Online Appendix S1', p. 2.
[26] I assume that of the 5 lbs. of pork products per week, 0.8 lbs. is lard, 1.5 lbs. is bacon and 2.7 lbs is meat: this is based on the assumptions in Gazeley and Horrell, 'Nutrition: Online Appendix S1', p. 2. Lard, bacon and pork meat had the following calories conversion factors respectively: 253 calories/oz., 151 calories/oz. and 136.78 calories/oz. Conversions from nutritiondata.self.com.

market. Gleaning was most common in southern and eastern England with very few poor law commissioners mentioning gleaning in the 1834 Poor Law Commissioners Report for parishes in the North. Thus, there were distinct regional patterns in gleaning that seem to also mirror the relative generosity of the poor law. There was some ambiguity about who had gleaning rights: the old, young and disabled or the working poor. However, by the mid-eighteenth century, King argues that generally any landless labourer was considered poor enough to have access to gleaning rights and 'by the late eighteenth century women and children from large labouring families were clearly the most important subgroup of gleaners'.[27] Clearly, gleaning could have provided an important additional source of income for families facing hardship.

In addition to gleaning, Humphries and later Shaw-Taylor have pointed out a number of additional income sources available to those with access to common rights. Table 2.1 replicates Shaw-Taylor's value estimates of these income sources for *c.* 1800. Grazing cattle on common pasture was clearly the most lucrative of the possible income streams providing somewhere between 56 and 80 per cent of what a family could earn in the labour market. In addition, squatter's cottages constructed on the commons and fuel rights could have provided substantial income for a family, from 8 to 20 per cent of what a family could earn. Families could have also fattened pigs on the common, though it seems few families had access to pigs and according to Shaw-Taylor common land did not provide enough feed to properly fatten a pig.[28] Humphries argues that the parliamentary enclosures of the late eighteenth and early nineteenth century decimated these female income streams making families more reliant on wage labour (proletarianisation) and devaluing women's economic position

[27] King, 'Customary Rights', pp. 469-471, 474.
[28] Humphries, 'Enclosures', pp. 35-41; Shaw-Taylor, 'Parliamentary Enclosure', pp. 644-645; Gazeley and Horrell, 'Nutrition', p. 6.

within the family.[29] Shaw-Taylor has problematized this assertion somewhat, at least for southern and eastern England, by suggesting that common rights may not have been as prevalent as Humphries believed.[30] Clark and Clark take an even more pessimistic view, arguing that common land available to the poor was a very small percentage of total land.[31] In any case, common rights and particularly gleaning could have substantially supplemented families' income in times of need when families did have access to these rights.

Table 2.1: Value of income sources from common rights *c.* 1800.

	Monetary (£)		As % of male earnings	
Resource	Lower Est.	Upper Est.	Lower Est.	Upper Est.
Two cows	14	20	70.0%	100.0%
One cow	7	10	35.0%	50.0%
Free fatting for one pig	3	4.5	15.0%	22.5%
One squatter's cottage	2	5	10.0%	25.0%
One quarter-acre garden	2	7.5	10.0%	37.5%
Fuel rights	2	5	10.0%	25.0%
Gleaning	1.3	3.4	6.5%	17.0%

Notes: Male earnings are assumed to be £20 per year.

Sources: Shaw-Taylor, 'Parliamentary Enclosure', p. 645.

Another key element of the economy of makeshifts in the second half of the eighteenth century was the poor law, which provided pensions and other forms of aid to families in need. The poor law varied widely across England with the South and East generally providing more relief in the early eighteenth century than the North. Historians of the poor law have identified 1780 as a turning point. Before 1780, Snell, Smith, King and others have argued that poor relief was fairly flexible and generous because pensions were held constant during a period of deflation. However, after 1780, structural changes in the agricultural sector and the loss of women's

[29] Humphries, 'Enclosures', pp. 17, 41.
[30] Shaw-Taylor, 'Parliamentary Enclosure', p. 658; Williams, *Poverty*, pp. 156-157.
[31] Clark and Clark, 'Common Rights'.

employment in cottage industries drastically increased the number of paupers applying for relief. At the same time, pensions were not increased in line with inflation at the end of the century, making the poor law far less generous than it was before.[32] Although much of the older literature blamed the formation of the Speenhamland system of subsidizing the able bodied poor (1795) for making the Old Poor Law unsustainable, Boyer argued that even thirty years before Speenhamland the poor law was being used to provide unemployment benefits to seasonally unemployed agricultural labourers.[33] This change has also been linked to a masculinization of poor relief as the main recipients of poor relief shifted from being disproportionately female in the seventeenth and first half of the eighteenth century to being male dominated at least in the South.[34] In any case, the poor law was playing an active role in providing income to families and needs to be considered in the simulation.

Samantha Williams's careful study of two parishes in Bedfordshire, Campton and Shefford, provides the best information about who was receiving relief, what percentage of the population they comprised, and what the actual level of relief was. Williams found that elderly people were only a minority of those receiving pensions with families and lone parent households, the vast majority of which were widows, making up a significant minority of pensions. She also found that in 1801, the first date for which this could be calculated, 63.8 per cent of families in Campton and 22.4 per cent of families in Shefford were receiving poor law pensions. These figures were outliers for the early nineteenth century, approximately twice the percentage of families receiving pensions at the other census years, but it shows how the poor law could be quite generous in times of crisis. Finally, in Campton pensions for families

[32] Williams, 'Poor Relief', 487.
[33] Boyer, 'Economic Model', pp. 129-130; Blaug, 'Myth', pp. 151-153.
[34] Williams, *Poverty*, pp. 12, 131; King, 'Meer pennies', pp. 125-126, 128-129.

and lone parents increased from 15 per cent of the weekly male wage in agriculture in 1767-70 to 27 to 40 per cent of the weekly male wage in 1794-96. Shefford was even more generous in 1795-96 with families receiving 37 to 55 per cent of the male weekly wage and lone parents receiving 43 to 65 per cent of the male weekly wage.[35] 1795 was clearly a bad year, but even if poor rates were half their 1795 level, poor relief could have made a substantial difference for families facing hardship in the late eighteenth century.

French, following King, has also highlighted occasional payments in cash and in kind for families who were struggling but who did not qualify for a weekly pension. In Terling, Essex weekly pensions only made up one-third of poor relief expenditure with occasional payments making up the other two-thirds of expenditure. In addition, there were regularly ten times the numbers of people receiving occasional payments than receiving pensions. Thus, the occasional payments were dispersed to families higher in the strata of the working class. Most of the payments were in the form of general sums of cash or specific amounts to purchase clothing, shoes, or fuel. The general cash allowances were only a small amount if measured on a per capita basis across the year, but the average person receiving these allowances was awarded 6s. 8.4d. an average of 2.6 times per year. Therefore, these payments could have been very helpful as replacement income for a few weeks each year, dealing 'with infrequent "emergencies" rather than persistent privation' even though on an annual basis they would only represent 0.5 per cent of an agricultural labourer's earnings. Occasional payments were also more likely to be awarded to married men and women, though this declined over second half of the eighteenth century.[36] Williams also studied these occasional payments for her parishes but found that they were less

[35] Williams, 'Poor Relief', pp. 496, 500-502, 506-508.
[36] French, 'Living', pp. 295-299, 306, 299 quote.

important than in Terling with more people receiving pensions than occasional payments after 1800. In addition, in Bedfordshire most of the recipients of clothing, which made up a large share of occasional payments, were elderly pensioners or lone parents with only 6 per cent of payment going to families with two parents.[37] Thus, it seems that while the occasional payments may have helped families to income smooth during the year, they would be unlikely to affect the poverty based on family structure that is measured in this chapter.

It is also important to remember that Williams's optimistic picture of poor relief in southern England has to be somewhat tempered when considering the nature of poor relief in northern England. Not only was poor relief less generous in the North, but Steven King has argued that poor law officials in the late eighteenth and early nineteenth centuries created a gendered 'work-relief nexus' whereby women's labour force participation was strongly encouraged by subsidizing women's employment activities and even employing women directly to serve as nurses, etc. for other families receiving poor relief.[38] Thus, poor relief administrators favoured subsidizing women's employment in the North (or at least Lancashire) instead of men's employment as in the South at the end of the eighteenth and beginning of the nineteenth century. Poor relief in the North 'subsidised individual household economies' whereas poor relief in the South 'subsidised farmers by supporting male wages' and sought to maintain 'community-level labour markets'.[39] These different purposes of poor relief in the North and South will require a nuanced interpretation of the Monte Carlo simulation.

The final strategy discussed in this paper is the father's extension of the working year in order to bring more income into the household. There is little

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37 Williams, *Poverty*, pp. 44, 54-57.
38 King, 'Meer pennies', pp. 126, 130.
39 King, 'Meer pennies', p. 133.

quantifiable information that yields simple insights into how the number of days worked per year changed over the eighteenth century. Voth ingeniously used witness statements in the Old Bailey in London and assize depositions from the Northern Assize Circuit to measure the percentage of people reporting being at work when they witnessed a crime. From this 'frequency-based method' Voth was able to determine the average number of hours worked per year and provide confidence intervals around these estimates. Thus, Voth finds an increase in the hours worked per year in agriculture from 2,311 in 1760 to 3,431 in 1800 while the number of hours worked per year increased from 2,668 to 3,293 for the economy as a whole.[40] Converting these figures into days worked per year is much more complex. In their paper testing the potential importance of expanding the working year, Allen and Weisdorf assumed a 10-hour working day across both periods in order to convert Voth's figures to working days.[41] This is problematic, however, because the increase that Voth observes could be driven by an increase in days worked per year or by an increase in hours worked per day. If we assume that the average working day was 9 hours in 1760 and that half of the increase in hours worked per year that Voth observes was driven by increases in the hours worked per day and half by increases in the number of days worked per year, we can produce some new estimates of the average number of days worked in agriculture. Thus, assuming 9 hour work days, the average working year in 1760 was 256.8 days in agriculture and 296.4 days in the economy as a whole. Assuming that the hours worked per day expanded as described above, Voth's 1800 estimate would yield a working year of 306.9 days per year in agriculture and 327.5 days per year in the wider economy. Thus, Voth argued that there was room for an

[40] Voth, 'Longest Years', pp. 1069-1076.
[41] Allen and Weisdorf, 'Was there an 'Industrious Revolution', p. 721.

industrious revolution in the second half of the eighteenth century because working hours (and here days) expanded substantially.

Clark and van der Werf have also made estimates of the working year by dividing the annual earnings of full time ploughmen by the average day wage of ordinary workers because employers would have no reason to hire people annually if they could hire wage labourers more efficiently. Thus, based on Arthur Young's observations on his tour of rural England in 1771, they calculate that the average working year was 280 days.[42] Allen and Weisdorf used both Voth and Clark and van der Werf's working year estimates to determine whether agricultural labourers and London building labourers could have expanded their working days in order to obtain a respectable level of consumption. They found that London building labourers had substantial room for extending their working year and increasing their consumption whereas the possibilities for agricultural labourers were much more limited. Thus, these estimates of the working year will provide useful bounds when determining how many more days per year a father would have to work to allow his family to reach a certain consumption target.

Clearly, the strategies presented here provided families with ample opportunity to supplement the income of the male breadwinner. However, it is important to note that the economy of makeshifts was not static during the second half of the eighteenth century or geographically uniform. As has been hinted above, the economy of makeshifts was quite different in northern and southern England, and faced divergent trajectories in the period from 1750-1834. In the South, the economy of makeshifts became less diversified by the end of the eighteenth century. Rising seasonal unemployment in agriculture (and underemployment after 1813), falling or

[42] Clark and van der Werf, 'Work in Progress', pp. 836-839.

stagnant agricultural real wages, the decline of cottage industries as sources of female employment and reduced charitable giving left struggling families relying more and more on the poor law and gleaning to supplement their income during periods of hardship. These factors, in part, help to explain the increase in poor law spending over the period.[43] In the North, however, the economy of makeshifts remained diversified across the second half of the eighteenth century. Although the poor law and gleaning played a smaller role in the North, wages were increasing faster in the North as it overtook the South as the high wage region in Britain; unemployment was lower because of the growing industrial sector; women's work in cottage industry was slower to decline; common lands and wastes were more common; and kinship networks and charity played a larger role in the economy of makeshifts.[44] These diverse experiences and the change across the second half of the eighteenth century introduce problems for a model that essentially treats England between 1750 and 1800 as a static, unified whole. However, wherever possible the model will be interpreted with these complications in mind.

2.2 Specifying the New Model

2.2.1 The Original Breadwinner Model

The model to predict realistic families for early modern England has been described in detail in the previous chapter and in print, but I will briefly describe the basics.[45] The model uses demographic statistics drawn from Wrigley *et al.*'s family reconstitution of 26 parishes in early modern England and could be implemented in two historical periods, 1650-1700 and 1750-1800. However, because quantitative

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[43] Snell, *Annals*, pp. 19-22, 57-66; Tomkins and King, 'Introduction', in King and Tomkins (eds.), *Poor*, p. 20

[44] Tomkins and King, 'Introduction', p. 20; Snell, *Annals*, p. 1; Schwarz, 'Trends', pp. 94-95; King, 'Customary Rights', pp. 467-468.

[45] Schneider, 'Real Wages and the Family', pp. 100-105; chapter one.

information on women and children's labour force participation rates in the seventeenth century is virtually non-existent, the analysis in the current chapter will be limited to 1750-1800. The model has two components: the demographic component which predicts marriage ages, births, deaths and the age when children leave the household and the welfare component which converts the demographic composition of the family into a level of family consumption that can be used to calculate welfare ratios (real wages).[46]

The demographic component of the model begins with the marriage of a couple. The parents' age at marriage is randomly picked from within a realistic distribution of age at marriage for men and women. The couple are then given certain probabilities of having children based on the parity progression ratios reported in Wrigley *et al*. Birth spacing is also allowed to vary within a lognormal distribution from the Wrigley *et al.* level with a shorter birth spacing following an infant death. The children and the parents are exposed to age-specific mortality risks each year.[47] This ensures that the number of children being supported at any given time matches the historical reality and that the correct number of single parent households is present in the predicted distribution. In the breadwinner model, if the father dies, then the mother immediately enters the labour force earning 50 per cent of the father's annual earnings. Finally, the age at which children leave the household is allowed to vary randomly over a normal distribution with a mean of 18 and a standard deviation 1.5 years.[48]

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[46] It should be noted that the reconstitution parishes were not wholly representative of the English population. They were mostly rural parishes and might not reflect the demography of growing industrial cities. Likewise, the family reconstitutions do not record all important family events such as periods of single parent household when the father deserts or is serving in the military.

[47] Wrigley *et al.*, *English Population History*, pp. 146-147, 250-251, 403, 438-439, 447.

[48] This is later than assumed in Schneider, 'Real Wages and the Family' and chapter one because that paper did not capture a teen's ability to work in the labour force.

The welfare component of the model has two steps. It is first necessary to compute the consumption level of the family in terms of adult male equivalents (hereafter consuming units).[49] Thus, I use the FAO daily energy requirement recommendations for children and adults of both sexes to reweight the consumption of children and adults in terms of one consuming unit. I also allow women additional energy when they are pregnant or nursing to cover these extra, demography-related activities. Second, welfare ratios are calculated for southern English agricultural labourers and building labourers in each year of the family life cycle.[50] Allen's method assumes that the husband worked 250 days per year. Thus, the welfare ratio is equal to the male day wage times 250 days worked divided by the number of consuming units in the family times the annual cost of the price basket. Two price baskets are utilized in this paper.[51] The subsistence basket is a theoretical basket that provides the bare minimum consumption required for survival at the cheapest possible cost. For England the subsistence basket contains 1,938 calories per consuming unit and is made up mostly of oatmeal and beans with a little meat. This was clearly not a desirable or comfortable level of consumption.[52] The respectability basket is based on Eden's study of household budgets in the 1790s and reflects a higher level of consumption both in terms of quality and quantity of food, containing 2,500 calories per consuming unit. Wheaten bread was the staple of the respectability basket with additional expenditure for beer, meat, eggs, cheese, and butter. Calories in the respectability basket were also over three time more costly than calories in the

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[49] Floud *et al.*, *Changing Body*, p. 44.

[50] Allen, spreadsheet.

[51] Allen has recently revised his baskets so that the subsistence basket has more calories and the respectability basket has fewer calories. Allen, 'Poverty Lines in History'. In this chapter these baskets are converted into energy that the family could buy, so the minimum level of energy in the basket is not important to the final results.

[52] Humphries, 'Lure of Aggregates', p. 5-6; Allen, *British Industrial Revolution*, pp. 36-7.

subsistence basket.[53] Welfare ratios are calculated for both agricultural labourers and building labourers to capture the effect of the economy of makeshifts for two different labouring groups.[54] Both prices and wages are held constant at the average level across the period 1750-1800 so that price and wage fluctuations would not cloud the outcomes of the model. Thus, the welfare ratios in the model are determined by changing levels of family earnings and consumption only.

There are three other assumptions in the original model worth mentioning. First, the welfare ratios calculated here are meant to reflect family welfare. Thus, only families with at least one adult and one child alive are factored into the model. The family life cycle begins when a couple marries and ends when the last child leaves the household. Therefore, there are no single people, infertile married people, or couples whose children have left the household left in the simulation. Second, the model ignores illegitimacy and remarriage. Finally, I assume that average English demography applies to the households of labourers. Class targeted demographic statistics do not exist for early modern England, so this is a necessary assumption.

2.2.2 Women's Labour Force Participation and Wages, 1750-1800

In order to incorporate women's labour force participation into family welfare ratios, we must first determine the percentage of married and widowed women participating in the labour market and their earnings relative to men in the second half of the eighteenth century. Finding representative and unbiased sources on women's labour force participation before the 1851 census is incredibly difficult. Although many historians have attempted to tackle this problem creatively, we still lack a truly

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[53] These baskets are more precisely defined in Allen, *British Industrial Revolution*, pp. 36-7; Schneider, 'Real Wages and the Family', p. 102; and chapter one.

[54] London wages are excluded because the 26 reconstituted parishes represent the demography of rural areas and small towns, not the metropolis.

robust and representative understanding of female and especially married women's labour participation in the eighteenth century. This uncertainty stems partially from the wide variety of experience across different parts of England, highlighted by Shaw-Taylor's analysis of women's labour force participation in the 1851 census.[55] Thus, rather than trying to find some aggregate middle ground between a number of estimates, this paper will utilize labour force participation from four sources in an attempt to measure the bounds of the effect and how different participation assumptions would change the distribution of family welfare ratios. The first two sources are census-like population listings for Cardington, Bedfordshire and Corfe Castle, Dorset from the late eighteenth century that were analysed by Osamu Saito.[56] The third source consists of the earliest household budgets used by Horrell and Humphries to measure household income and women and children's labour force participation across the Industrial Revolution.[57] The final source is Muldrew's work on spinning output from which I make an estimate of the percentage of married women involved in spinning. Each of these sources will be described in detail below.

Saito's source for measuring women's labour force participation in Cardington, Bedfordshire was a population listing conducted in 1782, which has been transcribed and edited by David Baker.[58] Cardington was a rural parish with strong cottage industries such as spinning and lace-making which employed women and girls but few employment opportunities for men and boys outside of agriculture: 76.7 per cent of male household heads were employed in agriculture. Poor relief expenditure per capita was over twice as high at 22s. in Cardington in 1803 as in England and Wales as a whole (9s.). Thus, Cardington was a relatively poor rural

[55] Humphries and Snell, 'Introduction', pp. 1-4; Shaw-Taylor, 'Diverse Experiences'.
[56] Saito, 'Who worked when?'.
[57] Horrell and Humphries, 'Women's Labour Force Participation'; Horrell and Humphries, 'The Exploitation of Little Children'.
[58] Baker, (ed.), *The Inhabitants of Cardington*.

parish that likely suffered from insecure seasonal employment for agricultural labourers who made up 59.3 per cent of household heads, increasing poor law payments.[59] Table 2.2 presents the women's labour force participation rate in Cardington, which was 67.5 per cent for married women and 67.7 per cent for widowed women in 1782.[60]

Table 2.2: Labour force participation rates across the various specifications of the model.

	Labour Force Participation Rates (%)			
Family Member	Corfe Castle	Cardington	H-H	Spinning
Father	100.0	100.0	100.0	100.0
Married Woman	8.7	67.5	64.1	47.7
Widows	82.1*	67.7*	*	*
Boys (aged 5-14)	32.1	1.2	32.8	32.8
Boys (aged 15 and over)	94.4	75.0	87.4	87.4
Girls (aged 5-14)	42.5	43.9	32.8	32.8
Girls (aged 15 and over)	75.9	83.3	87.4	87.4

Notes: * Widows' participation was held at 100 per cent in the model assuming that those widows who were not working were receiving poor relief on average 50 per cent of a male's earnings.

Sources: Corfe Castle – Saito, 'Who worked when', p. 221; Cardington – Saito, 'Who worked when', p. 221; Horrell-Humphries – Horrell and Humphries, 'Women's labour force participation', p. 98; Horrell and Humphries, 'The exploitation of little children', p. 497; Spinning – Muldrew, 'Th'ancient Distaff', pp. 518-19 and calculations in table 2.3.

Saito used another population listing prepared in 1790 to measure labour force participation in Corfe Castle, Dorset. Corfe Castle was also a rural parish, but it contained a market town and had a much more diversified occupational structure for adult males. Only 40.8 per cent of male household heads were involved in agriculture with others working as tradesmen or craftsmen or as clay cutters. Women's occupations, however, were much more scarce with the majority working in either spinning or knitting. Very few married women worked (Table 2.2), only 8.7 per cent, but a much larger share of widows, 82.1 per cent, worked. As Saito notes, even

[59] Saito, 'Who worked when?', pp. 209-15; Boyer, 'An Economic Model'.
[60] Saito, 'Who worked when?', p. 221.

contemporaries noted that spinning was beginning to fail in Dorset by the mid-1790s. Corfe Castle was also a relatively poor parish with poor law expenditures at 19s. per capita, well above the average rate for England and Wales.[61]

It is clear from the quality of the evidence that Saito has collected that these two parishes can provide a very useful starting point for the Monte Carlo simulation. Unfortunately, the parishes are probably not very representative. They are both rural and therefore do not capture the occupational structure of the growing cities in the late eighteenth century. However, they are, more or less, the same kind of parishes that are present in Wrigley *et al.*'s family reconstitutions. Five of the twenty-six reconstitution parishes were in Devon (quite close to Dorset) and one was in Bedfordshire.[62] Thus the demographic simulation should match well to these types of parishes. The parishes also appear to have been poorer than other parishes, which could mean that their labour participation rates were higher than the country as a whole because families had to send women and children into the labour force in order to earn a decent living. Despite these problems, it is worth entering the two parishes into the simulation in order to create a range of plausible outcomes.

The third source for women's labour participation rates utilized in this paper is the Horrell and Humphries sample of household budgets for the years 1787-1815. Horrell and Humphries gathered the budgets from a variety of sources in order to understand how household earnings (rather than male earnings) and women and children's labour force participation changed over the Industrial Revolution. The married women's labour force participation rates for the early period are based on 196 household budgets, which span England from Cornwall to Middlesex to Leicestershire to Lancashire to Durham. There are also 14 budgets (7 per cent) from

[61] Saito, 'Who worked when?', pp. 209-215.
[62] Wrigley *et al.*, *English Population History*, pp. 22-3.

Wales and Scotland. Horrell and Humphries divided the budgets into seven categories by the father's occupation: high-wage agriculture, low-wage agriculture, mining, factory, outwork, trades, and casual. Most of the budgets for the earliest period were agricultural budgets with relatively few in the other occupational classes.[63] One should also note that the Horrell-Humphries household budgets were mostly collected by social reformers targeting poorer households, so they are not strictly representative of all socio-economic groups.[64] However, despite some low sample sizes and a lower income bias, the geographic range and breadth of occupational groups makes the sample interesting and worth entering into the simulation.

Horrell and Humphries also noted the difficulty in defining women's labour force participation because labour force participation could be measured in three ways using the household budgets. First, participation could be defined as women who had a listed occupation in the original source, similar to the population listings for Cardington and Corfe Castle. Second, participation could be defined as a woman having non-zero earnings whether she had a listed occupation or not. Finally, participation could be defined as either having a listed occupation or having non-zero earnings. Generally, participation rates increased across the three participation types. This is somewhat worrying since it suggests that the population listings for the other parishes may understate women's labour participation. Therefore, in order to counter this potential error, I have opted to utilize Horrell and Humphries's most expansive measure of participation, when a woman either has a listed occupation or non-zero earnings. In order to simplify the simulation, I took a weighted average of participation across the seven household categories based on Shaw-Taylor *et al.*'s

[63] Horrell and Humphries, 'Women's Labour Force Participation', pp. 98, 114-15.
[64] Burnette, *Gender*, p. 308.

new occupational structure data for England and Wales in 1818.[65] These weights are slightly different than the weights used by Horrell and Humphries based on Deane and Cole and Lindert, but the overall participation rate changes very little. Thus, according to the Horrell-Humphries sample, women's labour force participation for the period 1787-1815 was 64.1 per cent (Table 2.2).

Incorporating the fourth source of women's labour participation, Muldrew's estimate of women's spinning employment, is unfortunately more complex than incorporating the other estimates. Muldrew has gone the farthest toward predicting the number of women involved in spinning wool, hemp and flax. Using estimates of domestic consumption and exports of various types of cloth, he estimates that approximately 75 per cent of women above the age of 14 were spinning.[66] However, Muldrew's estimates must be refined somewhat to incorporate them into the simulation. This is mostly because his estimates assume that all the women spinning were married. As Muldrew reports, Eden noted there were significant productivity differences in spinning between married and single women: single women could spin 6 lbs. of wool for the 'new draperies' per week whereas married women could only spin 2.5 lbs. of wool per week if they 'had housework and children to look after'. These figures suggest that single women were 2.4 times as productive as married women.[67] Thus, the number of single women spinners could drastically influence the participation of married women, and Muldrew's figures need to be recalculated to capture this effect.

In order to adjust Muldrew's figures, it is first necessary to calculate the number of single women in England in 1770, the year for which these calculations will be made. We can determine the number of women aged 15 to 64.9 alive in

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[65] Shaw-Taylor and Wrigley, 'Occupational Structure', p. 7.
[66] Muldrew, 'Th'ancient Distaff', p. 520.
[67] Muldrew, 'Th'ancient Distaff', pp. 507, 520.

England in 1770 assuming an equal sex ratio using Wrigley *et al.*'s figures.[68] We then need to determine what percentage of these women was single. This is a difficult task because some of the women would have been single because they had not yet married and others would have been single because they were never going to get married. There has been some debate over the percentage of the population ever marrying with Weir critiquing Wrigley and Schofield's original figures and Schofield responding. However, the general agreement is that in the second half of the eighteenth century 88 to 90 per cent of people were married at some point in their life.[69] These figures do not help determine the percentage of women who had not yet married though, since they deal exclusively with people over the age of 40. In order to roughly calculate the overall percentage of single women, I used the adjusted third English life table in Wrigley and Schofield to predict the age distribution of the population and the age distribution of married women in 1770.[70] The age distribution of the predicted population matched the age distribution in Wrigley *et al.* quite closely. Thus, the percentage of women single from 15 to 64.9 was approximately 25 per cent. This figure is imprecise, but it gives an idea of how many single women aged 15-64.9 were alive in Britain in 1770.

Thus, Muldrew's spinning participation rate can be recalculated accounting for the different productivity of single and married women. Table 2.3 shows this calculation in detail. There are three key assumptions that should be highlighted that could affect the married women's labour force participation rate. First, I have

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[68] Wrigley *et al.*, *English Population History*, pp. 614-15.

[69] Wrigley and Schofield, *Population History of England*, pp. 257-65; Weir, 'Rather Never than Late', pp. 346-350; Schofield, 'English Marriage Pattern', p. 14.

[70] Wrigley and Schofield, *Population History of England*, p. 714; Marriages were predicted from the crude marriage rate assuming that 95.2 per cent of marriages involved spinsters (see Wrigley *et al.*, p. 165). I assumed that 60 per cent of marriages occurred in the 20-24 age group and 40 per cent occurred in the 25-30 age group. These women were then subjected to age-specific mortality rates across time so that a full age-range of married women was predicted for the year 1770.

assumed that single women's productivity advantage in spinning higher value wool yarn (the new draperies as Muldrew calls them) was the same for lower value wool yarn, hemp and linen. I also assume that single women were able to work 42 weeks (252 days) a year rather than the 35 weeks Muldrew assumed for married women since single women likely relied almost entirely on spinning for their income. Thus, single women were not only more productive but they worked more during the year. Second, clearly not all single women were involved in spinning at the levels of productivity and time commitments just suggested. Thus, I had to make assumptions about the percentage of single women spinning as opposed to working in other jobs in the labour market. As the differing rates of married female labour participation across the columns in table 2.3 hint, the final married women's participation figure is highly sensitive to the number of single women engaged in spinning. If 90 per cent of single women were involved in spinning then only 35.3 per cent of married women would have been spinners, but if 50 per cent of single women were involved in spinning then up to 68.4 per cent of married women would be needed to spin the total output for England. This range demonstrates just how important it is to consider single women in these calculations. Third, Muldrew notes that younger women would likely have been less productive than more experienced spinners.[71] Thus, it is probably necessary to add a productivity penalty for single women under the age of 20. The life table exercise described above and in note 69 suggests that approximately 55 per cent of single women were aged 15-19.9 and probably spun at less productive rates. Table 2.3 allows for a 25 per cent productivity penalty, i.e. single women under 20 were 25 per cent less productive than their older single counterparts.

[71] Muldrew, 'Th'ancient Distaff', p. 517.

Table 2.3: Calculation of married English women's labour force participation in spinning in 1770.

		A	B	C	Source
(1)	Total Low Quality Wool Yarn Spun (lbs.)*	39,769,989	39,769,989	39,769,989	Muldrew, p. 518.
(2)	Total High Quality Wool Yarn Spun (lbs.)*	46,647,884	46,647,884	46,647,884	Muldrew, p. 518.
(3)	Total Hemp/Linen Spun (lbs.)	183,000,000	183,000,000	183,000,000	Muldrew, p. 519.
(4)	Married Rate of Spinning Low Quality Wool Yarn (lbs./week)	4.5	4.5	4.5	Muldrew, p. 517.
(5)	Married Rate of Spinning High Quality Wool Yarn (lbs./week)	2.5	2.5	2.5	Muldrew, p. 517.
(6)	Married Rate of Spinning Hemp/Linen (lbs./week)	6	6	6	Muldrew, p. 519.
(7)	Single Rate of Spinning Low Quality Wool Yarn (lbs./week)	10.8	10.8	10.8	(8) / (5) × (4)
(8)	Single Rate of Spinning High Quality Wool Yarn (lbs./week)	6	6	6	Muldrew, p. 507.
(9)	Single Rate of Spinning Hemp/Linen (lbs./week)	14.4	14.4	14.4	(8) / (5) × (6)
(10)	Total Women Aged 15-64.9	2,011,845	2,011,845	2,011,845	Wrigley *et al*., pp. 614-15
(11)	Percentage Single Women (15-64.9)§	25.00%	25.00%	25.00%	Predicted (see text)§
(12)	Number of Single Women (15-64.9)	502,961	502,961	502,961	(10) × (11)
(13)	**Single Women's Participation in Spinning†**	**90.00%**	**75.00%**	**50.00%**	**Assumption†**
(14)	Single Women Spinning	452,665	377,221	251,481	(12) × (13)
(15)	% of All Single Women Aged 15-19.9§	55.00%	55.00%	55.00%	Predicted (see text)§
(16)	Adult Single Workers (20-64.9)	203,699	169,749	113,166	(1 - (15)) × (14)
(17)	Young Single Workers (15-19.9)	248,966	207,472	138,314	(15) × (14)
(18)	Productivity of Young Single Workers (% of adult singles)†	75.00%	75.00%	75.00%	Assumption†
(19)	% Single Women Spinning Low Quality Wool Yarn[a]	15.00%	15.00%	15.00%	Assumption[a]
(20)	% Single Women Spinning High Quality Wool Yarn[a]	35.00%	35.00%	35.00%	Assumption[a]
(21)	% Single Women Spinning Hemp/linen[a]	50.00%	50.00%	50.00%	Assumption[a]
(22)	Total Low Quality Wool Yarn Spun by Single Women (lbs.)[o]	26,564,426	22,137,022	14,758,015	(16) × (7) × (19) × 42 + (17) × (7) × (18) × (19) × 42
(23)	Total High Quality Wool Yarn Spun by Single Women (lbs.)[o]	34,435,368	28,696,140	19,130,760	(16) × (8) × (20) × 42 + (17) × (8) × (18) × (20) × 42
(24)	Total Hemp/Linen Spun by Single Women (lbs.)[o]	118,064,117	98,386,765	65,591,176	(16) × (9) × (21) × 42 + (17) × (9) × (18) × (21) × 42
(25)	Remaining Low Quality Wool Yarn to be Spun (lbs.)	13,205,563	17,632,967	25,011,974	(1) - (22)
(26)	Remaining High Quality Wool Yarn to be Spun (lbs.)	12,212,516	17,951,744	27,517,124	(2) - (23)
(27)	Remaining Hemp/linen to be Spun (lbs.)	64,935,883	84,613,235	117,408,824	(3) - (24)
(28)	Weeks Required for Married Women to Spin Remaining Low	2,934,569	3,918,437	5,558,217	(25) ÷ (4)
(29)	Weeks Required for Married Women to Spin Remaining High	4,885,007	7,180,698	11,006,850	(26) ÷ (5)
(30)	Weeks Required for Married Women to Spin Remaining Hemp	10,822,647	14,102,206	19,568,137	(27) ÷ (6)
(31)	Married Women Working[o]	532,635	720,038	1,032,377	((28) + (29) + (30)) ÷ 35
(32)	Total Married Women (15-64.9)	1,508,884	1,508,884	1,508,884	(10) - (12)
(33)	**Married Women's Participation (15-64.9)**	**35.30%**	**47.72%**	**68.42%**	**(31) ÷ (32)**
(34)	Total Women Spinners	985,300	1,097,259	1,283,858	(14) + (31)
(35)	Total Women (15-64.9)	2,011,845	2,011,845	2,011,845	(10)
(36)	Total Women's Labour Participation Rate in Spinning	48.97%	54.54%	63.81%	(34) ÷ (35)

Notes: All figures are for 1770. Single women's participation in spinning (row 13) varies across the three columns. Married women's labour participation in column B (47.72 per cent) was used in the Monte Carlo simulation.

* I have renamed Muldrew's wool yarn categorizations. Muldrew's 'old draperies' have become low quality wool yarn, and his 'new draperies' have become high quality wool yarn.

§ I assume that 25 per cent of women between the ages of 15 and 64.9 were either never married single or had not married yet. Likewise, I assume that 55 per cent of all single women were aged 15-19.9. These figures are based on life table calculations and are approximations (see text for more detail).

† denotes assumptions for which there is limited evidential basis.

[a] denotes assumptions that are necessary but do not affect the final calculations.

[o] Married women are assumed to have worked 35 weeks per year (as Muldrew suggests), but single women are allowed to work 42 weeks per year (252 days per year) to bring them in line with the work effort expected of males.

Sources: Muldrew, 'Th'ancient Distaff', pp. 507, 517-19; Wrigley *et al.*, *English Population History*, pp. 165, 614-15; Wrigley and Schofield, *Population History of England*, p. 714.

The range of potential married women's labour force participation rates in table 2.3, from 35.3 to 68.4 per cent, is a bit astounding and suggests caution when drawing any definitive conclusions from Muldrew's estimates. However, it seems reasonable to me to assume that 75 per cent of single women were employed as spinners (they were called spinsters). Thus, the participation rates in column B of table 2.3, 47.7 per cent of married women and 54.5 per cent of all women aged 15-64.9, seem most appropriate. The latter figure is substantially higher than the 40.7 per cent of women aged 15 and over working as spinners in Cardington in 1782 and the 32.4 per cent of women in Corfe Castle in 1790 working as spinners, reflecting the rapid decline in spinning after 1780.[72]

Thus, table 2.2 summarizes the married women's labour force participation rates that will be utilized in the Monte Carlo simulation. Married women's labour participation was low in Corfe Castle but substantially higher in Cardington and in Horrell and Humphries estimations. Spinning participation split these other categories.

Having clarified some of the issues surrounding the estimation of married women's labour force participation rate, we must now consider married women's potential earnings relative to their husbands'. Much has been written about male/female wage gaps during the late eighteenth century and early industrial period. The general consensus in the literature is that women's wages tended to vary between one-third and two-thirds of the male wage depending on the occupation.[73] However, these wage differences cannot easily be translated into earnings because women may

[72] Saito, 'Who worked when', pp. 221-3; Muldrew, 'Th'ancient Distaff', p. 499; Participation in spinning in Cardington and Corfe Castle for women aged 15 and over was calculated by assuming that all children spinning were over the age of 15. Thus, these figures are an upper bound estimate for women working as spinners aged 15 and over.

[73] Burnette, *Gender*, pp. 72-3; Lane, 'A customary or market wage', pp. 102-3, 107-10; Verdon, *Rural Women Workers*, p. 48.

not have worked full time and their husband's wages also affected the wage ratio. Likewise, Burnette and others before her were mostly interested in the wage gap when men and women performed the same or similar tasks, but as Burnette herself argued, there was fairly rigid occupational sorting in the eighteenth century that precluded the vast majority of women from working alongside men. In addition, women could have received a substantial amount of their remuneration in kind and wages could vary by the woman's marital status, age, and number of children.[74] Steven King has also argued that both women's labour force participation and their wages were influenced by the poor law policies, which subsidized women's labour force participation at lower wages, especially in the North.[75]

Thus, we are more interested in the relative earnings of women rather than their relative wage, forcing us to turn to household budget data in order to understand how women's earnings faired relative to their husbands'. In Horrell and Humphries's budgets for the period 1787-1815, women's earnings ranged widely from only 7.2 per cent of the husband's earnings in trade related occupations to 69.2 per cent of male earnings in mining households.[76] Taking a weighted average of women's earnings weighted by the employment share for each family occupational type (see above), women's earnings were only 18.91 per cent of the husband's earnings (Table 2.4). This figure, therefore, likely provides the most realistic estimate of women's earnings available. However, it should be noted that while Horrell and Humphries had admirably large samples of budgets from the agricultural sector, they only had one mining family's budget and four budgets for factory and trade families for the earliest period.[77] These small sample sizes and the working class bias in the household budget

[74] Humphries and Snell, 'Introduction', pp. 4-9; Lane, 'A customary or market wage', pp. 105-6.
[75] King, 'Meer pennies', pp. 139-40.
[76] Horrell and Humphries, 'Women's Labour Force Participation', p. 107.
[77] Horrell and Humphries, 'Women's Labour Force Participation', p. 107.

analysis should give the reader caution in applying the 18.91 per cent figure too readily.

Table 2.4: Earnings relative to the father's earnings across the various specifications of the model.

	Earnings (% of male earnings)			
Family Member	Corfe Castle	Cardington	H-H	Spinning
Father	100.00	100.00	100.00	100.00
Married Woman	23.5, 17.6†	18.91	18.91	48.2, 36.1†
Widows	50.00	50.00	50.00	50.00
Boys (aged 5-14)	27.31	27.31	27.31	27.31
Boys (aged 15 and over)	45.12	45.12	45.12	45.12
Girls (aged 5-14)	27.31	27.31	27.31	27.31
Girls (aged 15 and over)	45.12	45.12	45.12	45.12

Notes: † denotes that separate earnings were used for married women in building labourer families and agricultural labourer families. The earnings of an agricultural labourer's wife are listed first.

Sources: Occupational weightings: Shaw-Taylor and Wrigley, 'Occupational Structure', p. 7.

Earnings: Corfe Castle – Wall, 'Some implications', p. 322; Horrell and Humphries, 'The exploitation of little children', p. 500; Cardington and Horrell-Humphries – Horrell and Humphries, 'Women's labour force participation', p. 107; Horrell and Humphries, 'The exploitation of little children', p. 500; Spinning – Muldrew, 'Th'ancient Distaff', pp. 507, 510; Horrell and Humphries, 'The exploitation of little children', p. 500.

We can also calibrate the simulation by inputting women's wages in spinning and knitting for Corfe Castle in 1790 reported by Richard Wall. Women could earn an average of 1s. 4.5d. in knitting per week and 2s. 6d. per week for spinning flax. If we assume that married women worked 35 weeks per year, this would mean that a woman could earn £2 8s. 1d. per year in knitting and £4 7s. 4d. in spinning.[78] We can then calculate how these earnings compare to male agricultural labourer and building labourer earnings assuming that the male is working 250 days per year and weighting the earnings of married women based on the number of women employed in each sector. Thus, dividing these annual earnings by the male annual earnings, £12 5s. per year for agricultural labourers and £16 132. 4d. per year for building labourers, we find that women could earn 23.5 per cent of an agricultural labourer's annual earnings

[78] Wall, 'Some Implications', p. 322.

and 17.6 per cent of a building labourer's annual earnings.[79] These figures are quite similar to the Horrell and Humphries levels.

The Corfe Castle and Horrell and Humphries weighted average level of married women's earnings will be used as a starting point in the Monte Carlo simulations below, but there are several reasons to believe that these levels of earnings would be a lower bound estimate of women's potential earnings in the second half of the eighteenth century. First and foremost, the Corfe Castle earnings and the earliest budgets in the Horrell-Humphries sample occur after women's hand-spinning employment had been all but decimated by the technological innovations developed in the late eighteenth century.[80] Although women had taken up lace-making, straw-plaiting, and handloom weaving to partially cover the loss of income from spinning, it is likely that the Corfe Castle 1790 earnings and the Horrell and Humphries earnings for the period 1787-1815 may understate women's earnings from spinning in the mid to late eighteenth century. As mentioned above, Muldrew has studied spinning in early modern England in great detail. In his calculations of total earnings from spinning Muldrew suggests that by the 1760s a married woman could earn £7 per year spinning wool and £5 5s. per year spinning hemp or linen.[81] Table 2.4 clearly shows that women could earn much more relative to men from spinning than the women in the Horrell-Humphries sample could. Women's average spinning earnings (£6 5d. per year) were 48.2 per cent of a male agricultural labourer's earnings and 36.1 per cent of a male building labourer's earnings. These are 2.5 and 1.9 times higher respectively than the female earnings in the Horrell-Humphries sample from 1787-1815. Thus, the simulation will be run with both the Horrell-Humphries and higher spinning level of women's wages.

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[79] Allen, spreadsheet.
[80] Burnette, *Gender*, pp. 39-40.
[81] Muldrew, 'Th'ancient Distaff', pp. 507, 510.

2.2.3 Children's Labour Force Participation and Wages, 1750-1800

Children's work could have also had a substantial effect on family income and needs to be accounted for in the model. Sources with detailed quantitative evidence on children's labour participation and wages are even scarcer than sources for women's labour participation. Fortunately, however, children's labour participation can be determined for three of the sources mentioned above: the two parishes Cardington (1782) and Corfe Castle (1790) and for the Horrell-Humphries early budget sample (1787-1815).

Saito reports children's labour force participation by age group and gender for both parishes (Table 2.2).[82] Children's labour force participation was quite high for children in Corfe Castle in 1790 with 32.1 and 42.5 per cent of boys and girls between the ages of 5 and 14 participating in the labour market respectively. Participation rates were higher for children over the age of 15 with 94.4 per cent of boys and 75.9 per cent of girls participating in the labour market. Male children in Corfe Castle worked as craftsmen, agricultural labourers, clay cutters, and in rope making whereas girls worked primarily in spinning and knitting. Cardington had lower levels of children's labour force participation in 1782 mostly because there were very few opportunities for boys to work there. Thus, only 1.2 per cent of boys aged 5-14 were working in Cardington and although the participation figure for boys over 15, 75.0 per cent, was quite high, this was because most boys had left the parish by this point to work as servants in other households.[83] However, despite the poor labour market prospects in Cardington for boys, many girls were able to work in the cottage industries that were so prominent in the parish: 43.9 per cent of girls aged 5-14 and 83.3 per cent of girls over 15 were employed. The very few boys employed in Cardington worked in crafts

[82] Saito, 'Who worked when', p. 221.
[83] Saito, 'Who worked when', pp. 220-1.

or trades whereas the vast majority of the girls, 83.6 per cent, were employed in lace making with the rest employed as spinners.[84]

Children's labour force participation in the Horrell-Humphries early budgets sample (1787-1815) was fairly similar to participation in Corfe Castle and Cardington. They reported children's labour participation across a range of households based on father's occupation.[85] The average for each age cohort was again calculated by taking a weighted average of the labour participation rate by the share of male employment in each male occupation category.[86] They also reported the age categories in five-year groupings, so the 5-9 and 10-14 year old grouping were combined in order to match the distributions in the other parishes. Horrell and Humphries were only able to distinguish between boys and girls for a small number of households in their sample, which prevented them from calculating participation rates by sex and age. Therefore, male and female child labour participation had to be held as equal when applying the Horrell-Humphries data to the simulation.[87] These adjustments left participation rates of 32.8 per cent for children aged 5-14 and 87.4 per cent for children over the age of 15 (Table 2.2).

Understanding whether these participation rates are representative for the population as a whole is again difficult. Using a large sample of working class, male autobiographies, Humphries has recently argued that child labour participation increased from the eighteenth century into the early nineteenth century, only to decline again after 1850. This transition was robust to a number of covariate factors that could have influenced children's labour participation.[88] Thus, it is possible that the Horrell-Humphries early budget sample could overstate the mid-eighteenth

[84] Saito, 'Who Worked When', pp. 222-225.
[85] Horrell and Humphries, 'Exploitation of Little Children', p. 497.
[86] Shaw-Taylor and Wrigley, 'Occupational Structure', p. 7.
[87] Horrell and Humphries, 'The exploitation of little children', p. 514.
[88] Humphries, *Childhood*, pp. 176, 205-6.

century children's labour participation that we are trying to capture in the simulation. Likewise, the demographic characteristics of the Horrell-Humphries early household budget sample are not representative of typical families in English society. The households are larger and the families have more resident children than is predicted from demographic simulations or is evident in historical sources in similar periods.[89] This is problematic because Humphries found that children with more siblings tended to enter the labour market earlier and thus likely had higher labour force participation.[90] Unfortunately, there is really no way to know whether this was true or to what degree the Horrell-Humphries figures should be adjusted. The fact that children's participation rates in the Horrell-Humphries sample were fairly similar to participation rates in Corfe Castle and Cardington is heartening though (Table 2.2). I will therefore use the Horrell-Humphries unaltered figures for the Horrell-Humphries and spinning specifications of the simulation.

Finally, it was necessary to set earnings levels for children. Again, there is very little historical evidence that gives children's earnings by age and sex, which is necessary for the simulation. There is a lot of scattered information on children's wages, especially from the nineteenth century, but it is difficult to know how many days children were working per year so that their wage can be recalculated as annual earnings.[91] Gazeley and Verdon report the earnings of children in the Eden and Davies households in the late eighteenth century, but unfortunately, they were not able to distinguish the earnings of different children. Thus, they report children's earning by the age of the oldest child.[92] The best source for children's wages, then, is

[89] Horrell and Humphries, 'The exploitation of little children', p. 513; Schneider, 'Real Wages and the Family', p. 106; Baker, *The Inhabitants of Cardington*, pp. 37-42; Wall, 'Leaving home and the process of household formation', p. 80.
[90] Humphries, *Childhood*, pp. 203-7;
[91] Humphries, *Childhood*, pp. 230-7.
[92] Gazeley and Verdon, 'The first poverty line', p. 11.

the Horrell-Humphries early budget sample. Again, the weighted average of the children's earnings was taken using the new Shaw-Taylor *et al*. occupational shares.[93] Children aged 5-14 earned 27.3 per cent of the father's earnings whereas children age 15 and over earned 45.1 per cent of their father's earnings (Table 2.4). There is also some reason to believe that there could have been gender discrimination in children's wages in the second half of the eighteenth century. Burnette shows that the female to male wage ratio in the 1830s was nearly one for children under the age of 16, but that it decreased to about 0.75 thereafter.[94] However, no evidence was available for the second half of the eighteenth century, so children's wages were simply held at the Horrell-Humphries level.

2.2.4 Incorporating Women and Children's Labour Force Participation into the Model

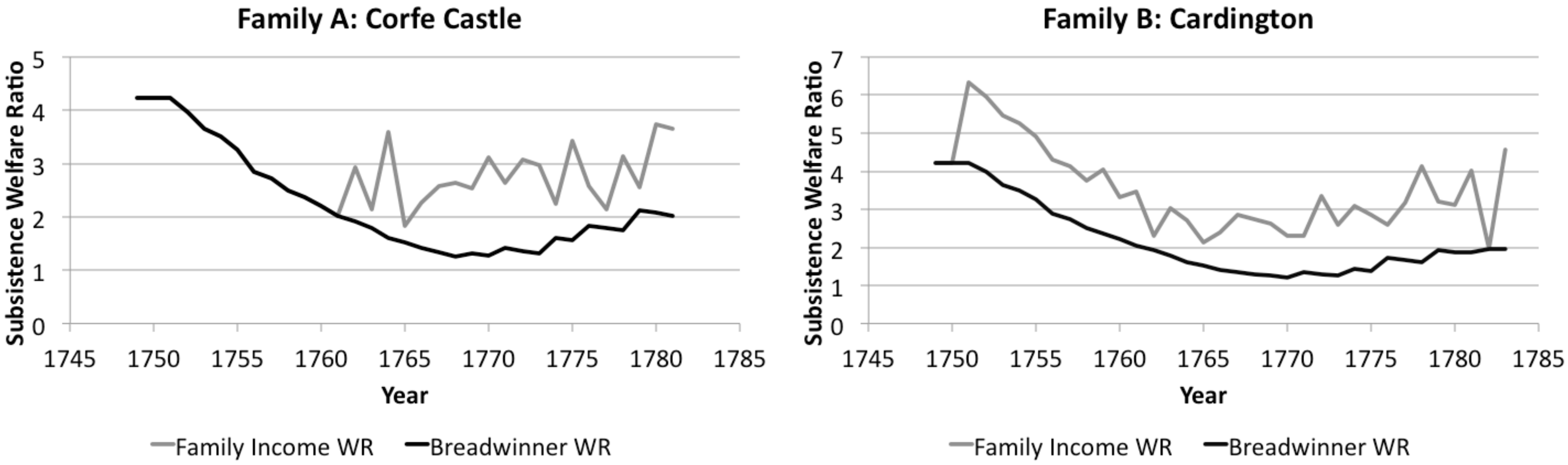
Having explained the logic and sources behind the estimates for women and children's labour force participation and earnings, I must now explain how their income is incorporated into the model. To predict women's income, the wife of each nuclear family is given a certain percentage chance (equal to the labour force participation rate) of participating in the labour market in each year. This probability is independent of whether the woman was in the labour market in the previous year and of the family's current welfare ratio. This is obviously a simplification, but it is difficult to know whether women in early modern England entered the labour market permanently or flitted in and out because most of the evidence available on women's labour participation is cross-sectional rather than longitudinal.[95] Thus, the wife has a certain probability of being in the labour force and getting her associated earnings for

[93] Shaw-Taylor and Wrigley, 'Occupational Structure', p. 7.
[94] Burnette, *Gender*, pp. 79-80; Burnette, 'How Skilled', p. 714.
[95] In a robustness check, I allow women to either enter the labour market or not enter the labour market permanently. See section 4.

all of the years she is alive. If the father dies, then the woman (his widow) is assumed to permanently enter the labour market with earnings of 50 per cent of the male wage. Children's labour participation and income enter similarly into the model. Children of the two age categories, 5-14.9 and over 15, and sexes were each given a percentage chance of being in the labour market according to the participation rates. If they were determined to be working, then their income was added to the family total. Again it is difficult to know whether the child labour market was as fluid as this way of modelling would suggest. However, it should be noted that a large majority of children 15 and over were working, so once the children had turned 15, nearly all of them had permanently joined the labour market.

Figure 2.1 shows two building labourer family's subsistence welfare ratios over the family life cycle: family A is a family predicted using the Corfe Castle specification and family B was predicted using the Cardington specification. These families are not representative but are provided to highlight how the model works. The black line in each graph marks each family's breadwinner welfare ratio, or the welfare ratio without women and children's labour participation. The grey line shows the family's welfare trajectory with women and children's labour participation. For family A located in Corfe Castle, the breadwinner and family welfare ratio curves are the same until the family's children become old enough to enter the labour market because women's labour participation was very low in Corfe Castle (8.7 per cent). However, in Cardington where women's labour force participation was high, women and children's income tended to shift the breadwinner welfare ratio curve upward rather than giving it a different shape. These curves could also easily be expressed in terms of calories by multiplying the welfare ratios by the calories in the subsistence

Figure 2.1: Building labourer subsistence welfare ratios with and without women and children's labour force participation over the family life cycle.



Notes: Breadwinner refers to families only relying on the male's earnings whereas family income includes the earning of all family members.

Sources: simulated results.

basket, 1,938 calories. I will focus primarily on two results for each family: the median welfare ratio across their life cycle and the minimum welfare ratio across their life cycle. These two indicators provide a good understanding of what the family's conditions were like in average times and the at the hardest times in the family life cycle.

2.2.5 Unequal Distribution of Household Resources

As mentioned above, there is ample historical evidence that resources were not divided equally in the family. I will test for two mechanisms for this outcome. First, men working in backbreaking occupations could have had higher energy requirements than women and children, especially if they were not working. Thus, women and children could have sacrificed their own consumption so that a father could have enough energy to work and provide an income. This will be called the female sacrifice specification of the model. Second, men could have spent more in the alehouse or on other forms of conspicuous consumption than their share of household resources. This would have left the wife and children in a relatively weak position, splitting the remaining resources. This form of unequal allocation will be referred to as the male hoarding specification.[96]

To incorporate this unequal distribution of household resources into the model, it is necessary to pick targets for the father's consumption. Unfortunately, the two scenarios for unequal distribution highlighted above require different methods for picking a target: the female sacrifice specification requires an energy target because the wife and children will only sacrifice resources that the father legitimately needs for work; and the male hoarding specification requires a consumption target because

[96] Horrell and Oxley, 'Bargaining', pp. 149-153.

the man will hoard resources to maintain a certain lifestyle. In order to make things simpler and perhaps easier to interpret, I have decided to use energy targets, or physical activity levels (PALs), to determine the allocation of household resources. PAL values are helpful because they give us an idea of how much physical activity a person with a certain calorie intake could perform. It is also easy to convert the subsistence welfare ratios calculated across the family life cycle into PAL values, the amount of energy the family could afford to buy, by dividing the amount of energy available per consuming unit (the welfare ratio times the number of calories in the price basket) by the basal metabolic rate (BMR) of the population. BMR is the amount of energy required to maintain the body at rest. Floud *et al.* have computed that the average basal metabolic rate (BMR) for an adult male in 1800 was 1,597 calories per day, which allows us to calculate PAL equivalents for different welfare ratios.[97]

Scientists have found that a PAL level of 1.27 is required for survival because humans expend energy in eating, digestion and hygiene. However, a PAL of 1.27 does not allow for any work including food preparation, so PAL levels actually must be much larger than 1.27 in order for a population to be productive.[98] The Food and Agriculture Organization of the UN (FAO) recommends PAL values in the range of 1.40-1.69 for a sedentary or light activity lifestyle, 1.70-1.99 for an active or moderately active lifestyle, and 2.00-2.40 for a vigorous or vigorously active lifestyle. Sedentary or light activity lifestyles refer to people who 'have occupations that do not demand much physical effort, are not required to walk long distances, generally use motor vehicles for transportation, do not exercise or participate in sports regularly, and spend most of their leisure time sitting or standing, with little body

[97] This BMR assumes that the average man was 1.68 m tall, weighed 59.3 kg and had a BMI of 21 kg/m^2. Floud *et al.*, *The Changing Body*, p. 120.
[98] Floud *et al.*, *The Changing Body*, p. 43.

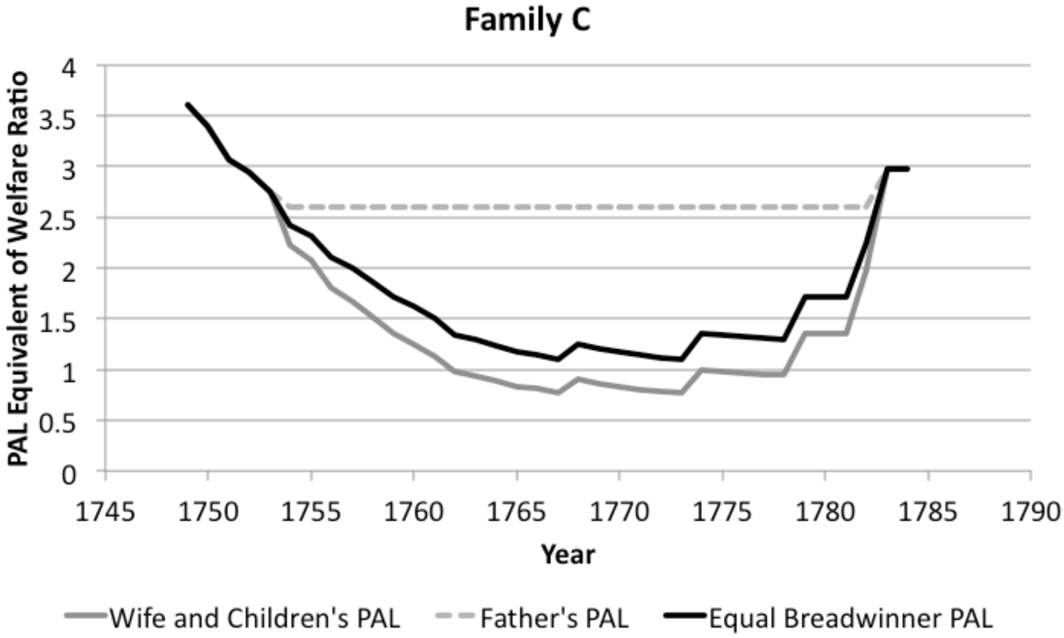
displacement'.[99] This obviously describes a very small minority of people living in England in 1800. Active or moderately active lifestyles refer to people whose occupations require more energy than sedentary lifestyles but who do not perform strenuous tasks. This category would include modern masons and construction workers (using machines), 'or rural women in less developed traditional villages who participate in agricultural chores or walk long distances to fetch water and fuelwood'.[100] Finally, vigorous or vigorously active lifestyles refer to people taking part in strenuous work such as 'non-mechanized agricultural labourers who work with a machete, hoe or axe for several hours daily and walk long distances over rugged terrains, often carrying heavy loads'.[101]

The categories are somewhat obscure, but suffice it to say that almost all male labourers would have fallen into the vigorous lifestyle category. Women and children may have had lower energy requirements depending on the kind of work they were doing, but at minimum they would have fallen in the active category. There is also good reason to believe that people living in England in the eighteenth century would have needed higher PAL levels in order to maintain their body heat in a cold climate and fight periodic diseases.[102] Thus, the target PAL levels for male workers employed in this paper will be 2.60. For women and children, two targets are necessary: a PAL of 1.85 for women and children who are not working and a PAL of 2.00 for women and children who are working. These levels would allow everyone in the family to have enough energy to carry out their respective duties. To compute the consumption target for the male hoarding specification, I have simply converted the cost of Allen's

[99] FAO, 'Human', pp. 38-39.
[100] FAO, 'Human', p. 39.
[101] FAO, 'Human', p. 39.
[102] I have set the PAL targets at a high level also because the calories are priced using the subsistence basket, which does not reflect the average consumption of the time. Thus the slightly high PAL values also allow for a bit of upgrading to more typical foods.

respectability level of consumption into its corresponding PAL value for the subsistence basket, 3.58.[103] These PAL targets, then, will form the basis for allocating resources within the household.

Figure 2.2: Results of unequal allocation of household resources where the father's consumption is not allowed to drop below a target PAL level of 2.6.



Notes: Physical activity level (PAL) equivalents are calculated for each welfare ratio by multiplying the welfare ratio by the number of calories in the subsistence basket (1,938 kcal/day) and then dividing by the basal metabolic rate (1,597 kcal/day). In this case the father's PAL level is not allowed to fall below his target consumption level of 2.6, and the rest of the family suffers lower PAL levels as a result.

Sources: simulated results; Floud *et al.*, *Changing Body*, p. 120.

With these targets in place, it is now possible to specify the model. I assume that the family divides resources equally until the father's equal share falls below the energy target. After this point, the father's PAL value is held at the target, and the women and children divide the remaining resources equally per consuming unit

[103] One respectability basket cost 2.19 g Ag in 1750-1800 while the subsistence basket cost 0.74 g Ag. Thus, to convert the cost of the respectability basket into a PAL value of the subsistence basket, one divides the respectability basket by the subsistence basket, then multiply this figure by the number of calories in the subsistence basket, 1,938 calories, and divide by the BMR of the population, 1,597 calories. This yields the PAL value of 3.58. Schneider, 'Real Wages and the Family', p. 102; Allen, spreadsheet; chapter one.

among themselves.[104] If the father dies, then resources are allocated equally in the family. Figure 2.2 shows how unequal allocation affected family C and will illustrate how the model works. For the moment, we will only consider the breadwinner family, excluding women and children from the labour market. The black line marks the family's PAL values assuming equal distribution of resources within the household. When resources are distributed unequally, the father's consumption is not allowed to fall below his target PAL. Thus, the dashed grey line displays the father's PAL level of consumption, which is held constant at the target level of 2.6 or 3.85 when the family's equally distributed PAL falls below that level. Finally, the solid grey line shows the women and children's PAL level, which is lower than the equal PAL black line when the equal PAL level falls below the target. Thus, it is possible to understand whether women and children's sacrifice would have allowed the family to scrape by and how much the father's hoarding of resources may have hurt the other members of the household.

2.2.6 Closing the Gap: Self-Provisioning, Poor Relief and Labour Intensification

Unfortunately, there is not enough information on the final four strategies, self-provisioning, poor relief, access to common rights and labour intensification, to incorporate them dynamically into the model. However, it is possible to calculate how much self-provisioning, extra income or additional days worked it would take to move a family from its median or minimum PAL level to a target PAL level such as the ones laid out above. Table 2.5 uses family C as a model to calculate the gap between the amount of energy the family could afford and the amount required for

[104] The women and children's welfare ratios in unequal distribution are equal to the total family income minus the cost of the male's consumption at the target divided by the price basket times the remaining consuming units in the family.

Table 2.5: Calculation of self-provisioning, additional income from poor relief, gleaning or charity, or extra day worked to meet target PAL.

		Family C		
		Equal	Unequal	Sources/Calculations
(1)	Median of Predicted Distribution of Median WRs	1.29	0.98	Sim. Results
(2)	Median of Predicted Distribution of Minimum WRs	0.91	0.63	Sim. Results
(3)	Calorie Equivalent of Median of Predicted Med WRs	2,491	1,906	(1) × 1,938
(4)	Calorie Equivalent of Median of Predicted Min WRs	1,754	1,231	(2) × 1,938
(5)	PAL Equivalent of Median of Predicted Med WRs	1.56	1.19	(3) ÷ 1,597
(6)	PAL Equivalent of Median of Predicted Min WRs	1.10	0.77	(4) ÷ 1,597
(7)	Median Consuming Unit	3.87	2.93	Sim. Results
(8)	Max Consuming Unit	5.72	4.78	Sim. Results
(9)	Male Agricultural Labourer Day Wage (g Ag/day)	8.36	8.36	Allen
(10)	Male Annualized earnings per day (g Ag/day)	5.72	5.72	(9) × 250 ÷ 365
(11)	Cost of subsistence basket per day (g Ag/day)	0.74	0.74	Allen
(12)	Father Target PAL	2.6	2.6	Assumption
(13)	Women and Children Target PAL	2.6	1.85	Assumption
(14)	Calories per Day from Median to Reach Target (family)	6,426	3,071	((13) - (5)) × 1,597 × (7)
(15)	Additional Income per day as % of Father's Day Wage	29.43%	14.07%	((14) ÷ 1,938) × (11) ÷ (9)
(16)	Add. Income as % of Father's Annualized Daily Earnings	42.97%	20.54%	((14) ÷ 1,938) × (11) ÷ (10)
(17)	Additional Days of Work Required	107.42	51.34	(15) × 365
(18)	Calories per Day from Min to Reach Target (family)	13,712	8,238	((13) - (6)) × 1,597 × (8)
(19)	Additional Income per day as % of Father's Day Wage	62.80%	37.73%	((18) ÷ 1,938) × (11) ÷ (9)
(20)	Add. Income as % of Father's Annualized Daily Earnings	91.69%	55.09%	((18) ÷ 1,938) × (11) ÷ (10)
(21)	Additional Days of Work Required	229.23	137.72	(19) × 365

Notes: sample calculations are provided in this table, but will not be provided in tables 2.6-2.13 because of space.

Sources: Allen, spreadsheet; simulated results.

work and survival. Rows 10-13 in table 2.5 report the gap between the women and children's median PAL value as predicted by the model and their target PAL value of 1.85, assuming they are not working. The calorie gap is calculated by subtracting the predicted PAL from the target PAL and multiplying this by the BMR of 1,597. This figure would then provide the number of calories needed per consuming unit, but we would like to know how many additional calories a family would need. Therefore, we multiply the number of calories by the median number of consuming units (minus the father's requirements for the unequal distributions), which are already captured in the model. This computation reveals that with unequal allocation of household resources at the median welfare ratio point of the life cycle, family C would need to be able to self-provision 3,071 calories per day in order to bring the women and children's PAL level from the predicted median of 1.19 to the target level of 1.85 holding the father's PAL level at 2.60 or above. This figure is much larger, though, for the minimum welfare ratio point in the family life cycle with the larger family needing to self-provision 8,238 calories per day.

To calculate the amount of extra income from poor relief, gleaning or charity needed to shift the women and children from the median PAL value to the target PAL value, we can simply express the number of calories predicted above in terms of the subsistence basket by dividing the predicted calories by the 1,938 calories in the subsistence basket. We then multiply this by the cost of the subsistence basket, giving the actual cost of the shortfall, and then divide this by the male day wage. Thus, row 11 in table 2.5 shows the amount of additional income required per day to move the women and children from the median PAL level to the target in terms of the male's day wage. We can also present this in terms of the father's annualized earnings, which is closer to the way that poor law historians tend to measure poor law pensions. At the median welfare ratio year, family C would have needed a daily poor law pension equal to 20.54 per cent of the annualized daily earnings in order for the women and children to reach their target PAL. This figure, again, increased substantially when looking at the minimum welfare ratio year. Family C would have needed a daily poor law pension of 55.09 per cent of the father's daily annualized earnings in order to give the women and children their target PAL value.

Finally, it is possible to calculate the number of extra days the man would have to work to allow women and children to reach the target PAL value. To do this, we simply multiply the percentage of the male day wage needed to fill the gap by 365 days in a working year. Thus, in their median welfare ratio year, family C's father would have had to work an additional 51 days in order to shift the women and children to the target PAL level. In the hardest year of the family life cycle, the father would have had to work an additional 138 days per year to provide the correct PAL values for his wife and children. Given that this would require the man to work 388 days per year, this would not have been a successful strategy.

Thus, although it is not possible to model which families were self-provisioning, receiving poor relief or charity, gleaning or extending the working year, these measures will allow us at least to understand what the size of these factors would have needed to be in order for families to have enough energy to work and survive in early modern England.

2.3 Results of the Monte Carlo Simulation

Having explained the sources of the various estimates for women and children's labour force participation and highlighted the changes made to the original model to incorporate the five strategies, we can now discuss the results of the Monte Carlo simulation. The tables presenting the results vary slightly from the original tables in the previous chapter and published in the article. Instead of reporting the minimum of the predicted distribution of median family welfare ratios (the poorest family at the average point in their life cycle), I have reported the median of the predicted distribution of minimum welfare ratios (the poorest point in the life cycle for the average family). I have also calculated calorie and PAL equivalents as explained above.

2.3.1 Results: Women and Children's Labour Participation

Tables 2.6 and 2.7 present the results for Southern English agricultural labourers and building labourers. The breadwinner model, highlighted in grey, contains the simulation without women and children's labour force participation similar to the models run for 1750-1800 in the previous chapter. We will begin with agricultural labourers. At 1.67 the median of the predicted distribution of *median* family welfare ratios for agricultural labourers' families is approximately equal to Allen's welfare ratio estimate. However, it should be noted that the median of the predicted distribution of *minimum* family welfare ratios, the average low point in each family's life cycle, was much lower (1.13) than the median. The average median welfare ratio would have allowed the entire family to work at a PAL of 2.03, which is not enough for the father to perform the hard labour of an agricultural labourer if resources were divided equally. The average minimum welfare ratio, though, would only have allowed the family to work at a PAL of 1.37. Thus, at the average low point in the welfare ratios across the family life cycle, families of agricultural laoburers could not afford enough food for members, including the father, to work at even the sedentary level as defined by the FAO. The impoverishment of these families is further evident by the fact that 9.74 per cent of total family years were lived at a subsistence welfare ratio below unity, which meant that the family could not survive.

The introduction of women and children's labour force participation, however, significantly increased the average predicted median and minimum welfare ratios. The participation rates and earnings in Corfe Castle served as a lower bound for the effect, increasing the median welfare ratio by 31 per cent, because women's labour force participation was so low there. Muldrew's adjusted participation rate for women

Table 2.6: Influence of women and children's labour force participation on southern English agricultural labourer family subsistence welfare ratios.

	Southern England Agricultural Labourers				
	Breadwinner	Corfe Castle†	Cardington*	H-H	Spinning†
Allen Subsistence Welfare Ratio (WRs)	1.73	1.73	1.73	1.73	1.73
Median of Predicted Distribution of Median WRs	1.67	2.18	2.28	2.34	2.47
Mean of Predicted Distribution of Median WRs	1.80	2.28	2.35	2.42	2.56
Median of Predicted Distribution of Min WRs	1.13	1.37	1.42	1.43	1.42
Calorie Equivalent of Median of Predicted Med WRs	3,236	4,225	4,419	4,535	4,787
Calorie Equivalent of Median of Predicted Min WRs	2,190	2,655	2,752	2,771	2,752
PAL Equivalent of Median of Predicted Med WRs[a]	2.03	2.65	2.77	2.84	3.00
PAL Equivalent of Median of Predicted Min WRs[a]	1.37	1.66	1.72	1.74	1.72
% of Total Family Years Below Subsistence	9.74%	0.54%	0.94%	0.55%	0.55%
Gini Coefficient	0.1533	0.0893	0.1040	0.0903	0.0950
Increase in Median Relative to Breadwinner	1.00	1.31	1.37	1.40	1.48
Increase in Min Relative to Breadwinner	1.00	1.21	1.26	1.27	1.26

Notes: The breadwinner specification is the model produced without women and children's labour participation and serves as a reference point. Tables 2.2 and 2.4 list earnings and participation rates for the various specifications. See text and previous chapter for the description of the model.

* denotes that male children had an earlier age at leaving home (mean of 15 and standard deviation of 1 rather than a mean of 18 and standard deviation of 1.5).

† denotes that married women's earnings as a percentage of the male earnings change between agricultural labourers and building labourers.

[a] Floud *et al.*'s basal metabolic rate (BMR) of 1,597 calories per day for 1800 was used to calculate the physical activity levels (PALs) in the table. This assumes that the mean height, BMI, and weight of a consuming unit (adult male) were 1.68 m, 21 kg/m^2, and 59.3 respectively. Floud *et al.*, *The Changing Body*, p. 120.

Sources: simulated results.

Table 2.7: Influence of women and children's labour force participation on southern English building labourer family subsistence welfare ratios.

	Southern England Building Labourers				
	Breadwinner	Corfe Castle†	Cardington*	H-H	Spinning†
Allen Subsistence Welfare Ratio (WRs)	2.45	2.45	2.45	2.45	2.45
Median of Predicted Distribution of Median WRs	2.37	3.09	3.23	3.32	3.41
Mean of Predicted Distribution of Median WRs	2.55	3.24	3.34	3.44	3.52
Median of Predicted Distribution of Min WRs	1.60	1.94	2.01	2.03	2.01
Calorie Equivalent of Median of Predicted Med WRs	4,593	5,988	6,260	6,434	6,609
Calorie Equivalent of Median of Predicted Min WRs	3,101	3,760	3,895	3,934	3,895
PAL Equivalent of Median of Predicted Med WRs[a]	2.88	3.75	3.92	4.03	4.14
PAL Equivalent of Median of Predicted Min WRs[a]	1.94	2.35	2.44	2.46	2.44
% of Total Family Years Below Subsistence	1.48%	0.04%	0.12%	0.05%	0.05%
Gini Coefficient	0.1533	0.0888	0.1040	0.0903	0.0926
Increase in Median Relative to Breadwinner	1.00	1.30	1.36	1.40	1.44
Increase in Min Relative to Breadwinner	1.00	1.21	1.26	1.27	1.26

Sources and Notes: see table 2.6.

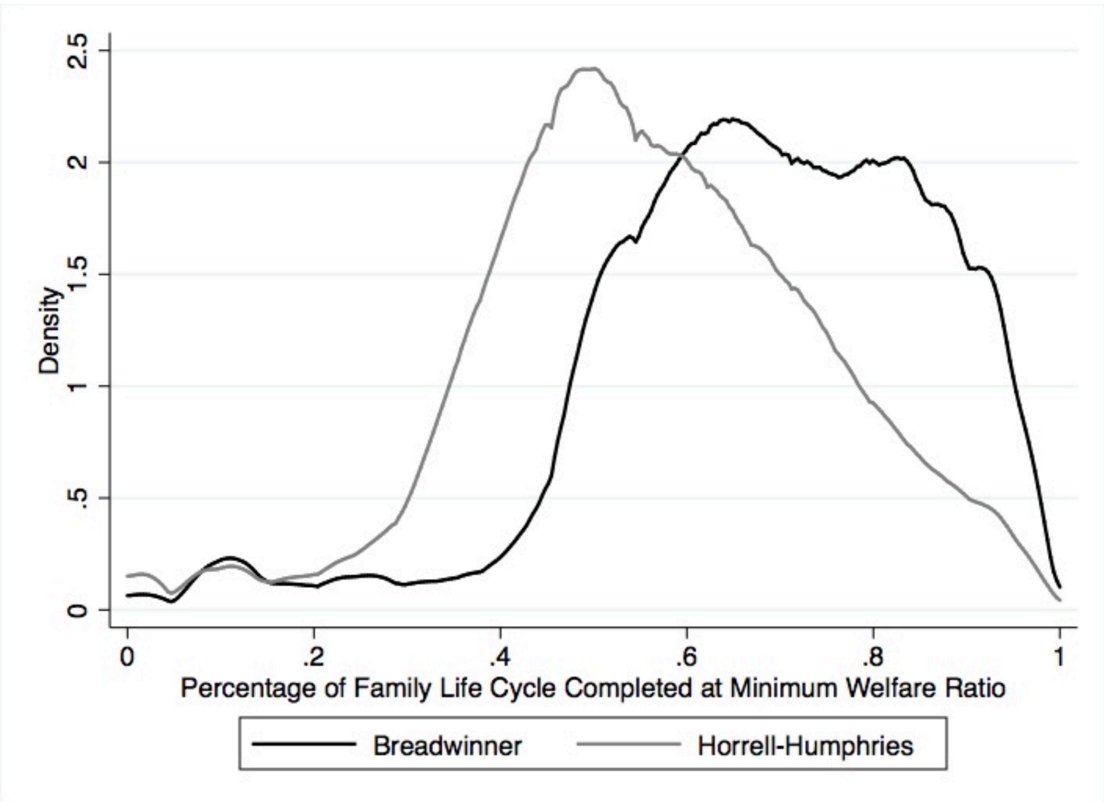
in spinning provided an upper bound for the increase in the median welfare ratio, 48 per cent. Thus, the higher earnings in spinning overshadowed the lower participation rate. Women and children's labour participation also increased the average minimum welfare ratio of families in the distribution, but the increase was smaller than the increase in the median welfare ratio in two regards. First, the increase in the average minimum welfare ratio ranged from 21 to 27 per cent never reaching the level of increase in the average median welfare ratio. Second, the average minimum welfare ratio did not continue to increase across the specifications reaching a ceiling around 27 per cent for the final three specifications. This was important in how women and children's income affected the amount of energy (PAL level) the family could afford. At the median PAL level in the family life cycle, the average family could afford enough food for the entire family to work at a PAL ranging from 2.65 to 3.00, plenty of energy. However, at the low point in the family life cycle, the average family barely had enough energy to work at an active lifestyle according to the FAO let alone perform strenuous labour. It is also worth noting that women and children's labour force participation drastically reduced the total number of family years lived below Allen's subsistence level of one, and significantly reduced the inequality in the median welfare distribution.[105] This reduction in inequality was almost completely driven by children's labour force participation since the poorest families in the model had lots of children who could become active in the labour market.

The results for the Southern English building labourers were similar to those above. Without women and children's labour force participation, the average building labourer family was not poorly off at the average point in the life cycle: they could afford to purchase a PAL level of 2.88 for the entire family, which could either be

[105] These Gini coefficients only refer to the inequality driven by differences in family size, not income.

consumed or upgraded for more expensive food items. However, at the average minimum welfare ratio level, the average family could not afford to purchase enough food for the father to perform strenuous work tasks if resources were divided evenly. Adding women and children's income almost completely freed building labourer families from these energy constraints. Even at the average low point in the family life cycle, the average family could afford a PAL level of 2.35 to 2.46, although this is slightly below the 2.6 PAL target for men. In addition, only a fraction of a percent of family years was lived below Allen's subsistence level. Because the building labourers had substantially higher incomes, it will become important to see whether they were targeting higher levels of consumption rather than just merely purchasing enough energy for work.

Figure 2.3: Distribution of the percentage of the life cycle completed when each family reaches its minimum welfare ratio.



Sources: simulated results.

Finally, incorporating women and children's labour force participation into the model changes the timing of the lowest welfare ratio in the family life cycle. Figure 2.3 shows that in the breadwinner model, the minimum welfare ratio tends to happen later in the family life cycle, on average 68.2 per cent through the family life cycle as defined in the model (ending when all of the children leave). If women and children in the same set of families were participating in the labour market, the minimum welfare ratio came earlier in the life cycle, about 55.8 per cent through the family life cycle. Thus, women and children's labour force participation shifted the hardest point in the family life cycle so that it no longer coincided with the period in the life cycle when the family was largest.

2.3.2 Results: Unequal Distribution of Resources in the Household

Given that the amount of work carried out by various members of the household could vary widely, it is also important to model the unequal allocation of household resources. Table 2.8 shows these adjustments for the breadwinner model and the Horrell and Humphries specification of women and children's labour force participation.[106] As mentioned above, the unequal distribution is modelled by not allowing the father's PAL level to fall below a certain level. In the female sacrifice specification, the male's PAL level is never lower than 2.6. Thus, the father would always have enough energy to carry out his work related duties. However, in the male hoarding specification the father's PAL level is held at the cost of Allen's respectability basket, a PAL of 3.58, assuming that the man took more than the

[106] Only the Horrell and Humphries specification was shown to conserve space. The unequal distribution adjustments were run with all specifications of women and children's labour participation, but the Horrell and Humphries specification is representative of the results from all of the specifications.

Table 2.8: Influence of unequal household distribution on southern English agricultural labourer subsistence welfare ratios.

	Southern England Agricultural Labourers					
	Breadwinner			Horrell and Humphries		
	Equal	F. Sacrifice	M. Hoarding	Equal	F. Sacrifice	M. Hoarding
Median of Predicted Distribution of Median WRs	1.67	1.44	1.14	2.34	2.34	2.05
Mean of Predicted Distribution of Median WRs	1.80	1.62	1.34	2.42	2.40	2.20
Median of Predicted Distribution of Min WRs	1.13	0.87	0.69	1.43	1.19	0.96
Calorie Equivalent of Median of Predicted Med WRs	3,236	2,791	2,209	4,535	4,535	3,973
Calorie Equivalent of Median of Predicted Min WRs	2,190	1,686	1,337	2,771	2,306	1,860
PAL Equivalent of Median of Predicted Med WRs[a]	2.03	1.75	1.38	2.84	2.84	2.49
PAL Equivalent of Median of Predicted Min WRs[a]	1.37	1.06	0.84	1.74	1.44	1.16
Father Target PAL[a]		2.60	3.58		2.60	3.58
% of Total Family Years Below Subsistence	9.74%	24.10%	39.30%	0.55%	1.63%	4.72%
% of Total Family Years With Unequal Distribution		70.41%	93.49%		38.31%	78.14%
Gini Coefficient	0.1533		0.2331	0.0903		0.1209
Decease in Median (Percentage of Equal)	1.00	0.86	0.68	1.00	1.00	0.88
Decease in Minimum (Percentage of Equal)	1.00	0.77	0.61	1.00	0.83	0.67

Notes: Resources are divided unequally in the female sacrifice and male hoarding specifications. In these specifications, resources are allocated equally until the household's PAL level falls below the target: 2.6 in the female sacrifice and 3.58 in the male hoarding specifications. At this point, the father's consumption is prohibited from falling below the target level, and the women and children divide the smaller pool of remaining resources. Thus, the figures in the unequal specifications only refer to the conditions of women and children, not men. See also the notes for table 2.6.

Sources: simulated results.

energy he needed for work from his family. Because the man's consumption is predetermined (when the family level falls below a certain level), the figures presented in the female sacrifice and male hoarding specifications only refer to women and children. The equal distribution is also provided as a reference.

Looking first at agricultural labourers and the breadwinner model, the women and children's welfare ratios fall across the specifications of the breadwinner model. Allowing the father to maintain a minimum PAL of 2.6 across the family life cycle (the female sacrifice specification) leads to a 14 per cent decrease in the median welfare ratio of the women and children and a 23 per cent decrease in their minimum welfare ratio. Although the father now had plenty of energy for work, the allocation left the women and children below their target PAL of 1.85 in an average year during the life cycle and below the 1.27 PAL necessary for survival at the low point. Resources were distributed unequally in 70 per cent of family years and women and children spent 24 per cent of the family life cycle below Allen's bare minimum subsistence level, a substantial increase from the equal allocation specification. The male hoarding specification was even worse for women and children. If men had consumed the 'respectable' level of consumption regardless of the condition of the rest of their family, then the women and children could not have survived because their PAL levels were just above the 1.27 threshold in average times and well below it at the worst of times. Likewise, 39 per cent of family years were spent below Allen's minimum consumption level. Clearly, both the sacrifice of women and children to maintain the father's consumption and the selfish father who hoarded family resources could have serious health consequences for the women and children of the family.

Table 2.9: Influence of unequal household distribution on southern English building labourer subsistence welfare ratios.

	Southern England Building Labourers					
	Breadwinner			Horrell and Humphries		
	Equal	F. Sacrifice	M. Hoarding	Equal	F. Sacrifice	M. Hoarding
Median of Predicted Distribution of Median WRs	2.37	2.37	2.14	3.32	3.32	3.32
Mean of Predicted Distribution of Median WRs	2.55	2.52	2.37	3.44	3.44	3.43
Median of Predicted Distribution of Min WRs	1.60	1.45	1.29	2.03	1.97	1.76
Calorie Equivalent of Median of Predicted Med WRs	4,593	4,593	4,147	6,434	6,434	6,434
Calorie Equivalent of Median of Predicted Min WRs	3,101	2,810	2,500	3,934	3,818	3,411
PAL Equivalent of Median of Predicted Med WRs[a]	2.88	2.88	2.60	4.03	4.03	4.03
PAL Equivalent of Median of Predicted Min WRs[a]	1.94	1.76	1.57	2.46	2.39	2.14
Father Target PAL[a]		2.60	3.58		2.60	3.58
% of Total Family Years Below Subsistence	1.48%	2.54%	5.36%	0.05%	0.05%	0.10%
% of Total Family Years With Unequal Distribution		38.09%	65.75%		7.45%	34.66%
Gini Coefficient	0.1533		0.1932	0.0903		0.0924
Decease in Median (Percentage of Equal)	1.00	1.00	0.90	1.00	1.00	1.00
Decease in Minimum (Percentage of Equal)	1.00	0.91	0.81	1.00	0.97	0.87

Notes and Sources: see table 2.8.

However, if women and children were involved in the labour market, the redistribution had a lesser effect on the amount of energy available to them. In the female sacrifice specification, the median PAL value for women and children was unaffected because reallocation only occurred in 38 per cent of family years lived. The minimum PAL value was still below the target for working women and children of 2.00, but it was not below the survival threshold of 1.27. The male hoarding specification had a larger affect on women and children's welfare, decreasing the average median family welfare ratio by 12 per cent and decreasing the average minimum family welfare ratio by 33 per cent. At the average low point in the family welfare ratio curve, the PAL value for women and children was below 1.27. Thus, even if women and children were participating in the labour market, a greedy agricultural labourer could still force his family into starvation.

The story was somewhat rosier for building labourers' families (table 2.9) because they started with higher income. Women and children's median PAL levels held constant in the breadwinner female sacrifice specification and their PAL level at the minimum level in the life cycle only dropped 9 per cent to 1.76, not far below the target of 1.85 for non-working women and children. The male hoarding specification did decrease the women and children's median welfare ratios by 10 per cent and minimum welfare ratios by 19 per cent, leaving 5 per cent of family years lived below Allen's subsistence level. However, even at the average minimum point in the family life cycle, the average family had a PAL of 1.57 well above the 1.27 threshold. If women and children were working in the labour force, then the average building labourer's family could allocate the resources however it wanted because the median welfare ratios were not affected by the allocation specification and the average minimum welfare ratios provided enough energy to be well above the PAL target of

2.00 for working women and children. Thus, it is clear that the unequal distribution of household resources would have had a much stronger influence on agricultural labourers' families than higher paid, semi-urban building labourers. This may be one of the reasons that historians have found higher excess female mortality in the countryside than in provincial towns and cities in the nineteenth century.[107]

2.3.3 Results: Self-Provisioning, Poor Relief and Labour Intensification

Tables 2.10 and 2.11 take the predicted PAL values for the equal and unequal distributions presented in tables 2.8 and 2.9 and use them to calculate the amount of self-provisioning, additional income from poor relief or gleaning and extra days worked it would take to shift the family up to its target PAL level. Again, only the breadwinner model and the Horrell and Humphries level of women and children's labour participation are reported because of space, but the results are very similar across the other specifications. One should keep in mind that the female sacrifice unequal distribution provided the minimum level of energy required for the family to survive and have enough energy for work, but this minimum level was purchased through the subsistence basket, which did not include many of the comforts that working class people had come to expect by the late eighteenth century. The subsistence basket makes no allowance for wheat bread, beer, cheese, or eggs and had minimal amounts of meat. Thus, it is also important to include other target levels of consumption. The male hoarding unequal distribution would have provided Allen's respectability level of consumption for the father but only the food in the subsistence basket for women and children. Thus, the final specification in table 2.10 shows the

[107] McNay *et al.*, 'Excess Female Mortality'.

Table 2.10: Estimates of amount of self-provisioning, additional income from poor relief, gleaning, and charity, or additional days worked necessary to shift an agricultural labourer's family to their target consumption PAL level.

	Southern England Agricultural Labourers							
	Breadwinner				Horrell and Humphries			
	Equal	F. Sacrifice	M. Hoarding	Equal Resp	Equal	F. Sacrifice	M. Hoarding	Equal Resp
PAL Equivalent of Median of Predicted Med WRs	2.03	1.75	1.38	2.03	2.84	2.84	2.49	2.84
PAL Equivalent of Median of Predicted Min WRs	1.37	1.06	0.84	1.37	1.74	1.44	1.16	1.74
Median Consuming Unit	2.81	1.87	1.87	2.81	2.81	1.87	1.87	2.81
Max Consuming Unit	3.95	3.01	3.01	3.95	3.42	2.48	2.48	3.42
Male Agricultural Labourer Day Wage (g Ag/day)	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89
Male Annualized earnings per day (g Ag/day)	4.03	4.03	4.03	4.03	4.03	4.03	4.03	4.03
Cost of subsistence basket per day (g Ag/day)	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Father Target PAL	2.6	2.6	3.58	3.58	2.6	2.6	3.58	3.58
Women and Children Target PAL	2.6	1.85	1.85	3.58	2.6	2	2	3.58
Calories per Day from Median to Reach Target (family)	2,569	305	1,390	6,959	Surplus	Surplus	Surplus	3,317
Additional Income per day as % of Father's Day Wage	16.70%	1.99%	9.04%	45.25%				21.57%
Add. Income as % of Father's Annualized Daily Earnings	24.39%	2.90%	13.19%	66.06%				31.48%
Additional Days of Work Required	60.96	7.25	32.98	165.16				78.71
Calories per Day from Min to Reach Target (family)	7,751	3,818	4,868	13,933	4,723	2,202	3,307	10,075
Additional Income per day as % of Father's Day Wage	50.40%	24.82%	31.65%	90.59%	30.71%	14.32%	21.50%	65.51%
Add. Income as % of Father's Annualized Daily Earnings	73.58%	36.24%	46.21%	132.26%	44.83%	20.90%	31.39%	95.64%
Additional Days of Work Required	183.95	90.61	115.53	330.66	112.08	52.25	78.49	239.11

Notes: see text and table 2.5 for calculation of figures in the table. The Equal Resp. specification moves the entire family to the respectability level of consumption (a PAL of 3.58). Surplus denotes that the family did not need any additional food or income in order to reach their consumption target. The four categories (calories, additional income, and days worked) each represent the required calories, income or days worked to move the family to their PAL target. Thus, for the equal breadwinner specification it would take self-provisioning of 2,569 kcal/day or additional income of 16.7 per cent of the father's day wage per day or 61 additional days worked for the family to reach their PAL target. The maximum number of consuming units is smaller for the Horrell-Humphries specifications than the breadwinner specifications because the minimum point in the family life cycle does not occur at the point when the most children are being supported when women and children's labour force participation is included.

Sources: see tables 2.5, 2.6 and 2.8; simulated results.

level of self-provisioning, poor relief, or additional days worked necessary to shift the entire family to the respectability level of consumption. This calculation is similar to the one conducted by Allen and Weisdorf, but rather than just calculating this level for the average family at the average point in the family life cycle, we can also calculate this for the average family at the lowest point in the family life cycle.[108] These estimates for how much self-provisioning, extra income, or additional days worked were needed to bring families out of poverty can be compared with the amount of additional food or income that could plausibly come from these strategies to understand whether this was enough to push the average family to their PAL target.

Looking first at the breadwinner model for agricultural labourers, it is clear that shifting from an equal distribution of household resources to a female sacrifice unequal distribution of household resources moved agricultural labourers' families much closer to the target PAL. Although it is unlikely that the family would have been receiving poor relief, the family would only have had to self-provision 305 calories per day, glean to earn an additional 2.9 per cent of the father's annualized wage or the father would have had to work an additional 7.25 days per year in order for the family to reach the target. This was clearly possible within the plausible bounds of self-provisioning, gleaning and extending the working year presented in section one above. However, at the low point in the family life cycle, the average family would have struggled to reach their target PAL even in the most efficient female sacrifice unequal specification. Families which had access to self-provisioning of 1,893 calories per day (perhaps 35 per cent of families) would still have needed to receive poor relief equal to 18 per cent of the male annualized daily earnings or to extend the working year by 45.7 days to meet the PAL target. While it is possible that

[108] Allen and Weisdorf, 'Was there an Industrious Revolution'.

poor relief payments could have, on occasion, reached 36 per cent of the male annualized wage for families or lone parents, these levels did not become prevalent until the very end of the eighteenth century.[109] If we generously allow the family to earn 15 per cent of the father's annualized earning through gleaning, the father would still have to work an additional 53 days or earn a poor law pension equal to 21 per cent of his daily annualized earnings in order for the family to reach the PAL target. It is also important to remember that gleaning and poor relief were less effective strategies in the North, making it even harder for these families to reach their minimum consumption target.[110] However, there was more potential for the extension of the working year in the North than in the South where seasonal unemployment in agriculture became more prevalent by the end of the eighteenth century.[111] Poor relief in the South and an extended working year in the North may have been complementary strategies used by working class families to make ends meet, but it still would have been difficult for the average agricultural labourers' family to make up the shortfall.

The male hoarding unequal distribution specification displays how much damage a father could do to his family by consuming more than his share of household resources. Since it is probably fair to assume that a father would not work extra days to fund his own excess consumption and that the poor law would probably not support average families at the average welfare ratio in their life cycle, this would leave women and children without access to self-provisioning or gleaning very vulnerable. This is especially true when considering the average minimum welfare

[109] Williams, 'Poor Relief', pp. 506-508.
[110] King, 'Common Rights', p. 467; King and Tomkins, 'Introduction', pp. 19-25; King, 'Meer pennies', pp. 125-126; Williams, *Poverty*, pp. 7-8.
[111] Tomkins and King, 'Introduction', p. 20; Snell, *Annals*, p. 1; Schwarz, 'Trends', pp. 94-95.

Table 2.11: Estimates of amount of self-provisioning, additional income from poor relief, gleaning, and charity, or additional days worked necessary to shift a building labourer's family to their target consumption PAL level.

	Southern England Building Labourers							
	Breadwinner				Horrell and Humphries			
	Equal	F. Sacrifice	M. Hoarding	Equal Resp	Equal	F. Sacrifice	M. Hoarding	Equal Resp
PAL Equivalent of Median of Predicted Med WRs	2.88	2.88	2.60	2.88	4.03	4.03	4.03	4.03
PAL Equivalent of Median of Predicted Min WRs	1.94	1.76	1.57	1.94	2.46	2.39	2.14	2.46
Median Consuming Unit	2.81	1.87	1.87	2.81	2.81	1.87	1.87	2.81
Max Consuming Unit	3.95	3.01	3.01	3.95	3.42	2.48	2.48	3.42
Male Building Labourer Day Wage (g Ag/day)	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36
Male Annualized earnings per day (g Ag/day)	5.72	5.72	5.72	5.72	5.72	5.72	5.72	5.72
Cost of subsistence basket per day (g Ag/day)	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Father Target PAL	2.6	2.6	3.58	3.58	2.6	2.6	3.58	3.58
Women and Children Target PAL	2.6	1.85	1.85	3.58	2	2	2	3.58
Calories per Day from Median to Reach Target (family)	Surplus	Surplus	Surplus	3,154	Surplus	Surplus	Surplus	Surplus
Additional Income per day as % of Father's Day Wage				14.44%				
Add. Income as % of Father's Annualized Daily Earnings				21.09%				
Additional Days of Work Required				52.72				
Calories per Day from Min to Reach Target (family)	4,153	434	1,368	10,335	Surplus	Surplus	Surplus	6,098
Additional Income per day as % of Father's Day Wage	19.02%	1.99%	6.26%	47.34%				27.93%
Add. Income as % of Father's Annualized Daily Earnings	27.77%	2.91%	9.15%	69.11%				40.78%
Additional Days of Work Required	69.43	7.26	22.87	172.77				101.95

Notes: see tables 2.5 and 2.10.

Sources: see tables 2.5, 2.7 and 2.9; simulated results.

ratio in the family life cycle in the male hoarding specification. The final equal respectability specification makes clear that it was impossible for an agricultural labourer's family where only the father worked to reach the respectability level of consumption. There is no way that self-provisioning, poor relief, gleaning and extension of the working year could fill the gap.

As highlighted above, agricultural labourer families did much better when women and children entered the labour market. Thus, assuming the Horrell and Humphries level of earnings and participation, at the average point in the life cycle, the average family could even afford the male hoarding specification. The respectability basket was also nearly within reach of those willing to self-provision, glean and work for more days during the year. However, the average family still had a hard time at the average low point in the family life cycle. This was driven, in part, by the fact that the women and children's target PAL had to be increased to reflect their greater energy needs when involved in the labour market. Under the female sacrifice unequal specification, the average family would have needed a poor law pension of 21 per cent of the father's annualized earnings or the father would have had to work an additional 52.3 days per year. These figures were too large to be filled by one strategy in the eighteenth century, but the gap could be closed if the family self-provisioned 1,893 kcal/day and gleaned at 15 per cent of the male's annualized daily earnings or gleaned and extended the working year by 36 days. However, there was no possible way for the average family to reach the respectable level of consumption at the average low point in the family life cycle. Thus, although women and children's labour participation could substantially increase the family's living standards, mitigate the effects of a greedy father and put the family within reach of a respectable level of consumption at the average point in the family life cycle, families were much more vulnerable at the minimum welfare ratio point in the family life cycle and would have needed to implement one or more of the three strategies highlighted in order to reach their PAL target even when household allocation was optimal.

Conditions for building labourers were much better (table 2.11). Even without women and children's labour participation, building labourer families were able to afford their PAL targets in the average year and were even within striking distance of a respectable level of consumption. At the average minimum welfare ratio point in the family life cycle, reaching the respectable level for all family members was probably not possible, but the other PAL targets were well within reach of the family willing to extend the working year somewhat. Rural strategies such as gleaning and self-provisioning were probably more difficult for urban building labourers to implement. When women and children's labour force participation is included for the building labourer families, their income was raised to such a level that they would have had no problem purchasing any of the specified PAL targets at the average point in the family life cycle. However, it still would have been quite difficult for them to purchase the respectable consumption level at the low point in the family welfare ratio curve.

2.4 Robustness Checks

Representing a complex historical reality in a model, always requires simplifying assumptions. This section attempts to quantify the influence of two simplifying assumptions on the key outcomes observed here. The two assumptions are that women entered and left the labour market frequently and that prices and wages were constant.

One potential objection to the model presented above is the fluidity with which wives enter and leave the labour market in the model. Essentially, every married woman is given an equal chance to be participating in the labour market in every year regardless of whether the woman was participating in the labour market the year before. Thus, women enter and leave the labour market fairly frequently. Unfortunately, there is very little information on women's longitudinal labour force participation that would provide information about whether women stayed in the labour market for their entire adult life, left the labour market when caring for young children, or never entered the labour force in the first place. The cross-sectional evidence available is also contradictory. At Cardington, Saito reports that women's married labour force participation rates were highest for the women aged 20-39 at 82 per cent and declined over time with only 51 per cent and 60 per cent of married women aged 40-59 and over 60 respectively engaging in the labour market. Thus, women did not seem to leave the labour market while they had young children. However, the opposite is the case in Corfe Castle. Labour force participation rates were over twice as high for married women over sixty than below sixty. Thus, women did seem to re-enter the labour market later in life.[112] These contradictions make it difficult to model how women's labour force participation changed over the life cycle.

Therefore, in addition to the model presented above where women had a random chance of participating in the labour market in every year, I have also included a robustness check that assumes that married women make a choice to join the labour force or not when they get married. If they choose to work (based on the labour force participation rates), then they participate in the labour market for the rest

[112] Saito, 'Who worked when', pp. 219-221.

of the life cycle. If they choose not to work, then they do not enter the labour force unless their husband dies. Obviously, the historical reality falls between the two extremes that are being modelled here, but hopefully, by viewing the difference between the two extremes, we can understand how variations in women's longitudinal labour force participation would affect the outcomes.

Table 2.12 presents the results of the random and fixed (selected at marriage) labour force participation of women for the equal allocation specifications of the model for Cardington, Horrell and Humphries and Spinning wages. In general, the random and fixed labour force participation results are incredibly similar. The medians and means of the distributions and the percentage of family years lived below Allen's subsistence level are nearly identical. However, the fixed labour participation specification is associated with a higher average low point in the family welfare ratio across the life cycle. Likewise, the fixed labour force participation specification has higher levels of inequality (for the distribution of median welfare ratios) than the random specifications presented above.

In order to explain these two effects, it may be helpful to look at density plots for the distributions of median and minimum welfare ratios for the spinning specification where there is the largest difference between the random and fixed specifications. Figure 2.4 displays the distributions median welfare ratios for the random and fixed spinning specifications with the breadwinner specification as a reference. The fixed spinning specification clearly has a larger variance than the random spinning one, with more families at the upper and lower ends of the distribution and fewer families in the middle, increasing the inequality in the distribution. This pattern is created because some wealthy families benefit from

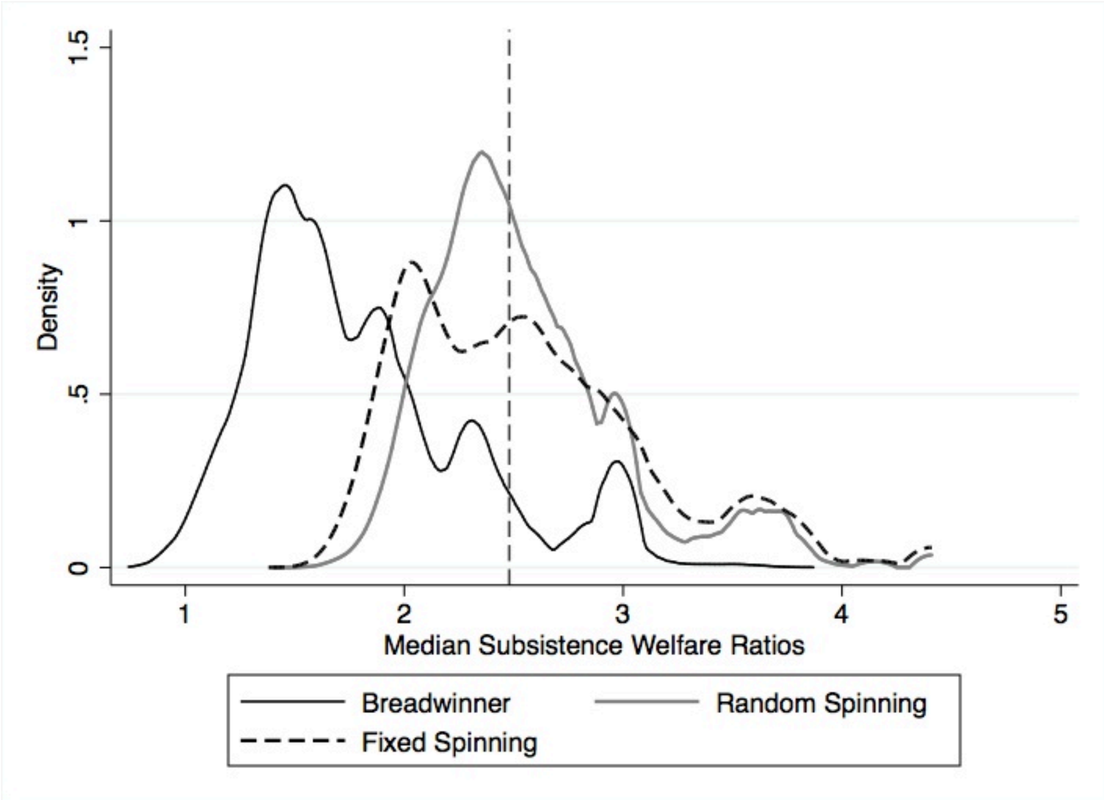
Table 2.12: Robustness check for the fluidity with which women enter and leave the labour force.

	Southern England Agricultural Labourers					
	Cardington		Horrell and Humphries		Spinning	
	Random	Fixed	Random	Fixed	Random	Fixed
Allen Subsistence Welfare Ratio (WRs)	1.73	1.73	1.73	1.73	1.73	1.73
Median of Predicted Distribution of Median WRs	2.28	2.29	2.34	2.35	2.47	2.49
Mean of Predicted Distribution of Median WRs	2.35	2.35	2.42	2.42	2.56	2.56
Median of Predicted Distribution of Min WRs	1.42	1.46	1.43	1.48	1.42	1.56
Calorie Equivalent of Median of Predicted Med WRs	4,419	4,438	4,535	4,554	4,787	4,826
Calorie Equivalent of Median of Predicted Min WRs	2,752	2,829	2,771	2,868	2,752	3,023
BMR	1,597	1,597	1,597	1,597	1,597	1,597
PAL Equivalent of Median of Predicted Med WRs	2.77	2.78	2.84	2.85	3.00	3.02
PAL Equivalent of Median of Predicted Min WRs	1.72	1.77	1.74	1.80	1.72	1.89
% of Total Family Years Below Subsistence	0.94%	0.93%	0.55%	0.54%	0.55%	0.55%
Gini Coefficient	0.1040	0.1085	0.0903	0.0962	0.0950	0.1208

Notes: Random denotes that women are given a random chance of being in the labour market in every year, whereas fixed denotes that women's participation in the labour force is determined at marriage.

Sources: simulated results.

Figure 2.4: Distributions of median agricultural labourer family subsistence welfare ratios showing the breadwinner and spinning specifications.



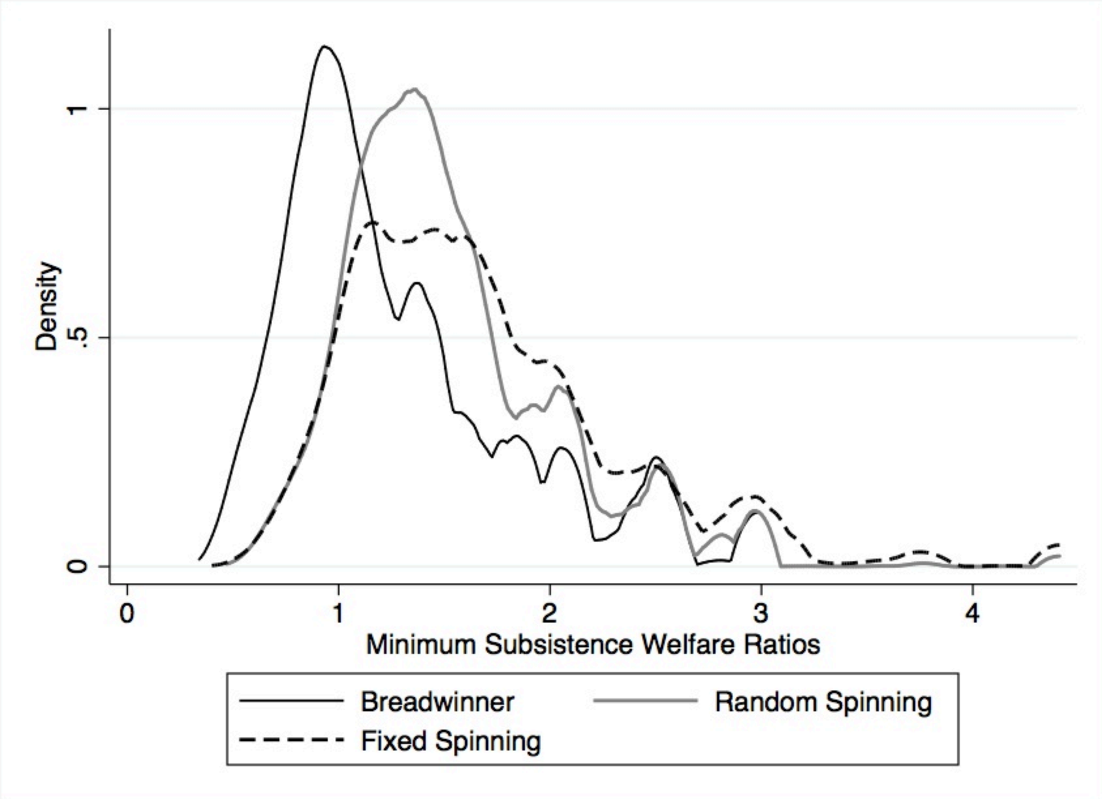
Notes: Random denotes that women are given a random chance of being in the labour market in every year, whereas fixed denotes that women's participation in the labour force is determined at marriage. The vertical dashed line reflects the median of the spinning distributions.

Sources: simulated results.

having the mother's income throughout the life cycle whereas other poor families must make do without any income from the wife. Note that the median welfare ratios still increase relative to the breadwinner specification because children are still allowed to work. There is no change in the measures of central tendency, then, because the increases in the upper and lower ends of the distribution are more or less symmetrical (the median is the vertical dashed line in the figure).

Figure 2.5 shows the distributions of predicted minimum welfare ratios for the random and fixed spinning distributions, and the pattern is somewhat different than that observed for the median welfare ratios. Instead of increases on the left and right

Figure 2.5: Distributions of minimum agricultural labourer family subsistence welfare ratios showing the breadwinner and spinning specifications.



Notes: Random denotes that women are given a random chance of being in the labour market in every year, whereas fixed denotes that women's participation in the labour force is determined at marriage.

Sources: simulated results.

tails of the distribution between the random and fixed specifications, we see that the increase is mostly on the right tail of the distribution. This results in an upward shift in the median between the two specifications. So why is the pattern different? The difference hinges on the kind of events that would precipitate a minimum welfare ratio. In a two-parent family the minimum welfare ratio occurs at the point when the family is largest. This is complicated somewhat when women and children's labour force participation is factored in, but on average this is likely to be true. For a single mother household, the minimum is likely to occur after the father dies not matter the size of the family. Thus, minimum welfare ratios for the poorest families do not decrease because the poorest families in the minimum welfare ratio distribution are widowed mothers, all of whom are assumed to be working and would have the same minimum welfare ratio regardless of how married women's labour participation was allocated among the families. The increase in inequality and in the median of the minimum predicted welfare ratio distribution is strongest for the spinning specification because the married woman's earnings are so much higher in spinning than in the Horrell and Humphries households.

One could criticize the previous robustness check by arguing that it merely replaced one form of randomness with another, and a better way of modelling married women and children's labour force participation would be to make it endogenous to the family's welfare ratio. Unfortunately, this is incredibly difficult to model, especially if one wants to keep within the guidelines of the labour force participation rates. However, there are several reasons that this is not too much of a problem. First, in the model, two things make a family poor: a large family and the death of a father. Because each child is given a random chance of being on the labour market in each year, larger families have more children and therefore have a higher probability of their children participating in the labour market than small families. Second, for the purposes of the model, all of these families are poor relative to the entire society because they are all earning an agricultural or building labourer's wage. Finally, although endogenizing women and children's selection into the labour market would likely reduce the inequality of the distribution, increase the average welfare ratio at the minimum point in the life cycle and decrease the percentage of years lived below subsistence, it would be unlikely to affect the median of the distribution of median welfare ratios because the increase in poorer (larger) family's welfare ratios would be matched by a decrease in richer (smaller) family's welfare ratios.

A second simplification of the model is that prices and wages are held constant across the life cycle. However, it is possible to simulate the effect of price variation by allowing annual prices to vary according to a normal distribution with a standard deviation equal to the observed standard deviation in prices over the period 1750-1800. This is a simpler way of modelling price variation than subjecting the families to the actual price variation, which would require assigning families different starting years and take the model outside of the period 1750-1800. Table 2.13 displays the results for this robustness check. Surprisingly, introducing price variation actually increased the median and mean of the predicted distribution of median welfare ratios. This is because increasing and decreasing prices had an asymmetric effect on the welfare ratio: if the price level decreased by 50 per cent, then welfare ratio would double, but if the price level increased by 50 per cent, the welfare ratio would only be reduced by a third. Thus, families benefited more from downward price swings than they lost from upward price spikes. However, introducing price variation substantially reduced the average minimum welfare ratio across the life cycle, pushing the average PAL level at the minimum below the requisite 1.27 necessary for survival if resources were allocated equally in the household. The percentage of years lived below Allen's subsistence level also increased, though the inequality of median welfare ratios was largely unchanged. Thus, price variation would seem to have had a relatively minor effect on families at the average point in the life cycle but made survival much more difficult when high prices coincided with periods when the family would have already been struggling at normal price levels.

2.5 Conclusion

In conclusion, agricultural labourers were certainly in a more precarious position in the second half of the eighteenth century than building labourers.

Table 2.13: Robustness check showing the effect of price variation on southern English agricultural labourer subsistence welfare ratios.

	Southern England Agricultural Labourers			
	Breadwinner		Horrell-Humphries	
	Constant Prices	Price Variation	Constant Prices	Price Variation
Allen Subsistence Welfare Ratio (WRs)	1.73	1.73	1.73	1.73
Median of Predicted Distribution of Median WRs	1.67	1.74	2.34	2.37
Mean of Predicted Distribution of Median WRs	1.80	1.85	2.42	2.46
Median of Predicted Distribution of Min WRs	1.13	0.94	1.43	1.27
Calorie Equivalent of Median of Predicted Med WRs	3,236	3,372	4,535	4,593
Calorie Equivalent of Median of Predicted Min WRs	2,190	1,822	2,771	2,461
PAL Equivalent of Median of Predicted Med WRs[a]	2.03	2.11	2.84	2.88
PAL Equivalent of Median of Predicted Min WRs[a]	1.37	1.14	1.74	1.54
% of Total Family Years Below Subsistence	9.74%	11.66%	0.55%	1.02%
% of Total Family Years Below PAL 2.6	70.41%	66.54%	38.31%	38.73%
Gini Coefficient	0.1533	0.1515	0.0903	0.0933

Notes: Price variation was added by allowing prices to fluctuate around a normal distribution with the mean and standard deviation determined by actual price fluctuations reported in Allen.

Sources: Allen, spreadsheet; simulated results.

Although they were nearly able to purchase the target PAL level for the female sacrifice unequal specification of the model at the average point in the family life cycle, they would have struggled to purchase the target PAL levels at the minimum point in the family life cycle, relying on self-provision, the generosity of the poor law and extending the work year wherever possible. The respectable level of consumption was clearly beyond their means. The female sacrifice unequal specification for the distribution of household resources helped the family by prioritizing the father's energy requirements necessary for hard work, but greedy or intemperate men could cause substantial harm to the health of the other family members who were left with substantially less food. This was partially mitigated by women and children's labour participation, which increased the median welfare ratios by 31 to 48 per cent, putting even agricultural labourers within stabbing distance of a respectable level of consumption if they were able to employ some of the other strategies. Building labourers were able to afford the respectability consumption level for the entire family, except at the low point in the family life cycle.

However, it is important to remain somewhat pessimistic about these results despite some glimmers of optimism for four reasons. First, the results deal solely with the average (median) family, which by definition means that 50 per cent of families lived at welfare ratios and PAL levels below that level. Second, there were substantial differences between what a family could afford at the average welfare ratio in their life cycle and what they could afford at the lowest welfare ratio in their life cycle. This suggests that poverty was not merely the experience of a particular class of large families, but could hit even the median family when they were at the lowest point on their welfare ratio curve. This poverty is hidden by Allen's focus on the average family at the average point in the life cycle. Third, although women and children's labour force participation played a very important role in helping families escape poverty, women's employment opportunities were on the decline by the end of the nineteenth century, removing this crucial part of the economy of makeshift. Child labour also came with a cost as it likely slowed human capital formation at least in terms of formal schooling and literacy. Finally, the measure for escaping poverty used in this paper is achieving the target PAL level in terms of the subsistence basket, but this was not a pleasant level of consumption, nor did it contain many of the staples of the southern English diet in the eighteenth century.[113] 85.5 per cent of daily calories in the subsistence basket came from oatmeal. Thus, barely being able to scrape by on this basket was hardly luxury. Clearly, agricultural labourers faced a precarious situation at the end of the eighteenth century.

[113] Humphries, 'The Lure of Aggregates'.

PART I: CONCLUSIONS

The previous two chapters have sought to test some of the problematic assumptions that Allen made in order to calculate real wages for a number of countries around the globe and across varying historical time periods. The results suggest that England was a 'high wage economy', at least relative to other countries at the time: Allen's welfare ratios underestimate the earning potential of the average household in the eighteenth century. This is probable for several reasons. First, family size was much smaller than previous historians had believed because wide birth spacing and high child mortality rates meant that the number of children being supported in a family at any give time was much smaller than the total number of children born. Second, the economy of makeshifts provided quite a number of ways for families to scrape together a living. Women and children's labour force participation increased family welfare ratios by 31 to 48 per cent above the pure breadwinner model. Unequal allocation of household resources also allowed families to focus their resources on those who were performing the most labour intensive tasks, though greedy fathers could also do substantial harm to their families by hoarding resources or consuming more than their fair share. The rest of the gap between a family's predicted consumption and target levels of consumption could be made up through self-provisioning, poor relief or extension of working days in the year. Building labourers were better off than agricultural labourers in both periods studied, but even agricultural labourers were close to reaching Allen's respectable level of consumption at the average point in the family life cycle if the wife and children were working. It is difficult to know how the results would turn out if the simulation was run for other countries, but family size would have had to be much lower and women and children's labour force participation and earnings levels would have had to be much higher in other countries to overcome England's real wage lead. Thus, Allen's fundamental argument that England had higher real wages than most other countries in the world seems plausible.

However, this did not mean that the English were immune from poverty. High mortality rates, poor diets, short statures and the descriptions of contemporaries prove that conditions were not optimal. In order to find this poverty, one must focus on the most vulnerable group, agricultural labourers, and look at the distribution of families and changes in welfare ratios over the family life cycle. These simulations provide a distribution of families of different sizes and with different compositions (two parent, widowed mother and father) to test these assertions. Thus, the simulation reaffirmed findings by many historians that female-headed households were substantially worse off than their two-parent counterparts.[1] It is also important to note that although Allen's welfare ratios tend to match or understate the median of the distribution of predicted median welfare ratios, the average (median) family was much worse off at

[1] Horrell *et al.*, 'Destined for Deprivation'.

the lowest point in their welfare ratio curve even if women and children were working. Thus, poverty was not merely a problem for female-headed families and families with a lot of children. Even the average agricultural labourer’s family would have had to either self-provision, glean, gain support from the poor law or extend the working year in order to make ends meet.

Part II:

Complicating Energy Cost Accounting

CHAPTER THREE:

INESCAPABLE HUNGER? ENERGY COST ACCOUNTING AND THE COSTS OF DIGESTION, PREGNANCY AND LACTATION

Over the past 300 years the quantity of calories available to the British population for food has increased dramatically from scarcity to abundance. By some estimates for 1800, 20 per cent of the British population barely had enough calories to survive let alone work at optimally productive levels.[1] Now, we face an entirely different crisis with an overabundance of calories leading to an obesity epidemic that is threatening the long-term health of populations in the developed world.[2] Understanding the amount of calories available to population at different points in time and how this changed allows economic historians to place the question of famine and dearth in the pre-modern period and obesity today in their historical context. In addition, it helps historians understand how general food shortage would have affected the health of the population and limited the productivity of workers. Trends in calorie availability can also be linked to Malthusian dynamics of population growth

[1] Floud *et al.*, *Changing Body*, pp. 72-7.
[2] Offer, *Challenge*, pp. 138-69.

and decline, to mortality decline during the nineteenth century, to an industrious revolution where individuals began to work longer hours, and to differing levels of productivity across countries.[3] Given the wide usage of these figures, it is important that calorie consumption estimates be improved so that historians have a better understanding of what the actual levels might have been.

Several economic historians have used information about agricultural production and food imports and exports to estimate the amount of calories available to the British population at various benchmark years. As is apparent from Table 3.1 below, there are wide margins of error between the various calorie consumption estimates produced so far, but this paper will not focus on reconciling the various estimates.[4] Instead, it focuses on two problems with the energy cost accounting methodology as it now stands that lead these authors generally to overestimate the availability of calories over time. First, the authors do not account for digestion costs in their calorie calculations, and second, the authors do not account for the additional energy requirements of women who are pregnant and nursing. Both of these problems vary in degree across the periods covered and therefore may actually change the estimated trends in calorie availability over time.

Therefore, this chapter will attempt to address both of these issues, using in the first instance Floud *et al.*'s figures as a baseline with robustness checks for Muldrew's high calorie estimates included later in the paper. Using measurable digestion costs of modern food as a guide and the general narrative history of dietary change in Britain from 1700 to 1900, I will propose certain levels of digestion costs for particular foods. These digestion costs are especially important when calculating

[3] Wrigley, *Energy*, pp. 17-21; Floud *et al.*, *Changing Body*, pp. 164-80; Muldrew, *Food*, pp. 161-62; Kelly *et al.*, 'Precocious Albion'.

[4] For a detailed review of the differences between the series, see Kelly and Ó Gráda, 'Agricultural Output'; and Meredith and Oxley, 'Food and Fodder'.

the energy derived from grains, which contain high amounts of dietary fibre difficult for humans to digest. Likewise, I will use demographic data on the total number of births and infant mortality rates to measure the energy cost of pregnancy and lactation for the British population. These adjustments lead to a 15 per cent reduction in Floud *et al.*'s calorie estimates in 1700 but only a 7 per cent reduction in 1909-13 because of changes in the average diet consumed across the eighteenth and nineteenth centuries. Digestion costs declined from 12.71 per cent in 1700 to 4.87 per cent in 1909-13 whereas pregnancy and lactation costs were stable at around 2.5 per cent. These reductions may seem small, but because the British population was already close to the margin in 1700, a small reduction in the average could push a large number of people below the energy levels required for even light work. The paper will first discuss the various calorie consumption estimates made to date; then introduce a methodology for measuring digestion, pregnancy and lactation costs; and finally present the results of these adjustments.

3.1 Historical Background and Context

In the last seven years, four very interesting books and articles have been published that attempt to measure total nutrition in kilo-calories available to the English population in the early modern and modern periods using energy cost accounting. Allen was among the first to systematically calculate the figures in a 2005 working paper.[5] Craig Muldrew's *Food, Energy and the Creation of Industriousness* focuses on the early modern period and suggests very high levels of food consumption on the order of 3,000-5,000 kcal per capita from 1600 to 1800 (Table

[5] Allen, 'English', p. 37.

3.1).[6] Floud, Fogel, Harris, and Hong also published a new book, *The Changing Body: Health, Nutrition, and Human Development in the Western World since 1700*, which extended and complicated Fogel's earlier work on average per capita calorie consumption. Floud *et al*.'s new and improved estimates suggest that consumption increased from 2,229 kcal per capita in 1700 to 2,977 kcal per capita in 1909-13.[7] Finally, Broadberry *et al.* have also come up with estimates as a part of calculating GDP from the output side for Britain from the thirteenth century to the present.[8]

These authors have used their figures to make a number of arguments about the historical British economy. One preoccupation of the authors is how the availability of calories in the economy affected the productivity and work effort of the population. Muldrew concludes from his high estimates of calorie availability that the British population had enough calories to support an industrious revolution in the early modern period. Thus, early modern Britons increased their work intensity in order to purchase the new consumer products of the seventeenth and eighteenth centuries such as cotton textiles, durable household goods, tea, sugar and tobacco.[9] For Muldrew, these high levels of energy also negated Fogel's earlier argument that up to 20 per cent of labourers in England in 1800 did not have enough calories to conduct more than one hour of hard manual labour per day.[10] Voth came to similar conclusions after submitting Fogel's calorie distribution methodology, reused in Floud et al., to additional scrutiny.[11] Mokyr and his co-authors have also highlighted how the greater availability of calories in the eighteenth century may have made British workers more productive than French workers thereby contributing to the high

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6 Muldrew, *Food*, p. 156.
7 Floud *et al.*, *Changing Body*, p. 167.
8 Broadberry *et al.*, 'British'.
9 Muldrew, *Food*, pp. 12, 161.
10 Fogel, 'New Sources', p. 12.
11 Voth, *Time and Work*, pp. 161-171.

wages observed in England.[12] Floud *et al.* have generally taken a more pessimistic view of calorie availability in preindustrial England. Their average calorie figures are substantially below Muldrew's, generally 60 per cent of Muldrew's figures, and they also reaffirm Fogel's earlier assertion that 20 per cent of the population did not have enough energy for more than a few hours of light work per day.[13] Again, Voth has challenged this argument in his earlier book, arguing that 'there is neither conclusive evidence of nutritional constraints before 1750, nor is there any indication of a markedly improved food supply during the subsequent period, when working hours increased'.[14] Floud et al., however, are more optimistic about the role of increasing calorie availability on economic growth, arguing that increasing energy available for human work effort can explain 30 per cent of British per capita income growth between 1800 and 2000.[15]

Table 3.1: Estimates of kilo-calories available per capita per day in England and Wales across the early modern and modern periods.

	Broadberry *et al.* (2011)	Floud *et al.* (2011)	Allen (2005)	Muldrew (2011)
1600	2,082			3,062
1700	2,162	2,229	3,255	3,579
1750	2,248	2,237	3,803	
1770				5,047
1800	2,165	2,439	2,938	3,977
1850	2,104	2,544	2,525	
1909		2,977		

Sources: Broadberry *et al.* – from Kelly and Ó Gráda, 'Agricultural Output', p. 21, citing Broadberry *et al.*, 'British'; Floud *et al.*, *Changing Body*, p. 167; Allen, 'English', p. 37; Muldrew, *Food*, p. 156.

The calorie estimates have also been used to make judgements about the standard of living of the British population at various points in time. Allen and

[12] Mokyr, *Enlightened Economy*, pp. 271-2; Kelly *et al.*, 'Precocious Albion'.
[13] Floud *et al.*, *Changing Body*, p. 167.
[14] Voth, *Time and Work*, pp. 181-184.
[15] Floud *et al.*, *Changing Body*, pp. 126-7.

Broadberry *et al.*'s figures showed a significant drop in calories per capita across the Industrial Revolution, suggesting the immiseration of workers across the period.[16] Floud *et al.* argue that the increase in adult male heights between 1770 and 1820 and the decrease in adult mortality between 1750 and 1820 is partially driven by the substantial increase in calorie availability from 1750 to 1800. Floud *et al.* also use their calorie estimates to conditionally defend McKeown's contentious argument that improving nutrition contributed to the mortality decline in the second half of the nineteenth century.[17] Clearly, these estimates have provided crucial evidence in helping economic historians discern the health and productivity of people in the past.

It is unfortunate, then, that the four estimates in Table 3.1 vary substantially even when calculated for the same year. Kelly and Ó Gráda have summarized the estimates and critiqued them in a recent working paper, so I will merely report some of their findings here. They focus on the years 1750-1800, but their findings are applicable to the broader period covered in this paper as well. Kelly and Ó Gráda generally find that Broadberry *et al.*'s figures are too low and Muldrew's figures are too high, while Floud *et al.* and Allen's figures seem to fall within a plausible range. Muldrew's figures are too high because he overestimated the amount of land planted with wheat, rye, barley, and oats; his extraction rate for barley was too high; and he assumed that too large a percentage of oats produced were used for human consumption. However, these overestimations were partially cancelled out because Muldrew also did not account for calories from potatoes and imported sugar and wine. Thus, Kelly and Ó Gráda suggest that Muldrew's figures for 1770 and 1800 should be revised downward by 1,100 kcal/person/day and 500-800 kcal/person/day in each year respectively. Broadberry *et al.*'s figures are low because they

[16] Allen, 'English', p. 37; Broadberry *et al.*, 'British'.
[17] Floud *et al.*, *Changing Body*, p. 162-3.

underestimated the acreage planted with rye before 1800, and they underestimated the number of calories derived from milk and meat products. Thus, Kelly and Ó Gráda suggest that Broadberry *et al.*'s estimates should be increased by 600-650 kcal/person/day in 1750 and 450-500 kcal/person/day in 1800.[18] Floud *et al.* do not escape criticism either. They assume substantial losses in milling and distribution of grains based on those in the early twentieth century US that are much higher than those of the other three sets of authors. This would lead them to underestimate the total calories available.[19] However, I would add that Muldrew's assumption of only 7.5 per cent losses from milling and distribution based on one pamphlet and one Farmer's account seems too low.[20]

Even with these adjustments, there is still a wide range of calorie per capita estimates from the more pessimistic figures of Floud *et al.* to the still-higher post-adjustment Muldrew figures. Thus, Muldrew's argument that high levels of calories per capita could have powered an industrious revolution in England and Floud *et al.*'s argument that a substantial minority of the population of England and Wales did not have enough energy to perform significant amounts of labour could both still hold within this margin of error.

I have decided to base my calculations on Floud *et al.*'s figures because they represent a middle point in the estimates that have been produced so far and because their calculations are clearly explained in a number of tables in their book. However, in a robustness check I will explain the implications of the two adjustments carried out for Muldrew's series as well since it is farthest from the other estimates.

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[18] Kelly and Ó Gráda, 'Agricultural Output', pp. 28-33.
[19] Meredith and Oxley, 'Food', pp. 13-14; Kelly and Ó Gráda, 'Agricultural Output', p. 34.
[20] Muldrew, *Food*, pp. 146-47.

3.2 Methodology: Measuring the Cost of Digestion

The first complication to energy cost accounting derives from a burgeoning literature among nutritionists questioning current methods for measuring the caloric composition of different foods. Nutritionist have shown that the Atwater factors based on metabolizable energy (ME) employed by the authors in their calorie consumption calculations often overstate the number of calories in foods because they do not correctly measure the energy cost of consuming and digesting different types of food. Both Floud *et al.* and Muldrew mention that food preparation and the composition of the diet can affect the absorption of nutrients, but they do not attempt to adjust for this in a systematic manner.[21] Calculating new figures called net metabolizable energy (NME) factors, the energy derived from protein, dietary fibre, and alcohol is 24, 25 and 10 per cent lower respectively than on published charts and nutritional labels.[22] Therefore, based on the quantity of protein and dietary fibre in various foods, the total calories calculated from ME factors will substantially overstate the actual calories obtained from the food. At a Food and Agriculture Organization (FAO) meeting in 2002, experts met and discussed whether to recommend that standards switch from an ME system to an NME system, but they decided against it principally because the difference between the two was quite small in modern mixed diets and because the FAO's own recommended energy requirements accounted for much of the difference between the two systems.[23] However, as I will attempt to argue below, historical diets were quite different from modern diets having higher proportions of dietary fibre and protein relative to fats and available carbohydrates. In addition, the FAO energy requirements are only an approximation for historical populations. Historical populations would likely have needed more calories to maintain body heat and fight

[21] Floud *et al.*, *Changing Body*, p. 162; Muldrew, *Food*, pp. 118-19.
[22] FAO, 'Food Energy', pp. 23-33; Livesey, 'Perspective'.
[23] FAO, 'Food Energy', pp. 33-7.

disease in an era when heating was not as prevalent and antibiotics were not available.[24] Thus, I believe it is useful and necessary to recalculate the energy in Floud *et al.*'s figures based on NME factors.

In addition to these digestion costs, the texture of foods can make a difference in the energy expended consuming food because hard foods are more difficult to chew and otherwise break down than soft foods. Nutritionists have shown that rats fed with soft pellets had higher fat content after 26 weeks than rats fed with hard pellets of the same energy content.[25] Likewise, the hardness or difficulty of chewing of diets in Japanese women has been linked to their waist circumference controlling for their body mass index (BMI).[26] Clearly, digestion costs have a substantial effect on the net energy converted from food.

Importantly, however, these digestion costs were not constant across time because the composition and preparation of food in England changed over the centuries. Therefore, accounting for digestion costs is more complicated than simply adjusting the volume to calorie conversions utilized by Floud *et al*. Determining general trends in food consumption and preparation from the medieval to the modern period in England is difficult because of the deficiencies of early sources and the wide regional variation in diets described by Eden in the 1790s.[27] However, some very broad trends in cereal preparation and consumption might serve as a useful starting point for this discussion considering that cereals made up a large proportion of the total calories in historical diets.[28] Before the Black Death, pottage and very coarse bread made up the largest share of English peasants' caloric consumption. After the

[24] Kelly and Ó Gráda, 'Agricultural Output', p. 19.
[25] Oka *et al.*, 'Food Texture'.
[26] Murakami *et al.*, 'Hardness'.
[27] Horrell and Oxley, 'Bringing', p. 3-6.
[28] Muldrew, *Food*, pp. 57-8; Kelly and Ó Gráda, 'Agricultual Output', pp. 8-9.

Black Death as real wages increased, peasants began to substitute toward bread.[29] Pottage, mainly in the form of oatmeal, did not disappear completely, but wheat household loaves and barley and oat cakes became more and more popular. These loaves were made with coarsely ground flour and were tough to chew and digest.[30] However, by the end of the eighteenth century and certainly by the mid-nineteenth century, many English people had shifted their consumption from coarse household loaves to more finely ground white wheat bread.[31] The invention of roller-milling in the 1880s made removing the bran and germ from flour even easier and solidified this trend.[32]

These shifts in cereal consumption and preparation would have influenced the digestion costs faced by the English population over time based on the relative levels of dietary fibre and the difficulty of chewing the various preparations of cereals. Pottage was obviously relatively easy to consume because it was boiled for hours and was mushy, but it also contained very high levels of dietary fibre because milling was only required to remove the outer husk of the grain rather than grinding it into much smaller pieces.[33] The shift to bread eating likely decreased dietary fibre in the average diet somewhat because bread flour was sifted to remove part of the bran, a key part of the dietary fibre. However, household bread was notoriously difficult to chew and still contained high levels of dietary fibre because it was made with coarsely ground flour.[34] Both of these factors would have kept the digestion and consumption costs quite high. Finally, the shift to consumption of good white bread reduced digestion costs because the bread became lighter and easier to chew, and the amount of bran in

[29] Stone, 'Consumption', in Woolgar *et al.*, *Food in Medieval England* (2006), pp. 17-18, 23-26.
[30] Muldrew, *Food*, pp. 60-2.
[31] Burnett, 'Trends', in *Our Changing Fare* (1966); Drummond and Wilbraham, *Englishman's Food*, pp. 186-8.
[32] Burnett, 'Trends', p. 63; Drummond and Wilbraham, *Englishman's Food*, pp. 296-8.
[33] Campbell, *Seigniorial Agriculture*, p. 398.
[34] Muldrew, *Food*, pp. 58-9, 119-20.

the bread was reduced by finer sifting. Eden, writing in the 1790s, even reports that Kentish people disliked the old common bread as opposed to the finest wheat bread because it 'disorder[ed] their bowels'.[35] Thus, changes in the preparation of food influenced the digestion costs differently across time.

Table 3.2: Comparison of metabolizable energy (ME) and net metabolizable energy (NME) calorie levels for various types of cereal products.

	Components of Food				Total		
	Protein	Fat	Carbohydrate	Dietary Fibre	Calories	NME/ME	Fibre/Carb
Oatmeal							
Grams	11	5	56	8			
ME Cal	44	45	224	0	313		
NME Cal	35.2	45	192	11.2	283.4	0.9054	14.29%
Whole Wheat Bread							
Grams	4	2	24	3			
ME Cal	16	18	96	0	130		
NME Cal	12.8	18	84	4.2	119	0.9154	12.50%
Baguette							
Grams	6.25	0	42.5	1.25			
ME Cal	25	0	170	0	195		
NME Cal	20	0	165	1.75	186.75	0.9577	2.94%
Wonder Bread							
Grams	2	1	14.9	0.5			
ME Cal	8	9	59.6	0	76.6		
NME Cal	6.4	9	57.6	0.7	73.7	0.9621	3.36%

Sources: ME and NME conversion factors from FAO, 'Food Energy', p. 29; Nutrition facts: oatmeal - http://nutritiondata.self.com/facts/breakfast-cereals/1597/2, whole wheat bread - http://nutritiondata.self.com/facts/baked-products/4878/2, baguette - http://www.caloriegallery.com/foods/calories-in-baguette.htm, wonder bread - http://caloriecount.about.com/calories-wonder-bread-i113246.

This pattern is especially clear if we look briefly at modern food as a comparison. As Table 3.2 shows even in modern oatmeal and whole wheat bread, the NME calorie measurement, which accounts for digestion costs, is about 10 per cent lower than the ME calculation. Modern whole wheat bread would have seemed like cake to early modern English people though, so the NME to ME ratio would likely be even lower for early modern household loaves. However, if the same NME to ME ratio is calculated for a baguette and for the pinnacle of American baking 'Wonder

[35] Horrell and Oxley, 'Bringing', p. 4, citing Eden, *State*, vol. II, p. 280.

Table 3.3: Adjustment of calories from grains for digestion and consumption costs.

A. Crop Yields from Chartres, Holderness, and Allen

	Kcal per capita per day Floud et al.					Cereal Adjustment Rates					Digestion Cost Adjustments					New Totals and Comparisons			
Year	Wheat	Rye	Barley	Oats	Maize/Rice/ Other	Wheat	Rye	Barley	Oats	Maize/Rice/ Other	Wheat	Rye	Barley	Oats	Maize/Rice/ Other	Adjusted Total	Floud et al. Total	Calorie Difference	Percentage Difference
1700	493.18	250.76	593.05	123.7	0	0.2	0.2	0.125	0.2	0.05	394.54	200.61	518.92	98.96	0	1,213.03	1,461	247.97	16.97%
1750	500.57	131.15	407.91	206.29	0	0.175	0.2	0.125	0.2	0.05	412.97	104.92	356.92	165.03	0	1,039.84	1,246	206.16	16.55%
1800	792.47	76.31	319.27	193.47	0	0.15	0.2	0.1	0.2	0.05	673.60	61.05	287.34	154.78	0	1,176.77	1,382	205.23	14.85%
1850	901.07	18.02	264	137.91	74.76	0.125	0.2	0.1	0.2	0.05	788.44	14.42	237.60	110.33	71.02	1,221.80	1,396	174.20	12.48%
1909-13	876.64	0	10.88	48.65	62.55	0.075	0.1	0.07	0.1	0.05	810.89	0	10.12	43.79	59.42	924.22	999	74.78	7.49%

B. Crop Yields from Turner, Beckett, and Afton

	Kcal per capita per day Floud et al.					Cereal Adjustment Rates					Digestion Cost Adjustments					New Totals and Comparisons			
Year	Wheat	Rye	Barley	Oats	Maize/Rice/ Other	Wheat	Rye	Barley	Oats	Maize/Rice/ Other	Wheat	Rye	Barley	Oats	Maize/Rice/ Other	Adjusted Total	Floud et al. Total	Calorie Difference	Percentage Difference
1700	493.18	250.76	593.05	123.7	0	0.2	0.2	0.125	0.2	0.05	394.54	200.61	518.92	98.96	0	1,213.03	1,461	247.97	16.97%
1750	646.63	131.15	404.53	270.31	0	0.175	0.2	0.125	0.2	0.05	533.47	104.92	353.96	216.25	0	1,208.60	1,453	244.40	16.82%
1800	778.2	68.75	311.04	205.39	0	0.15	0.2	0.1	0.2	0.05	661.47	55.00	279.94	164.31	0	1,160.72	1,363	202.28	14.84%
1850	923.82	17.94	263.31	156.65	74.76	0.125	0.2	0.1	0.2	0.05	808.34	14.35	236.98	125.32	71.02	1,256.02	1,437	180.98	12.59%
1909-13	876.64	0	10.88	48.65	62.55	0.075	0.1	0.07	0.1	0.05	810.89	0	10.12	43.79	59.42	924.22	999	74.78	7.49%

Notes: The 1750 wheat calories per capita have been corrected from the original to reflect an arithmetic error in calculating the total calories from wheat production.

Sources: Floud *et al.*, *Changing Body*, p. 161, tables D.2, D.3, D.4, D.5, D.7, D.8, D.16; for cereal adjustment see text and sources for table 3.1; meat adjustment calculated from meat nutrition facts from nutritiondata.self.com; NME to ME ratios calculated using FAO, 'Food Energy', p. 29.

Bread', the NME to ME ratios increase substantially with only a 5 per cent difference between the two. This is mostly driven by the fact that whole wheat bread has a much higher ratio of dietary fibre to carbohydrates than the more processed breads.

These modern examples also highlight the importance of calculating the digestion cost adjustment rate separately for each grain based on its use in the diet (Table 3.3). The digestion costs for rye, oats and maize are quite easy to calculate. Rye and oats were only roughly milled to remove the husks, so much of the bran remained. Thus it is fairly safe to assume that before the invention of roller milling in the late nineteenth century, the digestion costs of both oats and rye were around 20 per cent, and these declined to 10 per cent thereafter. Maize only became a substantial part of the British diet after 1850. Its NME to ME ratio was quite high with only a 5 per cent reduction required to adjust for digestion costs. The digestion cost adjustment rate for wheat decreased over time as more and more people shifted toward eating fine white bread. I have therefore allowed for an adjustment rate of 20 per cent for wheat in 1700 when a substantial majority of wheat eaten was being eaten as brown loaves, but this adjustment rate declines by 2.5 per cent every 50 years to mark the shift of more and more people to finer white bread.[36] The wheat adjustment rate drops from 12.5 per cent in 1850 to 7.5 per cent in 1909 reflecting the improvement in milling technology during that period.[37]

Determining digestion cost adjustments for barley is also difficult because barley could either be consumed as bread or as beer. The digestion costs for barley bread would have been similar to oats and rye bread since the barley was not finely milled, putting the adjustment rate at 20 per cent. However, the adjustment rate for

[36] Muldrew does use a lower calorie per pound ratio for early modern household bread than modern wholemeal bread when calculating the calories in early modern institutional diets because the bread may have been moister, but he does not include this adjustment in the aggregate calorie consumption calculations. Muldrew, *Food*, pp. 119-20.

[37] Burnett, 'Trends', p. 63; Drummond and Wilbraham, *Englishman's Food*, pp. 296-8.

beer was much lower; the adjustment rate for a modern beer would have been 7 per cent with the downward adjustment solely caused by the 10 per cent digestion costs for alcohol.[38] Therefore, I have assumed a digestion cost adjustment rate of 12.5 per cent from 1700-1750 assuming that roughly 60 per cent of the calories from barley were consumed as beer and 40 per cent as barley bread. Although beer drinking was widespread, Collins and others have highlighted the importance of barley bread in the diet of Northerners especially.[39] This ratio dropped over time, however, as barley bread and cakes became less popular. The adjustment ratio of 10 per cent in 1800 and 1850 suggests that around 75 per cent of barley calories came from beer and 25 per cent came from barley bread. Finally, by 1909 almost all barley was consumed as beer, so the adjustment ratio fell to 7 per cent. Although these estimated digestion costs are approximations, the adjustments seriously influence the total calorie estimations for the English economy.

It is also important to adjust the meat and dairy calorie numbers because, as mentioned above, the biggest differences between NME and ME factors are with dietary fibre and protein. The NME to ME ratio for meat is dependent on the fat content of the meat and dairy products. Higher fat meats have higher NME to ME ratios whereas leaner meats where most of the calories are derived from protein have lower ratios.[40] Thus, modern nutrition facts were used to calculate the NME to ME ratio for various kinds of meat and dairy products. For most modern lean meats, the downward adjustment was around 10 per cent, while for milk and cheese it was only 5 per cent. Meat and dairy products that were composed mostly of fat, such as lard and butter, were given no adjustment. Accounting for digestion costs led to

[38] Calories in beer from http://nutritiondata.self.com/facts/beverages/3827/2.
[39] Collins, 'Dietary Change', pp. 98-102; Horrell and Oxley, 'Bringing', pp. 3-6; Muldrew, *Food*, pp. 58-62; Drummond and Wilbraham, *Englishman's Food*, pp. 105-6, 186-7.
[40] FAO, 'Food Energy', pp. 33-7; Muldrew, *Food*, p. 121.

approximately a 7 per cent downward adjustment in the calories available from meat and dairy products. It is possible that improvements in breeding and fattening of animals between 1700 and 1900 increased the fat to protein ratio in the average cut of meat and therefore reduced digestion costs.[41] However, it is much more difficult to precisely time the changes in digestion costs for meat, which would have been much smaller than cereals anyway, so the digestion costs were held constant across time for the various meats.

3.3 Methodology: Measuring the Energy Costs of Pregnancy and Lactation

Another potential objection to Floud *et al.* and Muldrew's accounting procedure is that they do not account for the additional energy required by women during pregnancy and lactation. While digestion costs affected the average calories per capita in the economy, pregnancy and lactation costs influenced the relative calorie requirements of men and women and thus the conversion from per capita to consuming unit (adult male equivalent) requirements. Part of the lactation requirements might be captured by energy inputs for infants, but there were additional costs to women in making the milk not accounted for by the energy that was transferred to infants (entropy). The authors also seem to ignore increased energy requirements during pregnancy. The cost of pregnancy and breast-feeding upon fecund women could have been a potentially large source of error in their method because fertility rates were high in the past and women breast-fed for longer periods of time than is now common. These additional costs would increase the energy requirements of women relative to men, raising the total number of consuming units in the economy and lowering average calories available per consuming unit.

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41 Olmstead and Rhode, *Creating Abundance*, pp. 262-329.

Therefore, it is worthwhile to adjust Floud *et al.*'s figures based on these additional costs to women.

It is important first to set an initial baseline from which to compare men and women later. I have followed Humphries in using the latest FAO guidelines (2004) for men and women working at a physical activity ratio (PAR) of 1.75.[42] This is enough energy for a person to do 'light activity' and seemed like a good basis for comparison. The heights, weights and BMIs of prisoners held in Wandsworth House of Correction in the nineteenth century will be used as a standard for comparing the energy requirements of men and women. While prisoner populations may have been more malnourished than the general population, there is not good comparable height and weight data from other sources.[43] Men in the Wandsworth House of Correction were on average 165.39 cm tall, weighed 63.32 kg and had a BMI of 23.10.[44] Following the energy requirement calculations in the FAO report for men aged 18-29.9 with these anthropometric averages, a man in prison would need 2,880 kcal/day to carry out light activity.[45] Women in Wandsworth were substantially smaller with an average height of 155.08 cm, weight of 53.61 kg, and BMI of 22.27.[46] They therefore needed 2,242 kcal/day to carry out light activity. Thus, women required 77.8 per cent as much energy as men aged 18-29.9, Floud *et al.*'s baseline, to perform light tasks.

In determining the costs of lactation and pregnancy, I again follow Humphries and the FAO guidelines. Being pregnant raises a woman's daily energy requirements differently in each trimester of pregnancy: 85 kcal in the first, 285 kcal in the second, and 475 kcal in the third. This averages to 282 additional kcal/day throughout the

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[42] Humphries, 'Lure', p.13; FAO, 'Human', p. 59.
[43] Horrell, Meredith and Oxley, 'Measuring'.
[44] Oxley, personal communication.
[45] FAO, 'Human', 35-40.
[46] Oxley, personal communication.

pregnancy and 211.25 kcal/day on an annual basis. A woman needs an additional 675 kcal/day in the first six months of breast-feeding and 460 kcal/day after the first six months until weaning, which is assumed to take place at 18 months.[47] I will use these figures to estimate the additional energy burden placed on women by pregnancy and lactation and adjust Floud *et al.*'s figures. This will involve two parts: estimating the additional calories required for pregnancy and lactation in each benchmark year and calculating a new minimum energy requirement for women in their childbearing years.

In order to measure the additional calories that women would need for pregnancy and lactation, it is first necessary to understand how many women were pregnant and how many children were nursed. The simplest way to understand how many women were pregnant in a given year is to employ the crude birth rate, which reflects the outcome of pregnancy, a birth. This measure fails to capture miscarriages, which would increase the number of pregnancies in the economy, but since many miscarriages would have been caused by a lack of adequate nutrients, the adjustment for miscarriages would likely be quite small. The additional energy requirements needed for pregnancy can be calculated by multiplying the total births in a year, calculated from the crude birth rate and population levels, by the 211.25 kcal/day extra required and by 365 days. Table 3.4 shows these figures for the benchmark years employed by Floud *et al.* This figure of total calories per year needed for pregnancy is then divided by the age category listed in Wrigley *et al.* and Mitchell that best fits that of fecund women, the 25-59 age category, assuming that the sex

[47] Humphries, 'Lure', p.13; FAO, 'Human', p. 59. The British government does recommend lower calories per day during pregnancy (191 kcal in final trimester) and lactation (502 kcal in first six months) than the FAO, but the FAO figures, which are meant to apply to developing and developed countries, better reflect the conditions of women living in historical Britain before modern heating, medical care, and good nutrition. Scientific Advisory Committee on Nutrition, 'Dietary', pp. 64-73.

ratio was equal.[48] This calculation suggests that the cost of pregnancy across the entire population was 26 to 42 kcal/day per fecund aged woman. Of course there were women who would have had children before the age of 25, but by adjusting the 25-59 age category for the total additional calories required, these pregnancies will still be considered.

Table 3.4: Calculation of additional energy cost required for pregnancy.

Year	Population	CBR	Total Births	Percentage of Women of Fecund Age	Women Aged 25-59.9	Daily Calories Needed for Pregnancy (annualized)	Total Calories per Year Required for Pregnancy (000,000s)	Calories per Woman Aged 25-59.9 per Day (Pregnancy)
			((2) / 1000) * (1)		(4) * (1)		(3) * (6) * 365	(7) / (5)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1701	5,210,623	32.06	167,053	20.80%	1,083,810	211.25	12,881	32.56
1751	5,921,905	32.97	195,245	20.69%	1,224,946	211.25	15,055	33.67
1801	8,671,439	37.6	326,046	18.96%	1,643,671	211.25	25,140	41.90
1851	16,732,114	35.98	602,021	19.22%	3,215,076	211.25	46,420	39.56
1909	35,424,000	25.8	913,939	20.60%	7,297,054	211.25	70,470	26.46

Sources: 1701-1851: Wrigley, *et al.*, *English Population History*, pp. 614-15; 1909: Mitchell, *British Historical Statistics*, pp. 13, 15, 43; Calorie requirements: Humphries, 'Lure', p. 13; FAO, 'Human', p. 59.

Calculating the number of children who needed to be nursed is much more complex. Infant mortality was quite high, so children's deaths need to be incorporated into the model. Likewise, the energy requirements for lactating were higher in the first six months after pregnancy (675 kcal/day) than in the subsequent year until weaning (460 kcal/day). Therefore, when a child died within the year is also an important factor to consider. Fortunately, Wrigley *et al.* supply mortality rates of children at different points during the first year of life, which makes it possible to measure the number of children surviving that needed to be nursed. Table 3.5 shows this calculation. First, the number of children surviving after a number of days is

[48] Changing the sex ratio has a very small influence on the final figures produced.

Table 3.5: Calculation of additional energy cost required for lactation.

		1700	1750	1800	1850*	1909*
		Panel A. Legitimate Mortality Rate During Nursing Period (1000qx)				
(A1)	0-29	106.3	78.5	57.3	41.0	
(A2)	30-59	19.3	16	14.1	15.7	
(A3)	60-89	14.1	11.6	10.9	13.7	
(A4)	90-179	26.1	25.7	23.6	35.5	
(A5)	180-273	21.2	22.6	21	28.5	
(A6)	274-365	17.5	19.1	16.8	25.6	
(A7)	1-2 years	42.5	43.6	46.8	20**	
		Panel B. Children Surviving to a Certain Age				
(B1)	Total Births	167,053	195,245	326,046	602,021	913,939
(B2)	30 Days	149,295	179,918	307,364	577,314	876,431
(B3)	60 Days	146,413	177,040	303,030	568,242	862,658
(B4)	90 Days	144,349	174,986	299,727	560,451	850,832
(B5)	180 Days	140,582	170,489	292,653	540,567	820,644
(B6)	274 Days	137,601	166,636	286,508	525,185	797,293
(B7)	365 Days	135,193	163,453	281,694	511,718	776,848
(B8)	2 Years	129,447	156,327	268,511	491,249	761,311
		Panel C. Calories Needed to Nurse Surviving Babies (000,000s)				
(C1)	0-29	3,203	3,799	6,413	11,941	18,127
(C2)	30-59	2,994	3,614	6,180	11,599	17,608
(C3)	60-89	2,944	3,564	6,103	11,428	17,349
(C4)	90-179	8,655	10,494	17,994	33,443	50,771
(C5)	180-273	5,950	7,210	12,387	22,793	34,602
(C6)	274-365	5,709	6,908	11,891	21,699	32,942
(C7)	First Year Total	29,454	35,589	60,968	112,903	171,400
(C8)	Second Year Total	11,075	13,386	23,051	41,947	64,001
(C9)	Total Add Calories per Year	40,530	48,975	84,020	154,850	235,402
(C10)	Calories per Woman (25-59.9) per Day (Nursing)	102.45	109.54	140.05	131.96	88.38

Notes: I assumed the following calorie requirements for nursing: 675 kcal/day in first 6 months and 460 kcal/day thereafter. Calories required for lactation in Panel C were calculated assuming that mothers whose children survived nursed them every day. Children who died were assumed to have lived on average half way through the period. The calorie figure presented is thus the calories required by mothers whose children survived plus the calories required by mothers whose children died. An example calculation for C1 is as follows: C1 = B2 * 30 * 675 + (B1 - B2) * 15 * 675.

* An 1889-91 life table from Woods (2001) was used to calculate children surviving in 1850 and 1909. Using the 1889-91 life table likely underestimates the energy required for lactation in 1909 because infant mortality began to fall at the turn of the twentieth century, leaving more children who would need to be nursed. However, children were also weaned earlier by 1909, so the overall difference would be slight.

** The mortality in the second year of life (${}_1q_1$) in 1889-91 was estimated at 20 per thousand based on trends in Woods.

Sources: Legitimate mortality rates 1700-1825: Wrigley, *et al.*, *English Population History*, pp. 226, 250; Total births and women aged 25-59.9: see sources Table 3; Legitimate life table 1889-91: Woods, *Demography*, p. 260; Calories required for pregnancy from Humphries, 'Lure', p. 13 and FAO, 'Human', p. 65.

calculated from Wrigley *et al.*'s figures. Then, the total calorie requirements to feed the surviving children is calculated as follows. Children who survived to a particular cut off point had to be fed daily up to that point, so each child was given the requisite calories for that period. The children who died were assumed to live on average halfway through the period; thus, children who died in the first 30 days of life were assumed to have lived on average 15 days. This may overestimate the total calories required because especially in the first 30 days of life, deaths were not evenly distributed across the period with more children dying shortly after birth, but it is a reasonable approximation because women were likely to continue lactating for a short period after their child died. Assuming that children were weaned at 18 months, the calorie requirements of children in their second year were calculated by a similar method using the number of surviving children at the end of the first year as a benchmark. All of these daily calorie counts were added together to estimate the total additional calories needed per year for lactation. This total number was again divided by the number of women aged 25-59.9 with estimates of women in that age group needing on average an additional 88 to 140 kcal/day to cover the cost of lactation in the population.

Next, the total calorie requirements of women aged 25-59.9 were calculated using 2,242 kcal/day as a baseline and adding the additional average costs for pregnancy and lactation per year (Table 3.6). Women aged 25-59.9 needed 2,357 to 2,424 kcal/day, an additional 115 to 182 kcal/day from the 2,242 baseline to cover the increased energy requirements of pregnant women. These adjusted calorie requirements were divided by the male baseline energy requirements (2,880 kcal/day) to get a ratio between men and women's needs. The ratios calculated were all remarkably similar with a mean ratio of 0.8304. This is significantly higher than

Floud *et al.*'s calculation of a 0.7583 ratio of women to men at ages 15-24 and 0.6893 ratio of women to men at ages 25-59, suggesting that their figures have overstate the sufficiency of calories.[49]

Table 3.6: Calculation of new calorie requirements for women age 25-59.9 including the additional costs of lactation and pregnancy with a new ratio to the male consuming unit.

Year	Basic Energy Requirement for Women 30-59.9 (kcal/day)	Calories per Woman (25-59.9) per Day (Pregnancy)	Calories per Woman (25-59.9) per Day (Nursing)	Energy Requirements of All Women (25-59.9)	Diff from Assumption (2242 kcal/day)	% Increase from Assumption (2242 kcal/day)	Percentage of Male (2880 kcal 18-29.9) diet
				(1) + (2) + (3)	(4) - (1)	((4) / (1)) - 1	(4) / 2880
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1701	2,242	32.56	102.45	2,377.22	135.01	6.02%	0.8254
1751	2,242	33.67	109.54	2,385.42	143.21	6.39%	0.8283
1801	2,242	41.90	140.05	2,424.16	181.95	8.11%	0.8417
1850	2,242	39.56	131.96	2,413.72	171.51	7.65%	0.8381
1909	2,242	26.46	88.38	2,357.05	114.84	5.12%	0.8184

Sources: see previous tables for calorie sources; basic energy requirements from FAO, 'Human', pp. 35-40.

The final step and table attempt to recalculate Floud *et al.*'s figures of kcal/day available to a consuming unit. It is first necessary to substitute in the higher male to female ratio calculated above for Floud *et al.*'s lower figures. It was also necessary to adjust the energy requirements of infants since these would be captured by the cost of lactation. I assumed that infants were purely breast fed for the first six months and were fed half breast milk and half other food from six months to 18 months. Assuming somewhat dubiously equal one-year cohorts in the age group 0-4, I removed 10 per cent of the weight of the group to take out infants in the first six months and an additional 10 per cent for the energy required from breast feeding as half of energy requirements for the following year. Thus the percentages of the population aged 0-4 are each multiplied by 0.8 (Table 3.7). These new conversion

[49] This difference would have a much larger effect for the aggregate economy than for an individual family where the difference would be a third of the energy cost of supporting a toddler.

factors will be applied in the next section when converting calories per capita to calories per consuming unit.

Table 3.7: Calculation of adjusted conversion factors for men and women, 1700 – 1909-13

		Age					Total Conversion Factor
		0-4	5-14	15-24	25-59	>60	
	Calories Required as % of Adult Male (20-39):						
(1)	New Male	0.4413	0.8050	1.0084	0.9400	0.7500	
(2)	New Female	0.4367	0.7334	0.7583	---	0.5500	
(3)	New Average	0.4390	0.7692	0.8834	---	0.6500	
	1700:						
(4)	Person as % of pop	9.82%	19.81%	16.35%	42.18%	9.38%	
(5)	New Calories Required	0.0431	0.1524	0.1444	0.3723	0.0610	0.7732
	1750:						
(6)	Person as % of pop	10.09%	20.30%	17.47%	41.39%	8.22%	
(7)	New Calories Required	0.0443	0.1561	0.1543	0.3659	0.0534	0.7741
	1800:						
(8)	Person as % of pop	11.46%	23.09%	17.73%	37.60%	7.26%	
(9)	New Calories Required	0.0503	0.1776	0.1566	0.3350	0.0472	0.7667
	1850:						
(10)	Person as % of pop	10.48%	22.34%	19.10%	39.14%	7.32%	
(11)	New Calories Required	0.0460	0.1718	0.1687	0.3480	0.0476	0.7821
	1909-13:						
(12)	Person as % of pop	8.55%	19.95%	18.05%	43.27%	8.04%	
(13)	New Calories Required	0.0375	0.1535	0.1594	0.3804	0.0523	0.7831

Notes: Consuming unit equivalent for women aged 25-59 taken from Table 3.5 and applied in each year individually.

Sources: Floud *et al.*, *Changing Body*, p. 166.

3.4 Results: Accounting for the Costs of Digestion, Pregnancy and Lactation

The results of the digestion, pregnancy and lactation adjustments are quite striking and will be presented in turn below. Table 3.8 displays the digestion cost adjustments for cereal and meat in comparison with Floud *et al.*'s figures derived from the yield estimates of Chartres, Holderness, and Allen (CHA) and Turner, Beckett, and Afton (TBA). These adjustments reduce the calories available per capita by 283 calories to 1,946 calories per capita per day in 1700, a 12.7 per cent decrease, but the decrease is much smaller in 1909-13 at only 4.9 per cent. The trends over time have also changed slightly. Rather than seeing a strong decline in calories per capita between 1750 and 1800, the adjusted figures show a more stagnant trend followed by a small or moderate increase between 1800 and 1850 depending on the yield series utilized. These figures will be converted into calories per consuming unit at the end of the section. Clearly, digestion costs matter in energy cost accounting and need to be considered when calculating the calories that were available to a historical population.

It should be noted that while the switch from household to whiter loaves may have decreased the digestion costs for consuming foods, it could have had a detrimental effect on the nutritional value of people's diets. For instance, although roller milling was a significant advancement in whitening wheat flour by removing bran and germ, by removing the germ, it also decreased the amounts of vitamins B_1 and B_3 and iron in the bread.[50] In addition, recent work by Horrell and Oxley suggests that oats and rye bread were the most nutritious forms of bread in terms of micronutrients, followed by barley bread and wheaten brown bread. White wheaten bread had the lowest nutritional value.[51] Thus, although the digestion costs suggested here would have lowered the calories available to northerners and Welshmen who subsisted on oats and barley more than southerners who shifted to white wheaten bread earlier, northerners may still have had a better diet.[52] This difference was exasperated by the higher milk consumption in the North than in the South. In fact, Horrell and Oxley have shown that people born in the southern counties were shorter and thus less healthy than their northern counterparts in the early nineteenth century.[53]

[50] Drummond and Wilbraham, *Englishman's Food*, pp. 388-90.
[51] Horrell and Oxley, 'Bringing', pp. 1360-62.
[52] Collins, 'Dietary Change', p. 105.
[53] Horrell and Oxley, 'Bringing', pp. 1363, 1366-74.

Table 3.8: Calculation of new calorie per capita figures adjusted for digestion and consumption costs.

A. Crop Yields from Chartres, Holderness, and Allen											
	Kcal per capita per day Floud, *et al.*					Digestion Cost Adjusted		New Totals and Comparison			
Year	Cereals	Fish	Fruit and Veg	Meat and Dairy	Other	Adjusted Cereal	Adjusted Meat and Dairy	Adjusted Total	Floud, et al. Total	Calorie Difference	Percentage Difference
1700	1,461	24	167	538	39	1,213.03	502.71	1,945.74	2,229.00	283.26	12.71%
1750	1,246	24	189	786	83	1,039.84	732.07	2,067.91	2,328.00	260.09	11.17%
1800	1,382	24	247	708	113	1,176.77	660.01	2,220.78	2,474.00	253.22	10.24%
1850	1,396	24	338	599	147	1,221.80	558.77	2,289.57	2,504.00	214.43	8.56%
1909-13	999	32	476	1,075	395	924.22	1,004.89	2,832.11	2,977.00	144.89	4.87%

B. Crop Yields from Turner, Beckett, and Afton											
	Kcal per capita per day Floud, *et al.*					Digestion Cost Adjusted		New Totals and Comparison			
Year	Cereals	Fish	Fruit and Veg	Meat and Dairy	Other	Adjusted Cereal	Adjusted Meat and Dairy	Adjusted Total	Floud, et al. Total	Calorie Difference	Percentage Difference
1700	1,461	24	167	538	39	1,213.03	502.71	1,945.74	2,229.00	283.26	12.71%
1750	1,453	24	169	786	83	1,208.60	732.07	2,216.67	2,515.00	298.33	11.86%
1800	1,363	24	231	708	113	1,160.72	660.01	2,188.73	2,439.00	250.27	10.26%
1850	1,437	24	338	599	147	1,256.02	558.77	2,323.78	2,545.00	221.22	8.69%
1909-13	999	32	476	1,075	395	924.22	1,004.89	2,832.11	2,977.00	144.89	4.87%

Notes: The 1750 cereal calories per capita have been corrected from the original to reflect an arithmetic error in calculating the total calories from wheat production.

Sources: Floud *et al.*, *Changing Body*, p. 161, tables D.2, D.3, D.4, D.5, D.7, D.8, D.16; for cereal adjustment see text and sources for table 3.1; meat adjustment calculated from meat nutrition facts from nutritiondata.self.com; NME to ME ratios calculated using FAO, 'Food Energy', p. 29.

Shifting to pregnancy and lactation costs, after having adjusted the energy requirement ratios above, it is now possible to re-estimate the amount of food energy available in the economy. First, the energy requirement ratios for men and women in the different age groupings are averaged (table 3.7). This average ratio is multiplied by the percentage of the population falling in that age grouping. These new ratios are summed up to yield a conversion factor to convert calories per capita into calories per consuming unit. We can then substitute these new conversions factors and estimate new figures of calories available per consuming unit for both series of kcal/capita/day that Floud *et al.* calculate (Table 3.9). What is noticeable is how little the figures have changed when incorporating pregnancy and lactation costs. Before 1800 the energy available to consuming units per day is only 70 kcal lower or about 2 per cent. These figures are higher later, but the food energy available had also increased. The mean percentage decrease in the figures was 2.47 per cent. As a robustness check, the figures were recalculated with a weaning age at two years, but this only raised the downward adjustment to 2.75 per cent. This suggests that pregnancy may not have been as much of a burden on the energy requirements of societies as some historians (myself included) might have thought.

Pregnancy and lactation costs were low because although they added substantial energy costs to individual women, in aggregate only 6 to 7 per cent of women (of all ages) were pregnant and only 8 to 9 per cent of women were breast-feeding at any given time. These figures were low enough to make the aggregate energy cost marginal. Obviously, women were not able to spread the energy requirements of pregnancy and lactation among themselves, so pregnancy and lactation could have had burdensome cyclical effects on women's energy requirements. The 675 additional kcal/day required during the first six months of breast-feeding and the 475 kcal/day needed in the final trimester of pregnancy compare well with the nearly 1000 kcal/day required to move from light activity to hard manual labour. Pregnancy and breast-feeding had high-energy requirements.

Table 3.9: Calculation of calories available per consuming unit per day with Floud *et al.*'s conversion factors and the new conversion factors

A. Crop Yields from Chartres, Holderness, and Allen							
Year	Floud et al. Calories per Capita	Floud et al. Conversion Factor	Adjusted Conversion Factor	Floud et al. Calories per Consuming Unit (kcal/day)	Adjusted Calories per Consuming Unit (kcal/day)	Adjustment Difference (kcal/day)	Adjustment Difference (per cent)
				(1) / (2)	(1) / (3)	(4) - (5)	(6) / (4)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1700	2,229	0.7553	0.7732	2,951.15	2,882.69	68.46	2.32%
1750	2,584	0.7564	0.7741	3,416.18	3,337.92	78.26	2.29%
1800	2,472	0.7506	0.7667	3,293.37	3,224.31	69.06	2.10%
1850	2,504	0.7564	0.7821	3,310.42	3,201.54	108.88	3.29%
1909-13	2,977	0.7646	0.7831	3,893.54	3,801.35	92.19	2.37%
						mean	2.47%

B. Crop Yields from Turner, Beckett, and Afton							
Year	Floud et al. Calories per Capita	Floud et al. Conversion Factor	Adjusted Conversion Factor	Floud et al. Calories per Consuming Unit (kcal/day)	Adjusted Calories per Consuming Unit (kcal/day)	Adjustment Difference (kcal/day)	Adjustment Difference (per cent)
				(1) / (2)	(1) / (3)	(4) - (5)	(6) / (4)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1700	2,229	0.7553	0.7732	2,951.15	2,882.69	68.46	2.32%
1750	2,515	0.7564	0.7741	3,324.96	3,248.79	76.17	2.29%
1800	2,439	0.7506	0.7667	3,249.40	3,181.26	68.14	2.10%
1850	2,544	0.7564	0.7821	3,363.30	3,252.68	110.62	3.29%
1909-13	2,977	0.7646	0.7831	3,893.54	3,801.35	92.19	2.37%
						mean	2.47%

Sources: Floud *et al.*, *Changing Body*, p. 167 with 1750 cereal correction.

The cyclical nature of women's energy requirements highlights something that historians have not yet captured about household budgets: the flexibility in household allocation over time. How quickly was the household allocation of food and other resources changed during the pregnancy cycle? Where did the additional resources required by the mother come from: the father, other children, poor relief? Of course the cycle was further amplified by the loss in women's productivity in the third trimester of pregnancy and during nursing. This likely led women over time to wean their children earlier so that they could return to the labour market. These questions were clearly in contemporaries' minds as promoting breast-feeding was an important part of the reform movement's attempts to tackle high infant mortality at the start of the twentieth century. [54]

The final figures of calories per consuming unit adjusted for both digestion and pregnancy and lactation costs are shown in table 3.10 below. With both the digestion cost and pregnancy/lactation adjustments the adjusted figures are a full 14.7 per cent lower in 1700 than those that Floud *et al.* calculated. This had diminished to 7.11 per cent by 1909-13 but there were still 277 fewer calories per consuming unit than Floud *et al.* calculated. In 1700 the average calories per consuming unit was less than the 2,880 kcal/day FAO recommended daily energy requirement for light activity. In fact, the average calories per consuming unit did not substantially pass this level until 1850 and really only in 1909-13. This suggests that food was not as prevalent in the English economy as Floud *et al.* argued even without accounting for distributional effects.[55] The trends in energy available are also substantially different than Floud *et al.*'s original figures would suggest (Figure 3.1). When the CHA yields are used, there is steady growth in calories per consuming unit from 1700 to 1800, with relative stagnation between 1800 and 1850. With the TBA yields, the greatest gain in calories takes place between 1700 and 1750 with relative stagnation between

[54] Woods, *Demography*, pp. 284-9.
[55] Floud *et al.*, *Changing Body*, p. 168.

1750 and 1850.[56] However, both estimates show a great increase in calories per consuming unit between 1850 and 1909-13.

Table 3.10: Comparison of Floud *et al.*'s Calories per Consuming Unit Figures with Digestion and Pregnancy/Lactation Cost Adjusted Figures.

A. Crop Yields from Chartres, Holderness, and Allen						
Year	Digestion Adjusted Calories per Capita (kcal/day)	Pregnancy/ Lactation Adjusted Conversion Factor	Adjusted Calories per Consuming Unit (kcal/day)	Floud, *et al.* Calories per Consuming Unit (kcal/day)	Calorie Difference	Percentage Difference
1700	1,945.74	0.7732	2,516.36	2,951	434.64	14.73%
1750	2,067.91	0.7741	2,671.26	2,776	104.74	3.77%
1800	2,220.78	0.7667	2,896.63	3,293	396.37	12.04%
1850	2,289.57	0.7821	2,927.37	3,311	383.63	11.59%
1909-13	2,832.11	0.7831	3,616.34	3,893	276.66	7.11%

B. Crop Yields from Turner, Beckett, and Afton						
Year	Digestion Adjusted Calories per Capita (kcal/day)	Pregnancy/ Lactation Adjusted Conversion Factor	Adjusted Calories per Consuming Unit (kcal/day)	Floud, *et al.* Calories per Consuming Unit (kcal/day)	Calorie Difference	Percentage Difference
1700	1,945.74	0.7732	2,516.36	2,951	434.64	14.73%
1750	2,216.67	0.7741	2,863.42	2,957	93.58	3.16%
1800	2,188.73	0.7667	2,854.83	3,249	394.17	12.13%
1850	2,323.78	0.7821	2,971.12	3,363	391.88	11.65%
1909-13	2,832.11	0.7831	3,616.34	3,893	276.66	7.11%

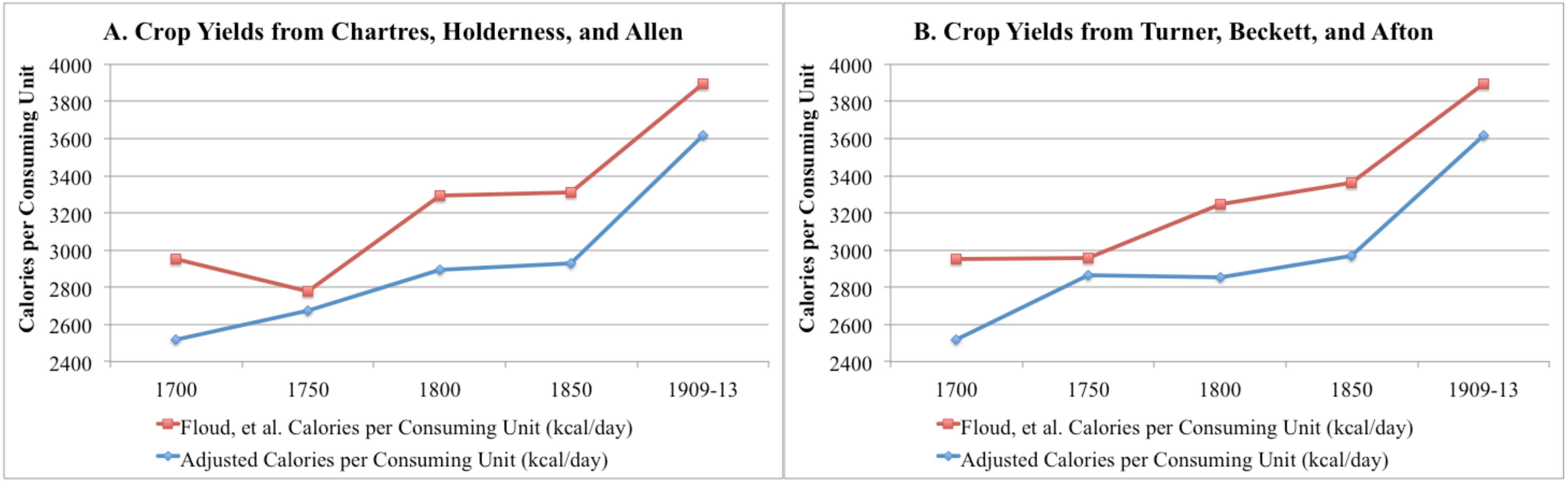
Sources: see sources for other tables; Floud *et al.*, *Changing Body*, p. 167.

3.5 Robustness Checks: Digestion, Pregnancy and Lactation Costs with Other Calorie Estimates

As mentioned above, there are a wide range of calorie estimates and Floud *et al.*'s estimates fall toward the lower middle end of existing figures. Thus, it is

[56] This is also driven by the correction of an arithmetic error when calculating total calories available from wheat in 1750 in Floud *et al.* Thanks to Deborah Oxley for pointing this out.

Figure 3.1: Comparison of Floud *et al.*'s original figures with the adjusted figures.



Sources: see table 3.8.

worthwhile to think about how these adjustments would affect the other authors' estimates. I will focus on Muldrew's figures since they are the highest figures and after the adjustments suggested by Kelly and Ó Gráda reflect a plausible upper bound of potential energy availability.

Determining digestion costs for Muldrew's higher estimates is a bit more difficult than merely subtracting the same percentage of the total unadjusted figure because the balance of cereals in Muldrew's figures is different. The tables and calculations showing the adjustment of Muldrew's figures could not be included in the paper because of length, but in the end the percentage difference in Muldrew's figures is approximately similar to Floud *et al.*'s. There was a decrease in calories from grains of around 15 per cent and a total decrease in calories from all foods of approximately 13 per cent from 1700-1800. Of course despite these declines, Muldrew's figures are still roughly 1,200 kcal/person/day higher than Floud *et al.*'s figures in 1700 and 1800. However, if Kelly and Ó Gráda's adjustments are also included the gap between Muldrew and Floud *et al.*'s digestion adjusted figures closes to 720 kcal/person/day in 1800. Thus, although there is a range of possible figures, accounting for the cost of digestion reduces estimates of calorie consumption by at least 12 per cent before the Industrial Revolution with the gap closing as people switched from eating rye, barley and oats to wheat bread and from brown wheat bread to fine wheat bread across the nineteenth century. The adjustment for the costs of pregnancy and lactation is separate from the agricultural output calculations, so the decline would be the same for Muldrew and the others' figures.

Applying both the digestion and pregnancy and lactation cost adjustments, Muldrew's figures are still much higher than the Floud *et al.* adjusted figures. Thus, the 14.7 per cent downward adjustment would not have pushed the English population below the 2,880 kcal/day threshold for light work. However, if Muldrew's figures are adjusted as Kelly and Ó Gráda suggest, the 14 per cent downward shift would certainly further limit the industriousness of the English population: Muldrew's figures of 6,672 and 5,298 kcal/consuming unit/day in 1770 and 1800 respectively decline to 4,473 and 3,839 kcal/consuming unit/day respectively. Thus, plausibly adjusted figures for 1800 range from Floud *et al.*'s 2,855 kcal/consuming unit/day to Muldrew's 3,839 kcal/consuming unit/day. In order to narrow the range of possible consumption figures, more work is needed similar to Kelly and Ó Gráda and Meredith and Oxley's work in questioning the assumptions in the different estimates and providing new, better assumptions that bring us closer to a true population calorie consumption estimate.

3.6 Conclusion

In the end, incorporating digestion costs and to a lesser extent pregnancy and lactation costs reveals a more pessimistic story of nutrition in England over the past 300 years than Floud *et al*., Muldrew, and the others have told. These additional burdens on the population reduced the calories available for human energy by around 15 per cent in 1700, suggesting that the population was much closer to the subsistence margin with the resulting poorer health and lower productivity than previously thought. However, the adjustment was smaller in 1909-13, about 7 per cent, because diets had become more refined and varied, reducing digestion costs.

Drawing interpretations from the adjusted series is difficult because the level of calories available varies based on which estimates are taken to be most reliable. Even when potential errors are removed from Muldrew's estimates there is a 1,000 kcal/consuming unit/day difference between the adjusted Floud *et al*. and Muldrew figures. If we accept Muldrew's figures, then there was substantial room in preindustrial England for an industrious revolution where people worked harder in order to purchase new consumer products.[57] However, the adjusted Floud *et al.* figures suggest a level of energy intake that almost certainly could not have supported an industrious revolution. Calorie consumption did not substantially exceed the 2,880 kcal/day threshold for light work until the 1909-13 benchmark.

The trend in calorie availability also changes when the digestion and pregnancy and lactation costs are included. Floud *et al.*'s original argument that the increase in calorie availability between 1750 and 1800 was in large part responsible for the increase in adult male heights and the decline in adult mortality over the same period becomes difficult to defend because in the adjusted figures, the growth between 1750 and 1800 largely disappears.[58] Relatively stagnant growth in the calories available to the population from 1750 to 1850 also strengthens the pessimists claims in the British standard of living debate. British workers were clearly not able to enjoy more plentiful diets during the Industrial Revolution. Stagnant calorie growth also suggests that changes in the capacity for human work effort were relatively unimportant in the Industrial Revolution and the beginnings of modern economic growth.[59] The evidence is more partial toward Wrigley's argument that modern economic growth was caused by a transition from an organic economy where energy was derived from working muscle (human or otherwise) to an 'energy-intensive mineral-based economy' where inorganic sources of energy drove output growth.[60]

Assuming that Floud *et al.*'s figures were most accurate, incorporating the costs of digestion, pregnancy and lactation into the energy cost accounting

[57] Muldrew, *Food*; de Vries, *Industrious Revolution*.
[58] The disappearance of growth from 1750-1800 also reflects the mistake in wheat yields mentioned above. Floud *et al.*, *Changing Body*, pp. 162-3.
[59] Harley, 'Reassessing', pp. 192-6.
[60] Wrigley, *Energy*, pp. 21-5.

methodology suggests that for a large percentage of the British population, hunger may well have been inescapable until the early twentieth century. Although significant mortality from famines disappeared from England before the period considered by this paper, the English population was in a state of chronic undernourishment visible in their short statures and high mortality rates.[61] This undernourishment persisted, despite productivity gains in agriculture and low fertility, until two key factors changed in the late nineteenth century: the Industrial Revolution and modern economic growth increased British income dramatically; and better transport infrastructure enabled the British to import the majority of their food.[62]

[61] Floud *et al.*, *Changing Body*, pp. 134-51; Kelly and Ó Gráda, 'Poor Law'.

[62] British food imports tripled from 555 kcal/capita/day in 1850 to 1,718 kcal/capita/day in 1909-13, an increase from 21.8 per cent of daily consumption in 1850 to 57.7 per cent of daily consumption in 1909-13. Floud *et al.*, *Changing Body*, pp. 158-60.

PART III:

CHILDREN'S GROWTH AS A MEASURE OF LIVING STANDARDS AND HEALTH

Chapter Four:

Children's Growth in an Adaptive Framework: The Case of American Slaves and Beyond

Human growth is an extremely complex process driven by both genetic inheritance and epigenetic adaptation to environmental conditions. For instance, it is influenced by parental growth patterns, the pelvis size of the mother, maternal health and nutrition during pregnancy, morbidity and infection, physical exertion, elevation, and exposure to cold environments. Human biologists, anthropologists, economists and anthropometric historians have tended to treat these inherited and environmental factors as intrinsically separate. Because environmental factors explained more of the variation in mean heights than genetic differences within a like population under good nutritional and disease environments, these scholars mostly ignored genetic or inherited influences on height to focus on the effects of varying environmental conditions on nutritional status.[1] This omission may be a useful heuristic device in studying variation in adult stature, but it seriously oversimplifies the complex

[1] See for instance Stinson, 'Growth Variation', p. 456; Silventoinen *et al.*, 'Genetic Regulation', p. 292.

interactions between environmental, genetic, and other inherited characteristics and their influence on prenatal, infant, childhood, and adolescent growth.

In order to understand these interactions, we must begin considering adaptive models of prenatal and postnatal growth. Within an adaptive framework, it is possible to understand how environmental conditions trigger certain genetically and epigenetically encoded life strategies, which, in turn, affect final height, longevity, and morbidity throughout the life cycle. An adaptive framework for growth can also help historians to make sense of the incredibly varied patterns of growth in historical populations. For instance, it can help explain why the timing of the pubertal growth spurt varies widely across populations and why some groups of children experience catch-up growth when others do not.

In this chapter, I will first introduce the adaptive framework for understanding children's growth and then apply this framework to the 'peculiar' pattern of slave children's growth in antebellum America and the Caribbean. Later, I will draw on secondary literature to develop three stylized facts about children's growth patterns in the past and use these stylized facts to interpret the growth patterns of eleven groups of boys and girls. The adaptive framework of growth points toward four important issues, which should form the basis for additional and continued research on children's growth. It highlights the importance of the nutritional environment *in utero* and maternal health for later growth; the deleterious consequences of mismatches between the prenatal and postnatal environment; the critical role morbidity may play in shaping children's growth; and the different ways in which girls and boys may adapt their growth to similar environmental conditions.

4.1 Children's Growth in an Adaptive Framework

4.1.1 Background in Evolutionary Biology

Before delving into the adaptive models of children's growth in detail, it is first necessary to explain the theoretical underpinnings in evolutionary biology for understanding growth in an adaptive framework. The theory of evolution has undergone several modifications since Darwin first published his famous work *On the Origin of the Species* in 1859. According to Darwin's original formulation, individuals in a population who were better adapted for the environment in which they lived had a better chance of surviving to reproductive age than those who were not as well adapted. Through natural selection, the continued survival and reproduction of those best fit for the environment allowed a species to evolve.[2] The problem with Darwin's original conception, though, was that there was no defined way by which characteristics were passed from one generation to the next. With the rediscovery of Mendelian genetics and further elaboration and discovery of what genes were and how they worked, a new Modern Synthesis arose in evolutionary biology. The Modern Synthesis redefined the theory of evolution in purely genetic terms as the change in gene frequencies from one generation to the next within a population. Because genes encoded the many physical characteristics (phenotypes) that were selected through the process of natural selection, a bias toward certain combinations of genes in subsequent generations led to changes in the phenotypes expressed in the population. This Modern Synthesis has been the dominant theory in evolutionary biology for over fifty years, but in the past fifteen years, a growing

[2] Darwin, *The Origin of Species*, pp. 5-6.

number of evolutionary biologists have begun to realize that the Modern Synthesis may need to be expanded.[3]

There are two important ideas in the new conception of the Modern Synthesis, called the Extended Evolutionary Synthesis, that are important fundamental concepts for this paper. First, contrary to the main tenant of the Modern Synthesis, phenotypes are determined by much more than the genotype, the genetic blueprint. There is a complex system of epigenetic processes—epigenetic means literally 'above the genome'—that regulates gene expression, in part based on environmental factors.[4] As Jablonka and Lamb describe, the DNA and genes form the musical score of the body's functioning, but the epigenetic mechanisms serve as the musicians and conductor, who interpret the score for themselves. Therefore, the phenotype that is produced in the end is the combination of the genes present and the way the genes are expressed through epigenetic processes.[5] These epigenetic processes are important in the development of different tissue cells during embryogenesis and the foetal period and can also help shape the foetus based on environmental conditions in the womb.[6]

The second concept, phenotypic plasticity, is the ability of an organism to make 'an environmentally based change in the phenotype'.[7] Phenotypic plasticity occurs most commonly during early development when the growing foetus can change its physiology in response to environmental conditions.[8] Epigenetic mechanisms play a prominent role in phenotypic plasticity because they expand the

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[3] Pigliucci, 'Do We Need an Extended Evolutionary Synthesis?', pp. 2744; Jablonka and Lamb, *Evolution*, pp. 1-2, 272-74.

[4] Wolffe and Matzke, 'Epigenetics', pp. 481-2; Dolinoy and Jirtle, 'Environmental Epigenomics', p. 4; Jirtle and Skinner, 'Environmental Epigenomics', pp. 253-54; Feinberg, 'Phenotypic Plasticity', p. 433; Jablonka and Lamb, *Evolution*, pp. 137-45.

[5] Jablonka and Lamb, *Evolution*, p. 245; Feinberg, 'Phenotypic Plasticity', p. 438.

[6] Jirtle and Skinner, 'Environmental Epigenomics', p. 253; Doniloy and Jirtle, 'Enivironmental Epigenomics', p. 4-5; Gluckman and Hanson, 'Consequences', pp. 6-8; Gluckman and Hanson, 'Evolution', pp. 8-9; Gluckman et al., 'Environmental Influences', pp. 672-3.

[7] Via et al., 'Adaptive Phenotypic Plasticity', p. 212.

[8] Feinberg, 'Phenotypic Plasticity', p. 438; Dolinoy and Jirtle, 'Environmental Epigenomics', p. 5.

range of phenotypes that can be expressed by the genotype. In other words, the outcome of our musical analogy above is not one single symphony, based on the genotype, but millions of different symphonies, changed by the different concert halls in which they are performed (environmental factors) and the musical abilities and sensibilities of the conductor and musicians (epigenetic mechanisms).[9]

Two final important concepts, though not really a part of the Extended Evolutionary Synthesis, are immediate and predictive functional adaptations. Functional adaptations are adaptations that improve an organism's fitness or functional viability[10] within a specific environment during an organism's lifetime and therefore encompass most of the responses of phenotypic plasticity.[11] Immediate adaptations confer immediate functional benefit to the organism but could have long-term costs for fitness later in life. Predictive adaptive responses attempt to align the organism's physiology with later environmental conditions, conferring long-term advantages, but not necessarily improving the immediate fitness of the organism.[12] Whether adaptations confer improved fitness to the organism in both the short and long run is not an absolute but a relative calculation.[13] The adaptive frameworks presented in this paper improve human fitness, but they also have some negative long-term consequences. These three evolutionary concepts, epigenetic mechanisms, phenotypic plasticity, and functional adaptations, are crucial to the adaptive frameworks of prenatal and postnatal growth that follow.

[9] Jablonka and Lamb, *Evolution*, p. 245.
[10] Fitness is defined as surviving to reproductive age and producing viable offspring.
[11] Frisancho, *Human Adaptation*, pp. 4-5; Huss-Ashmore, 'Theory', pp. 13-15.
[12] Gluckman et al., 'Environmental Influences', p. 672.
[13] Stinson, 'Nutritional Adaptation', p. 161.

4.1.2 Prenatal Growth in an Adaptive Framework

There has been growing evidence in the past decade that conditions in the prenatal period are extremely important to growth and health later in life. Barker initiated much research and debate when he published his hypothesis in 1990, sometimes known as the 'early origins hypothesis' or 'foetal programming', suggesting that foetuses limit their growth and permanently change their physiology and metabolism based on the availability of nutrients in the womb. Barker further argued that these physiological and metabolic changes could be responsible for higher incidences of coronary heart disease, hypertension, stroke, and diabetes among low birth weight children later in life.[14] Since then, there has been a tremendous amount of scholarship published attempting to explain the detailed mechanisms of foetal programming, the ways nutrients reach the foetus in the womb, and the consequences of low birth weight for longevity, height and morbidity in later life.

The complex and varied results of this research agenda allowed Gluckman and Hanson to place Barker's Hypothesis in an adaptive framework. They argued that there are three ways of interpreting a foetus's response to poor environmental conditions in the womb. First, if nutrient conditions in the womb are extremely dire, the foetus could experience developmental disruption, which is not adaptive and can lead to severe birth defects.[15] Second, an immediate adaptive delay in growth might allow the foetus to survive a nutritional insult that would have killed it if it did not curtail its growth. Third, low nutrient levels in the womb could trigger a predictive adaptive response in the growing foetus where nutrient conditions *in utero* are taken to be a good prediction of future conditions and the growth, metabolism, and physiology of the foetus are adapted to best fit that predicted environment. In other

[14] Barker, 'Fetal and Infant Origins', p. 1111; Barker, 'Maternal Nutrition', pp. 807, 812.
[15] Gluckman et al., 'Environmental Influences', p. 672.

words, if a foetus is undernourished in the womb, epigenetic and hormonal processes programme it to be able to survive better in a postnatal environment with limited nutrients. This programming includes a shorter stature that requires fewer calories to survive, faster maturation and an earlier age at menarche so that the foetus reaches reproductive viability early and has a better chance of reproducing before it dies.[16]

The predictive adaptive theory is further strengthened by phenotypic plasticity, which allows for the broad range of phenotypes that develop in response to different intrauterine environments.[17] Phenotypic plasticity is greatest during the embryonic and foetal period of a child's development because DNA is being replicated at a very high rate—the cells are dividing very quickly to facilitate growth—and because epigenetic processes that shape the foetus based on the surrounding nutritional environment are established in early development. However, phenotypic plasticity declines throughout the intrauterine development process and postnatal growth.[18] There is therefore an important difference between prenatal predictive adaptations and later, postnatal immediate adaptive stunting in response to poor environmental conditions: a prenatal predictive adaptive response is long lasting if not entirely permanent whereas postnatal stunting is a temporary adaptive mechanism to deal with a poor nutritional or disease environment.[19] This prenatal adaptive framework serves as a starting point for studying the environmental, hormonal, genetic, and epigenetic influences on prenatal growth as well as long-term effects of this trade-off for the developing organism.

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[16] Gluckman and Hanson, 'Consequences', pp. 6-8; Gluckman and Hanson, 'Evolution', pp. 8-9; Gluckman et al., 'Environmental Influences', pp. 672-4; Godfrey, et al., 'Epigenetic Mechanisms', pp. 5-7.

[17] Feinberg, 'Phenotypic Plasticity', p. 438.

[18] Dolinoy and Jirtle, 'Environmental Epigenomics', pp. 4-5.

[19] Gluckman and Hanson, 'Consequences', p. 11.

There are many factors that feature in limiting foetal growth in the prenatal period. Genetics plays a large role in the earliest stages of foetal development; there is evidence that mutations in the gene encoding insulin-like growth factor I (IGF-I) can affect the birth length and weight of a child and that genetic polymorphisms in genes affecting placenta formation can limit the nutrients available *in utero*. However, these genetic influences are soon displaced by environmental and hormonal factors in later intrauterine development.[20] Hormones play a critical role because they manage the development and growth of the foetus and serve 'as maturational and nutritional signals *in utero*'.[21] Hormone production and regulation are also sensitive to total energy intake and protein consumption, so good maternal nutrition is important to the proper regulation of growth by hormones like growth hormone (GH) and IGF-I.[22] Finally, maternal health and nutrition is extremely important. The mother serves as the supply chain for all the nutrients and oxygen that her child needs, so disruptions in the supply chain are detrimental to the child. In modern developing countries, one cause of disruption in the supply chain is the infection of the placenta with malaria.[23]

The mother's own nutrition and disease history and therefore her final height can also place limits upon the growth of the foetus. Through the process of 'maternal constraint', the mother can limit the amount of nutrients reaching the foetus through the placenta so that the foetus does not outgrow the dimensions of the womb and pelvic canal. Maternal constraint is therefore more active in shorter women who have smaller pelvic canals and prolongs the effects of stunting in a population: small

[20] Gicquel and Le Bouc, 'Hormonal Regulation', p. 28; Gluckman and Hanson, 'Consequences', p. 7; Dauncey and Pell, 'Genetic Regulation', p. 142.
[21] Gicquel and Le Bouc, 'Hormonal Regulation', p. 28.
[22] Dauncey and Pell, 'Genetic Regulation', pp. 142-43; Noguchi, 'Protein Nutrition', p. s241.
[23] Gluckman and Hanson, 'Consequences', p. 7; Moormann et al., 'Malaria and Pregnancy', pp. 1989-92.

women will have smaller babies, inhibiting potential increases in stature with improving socioeconomic conditions.[24]

There are several long-term consequences of either an immediate adaptive or predictive adaptive response by the foetus to nutritional deprivation in the prenatal period. Barker and others have found that low birth weight increased the prevalence of heart disease, stroke, and diabetes in later life. These diseases not only increase risks of early mortality but also keep the body from functioning normally, increasing basic energy requirements and decreasing growth velocity.[25] In addition, low birth weight has also been linked to cognitive impairments.[26] As mentioned above, a prenatal predictive response leading to stunting in the womb accelerates maturation, measured by age at menarche. This adaptive response increases the likelihood that the foetus will be able to reproduce before falling victim to poor environmental conditions.[27] Finally, a poor intrauterine nutritional environment leads to underdevelopment of the pancreas and other insulin supplying mechanisms, which govern metabolism, therefore giving the foetus some level of 'insulin resistance' and economizing energy consumption.[28]

Another consequence of the foetal predictive adaptive mechanism is that the foetus permanently changes its internal physiology, decreasing its final height potential. Karlberg and Luo found in a study of healthy, full-term Swedish babies that foetal size, measured as length at birth, along with the genetic height potential, measured as midparental height, played a strong role in defining the final height

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[24] Gluckman and Hanson, 'Consequences', p. 7.
[25] Barker, 'Maternal Health', pp. 811-12; Jirtle and Skinner, 'Environmental Epigenomics', p. 253; Doniloy and Jirtle, 'Environmental Epigenomics', pp. 4-5.
[26] Silventoinen *et al.*, 'Genetic Regulation', p. 292; Gluckman and Hanson, 'Consequences', p. 8.
[27] Gluckman and Hanson, 'Evolution', pp. 8-9.
[28] Gluckman *et al.*, 'Environmental Influences', pp. 673.

potential of the child.[29] In addition, Gluckman and Hanson discovered that sheep exposed to intrauterine undernutrition experienced less catch-up growth following a postnatal nutritional insult than sheep who had a normal, healthy prenatal environment. Gluckman and Hanson also found evidence that small birth weight children were less responsive to hormones signalling growth, i.e. insulin, GH and IGF-I, when these hormones were excreted at higher levels to spur catch-up growth following a nutritional insult; in other words, their catch-up growth happened more slowly and was smaller on an absolute scale than normal birth weight children.[30] Therefore, low birth weight children have lower final height potentials and do not respond to hormonal growth signalling in the same way as normal birth weight children.

Clearly, impaired prenatal growth can have many serious consequences for the postnatal life of the foetus, including increased risk of disease, cognitive impairment, earlier age of maturation, lower final height potential, and limits to normal growth mechanisms. However, these consequences, some more negative than others, do not preclude an adaptive framework from the prenatal predictive response. If the foetus predicts that its nutritional environment will be poor in its postnatal life, then limiting its body size so that it requires fewer calories and nutrients to survive is a beneficial response despite some of the negative consequences listed above. The problem arises when there is a 'mismatch' between the foetal predictive response and the actual conditions of the postnatal environment, for instance, a better nutritional environment in postnatal life. This mismatch could increase the risk of developing metabolic diseases, obesity and diabetes. However, significant long-term improvements in

[29] Karlberg and Luo, 'Foetal Size', pp. 632, 635-36.
[30] Gluckman and Hanson, 'Consequences', p. 8.

environmental conditions were rare at the time this trait evolved, so the prenatal predictive adaptive response was beneficial in its original context.[31]

4.1.3 Postnatal Growth in an Adaptive Perspective

Previous attempts to place postnatal growth stunting in a functionally adaptive perspective have been greeted with much scepticism and even outright disdain in the fields of anthropology and development economics. The most familiar argument is Sukhatme and Seckler's 'small but healthy' hypothesis. Sukhatme and Seckler argued that children responded to undernutrition by slowing their growth to minimize their basal metabolic needs but maintained the appropriate weights for their height. Most controversially, they argued this adaptive stunting had no adverse effects on the child's health.[32]

These arguments were justifiably criticised, especially their argument that this adaptation led to a healthy, homeostatic state for malnourished children. There is a wealth of evidence suggesting that the malnourished children that Sukhatme and Seckler would have considered healthy had higher rates of morbidity and mortality.[33] In addition, Waaler had published his analysis of Norwegian veterans, linking low weight and height with higher relative risk of mortality.[34] Finally, there was a general outcry that to accept this hypothesis would be tantamount to surrendering to the detrimental effects of disease and poverty rather than having the audacity to attempt to change them.[35] For all of these justifiable reasons, the 'small but healthy' hypothesis was rejected.

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[31] Gluckman and Hanson, 'Consequences', p. 10.
[32] Seckler, 'Small but Healthy', pp. 127-28; Sridhar, *Battle*, pp. 70-74.
[33] Sridhar, *Battle*, pp. 70-74; Schaible and Kaufmann, 'Malnutrition and Infection', pp. 806-7; Shetty, 'Malnutrition and Undernutrition', pp. 525-28.
[34] Fogel, *Escape from Hunger*, pp. 23-27.
[35] Sridhar, *Battle*, pp. 73-74.

However, it is too early to abandon the concept of an adaptive framework for postnatal growth stunting.[36] There are two potential adaptive frameworks for postnatal stunting in response to poor environmental conditions: an immediate adaptive response of limiting growth to minimize the basal metabolic rate and an immediate adaptive response of delaying the pubertal growth spurt and menarche in females in order to postpone sexual maturity. I will first describe these adaptive responses and then discuss how environmental and genetic factors may affect these responses.

The first immediate adaptive framework for postnatal stunting is admittedly speculative, and more evidence is needed to test and define the model further. The fundamental tenant of the framework is that the height potential and growth curve of an individual is based upon a mixture of his/her genotype and any phenotypic plasticity that takes place in the prenatal period mostly through epigenetic mechanisms. The height potential and growth curve then set limits on postnatal growth. In accordance with Sukhatme and Seckler's hypothesis, when faced with a nutritional or disease insult, the child slows or halts its growth until conditions improve. This is a beneficial adaptive response because the child limits increases to its basal metabolic rate that come with growth in order to conserve energy. However, a child who undergoes postnatal stunting is neither healthy nor normal. The child is at a higher risk of disease because malnourishment weakens the immune system, and the child is knocked off its genetically and epigenetically defined growth curve.[37]

If environmental conditions improve later, the child can experience catch-up growth. Boersma and Wit defined three types of catch-up growth. Type A catch-up growth is a period of rapid growth after a nutritional insult that attempts to bring the

[36] Stinson, 'Nutritional Adaptation', p. 161.
[37] Shetty, 'Malnutrition and Undernutrition', pp. 525-28; Schaible and Kaufmann, 'Malnutrition and Infection', pp. 806-7.

child back in line with its genetically and epigenetically defined growth curve. Type B catch-up growth does not involve growth at more rapid than normal levels. Instead, the growth period is extended longer than normal so that children can attain a higher height-for-age at the cessation of growth. Type C catch-up growth includes both type A and type B catch-up growth.[38] Catch-up growth occurs most commonly among children who are substantially below modern standards in terms of height-for-age and when the nutrition and the disease environment they are exposed to improves during the growing years. There also appears to be differences in the type of catch-up growth children who faced different forms of deprivation can achieve. It appears that all children who have suffered deprivation either *in utero* or in the postnatal period can achieve type A catch-up growth. However, several recent studies suggest that improving nutrition, health and type A catch-up growth in children who suffered malnutrition in both the prenatal and postnatal period may trigger earlier pubertal development, limiting the amount of type B catch-up growth children could achieve.[39] However, no matter what the type or circumstance, catch-up growth is also adaptive because it helps children attain their height potential and confers upon them the advantages of larger body size: greater productivity, health and self-defence.

In order to understand whether these adaptations are beneficial to the child, the costs of the trait must be measured, and it must be compared with alternate outcomes. Waaler's findings that shorter people are at a higher risk for old age morbidity and mortality have been cited as demonstrating the negative effects of postnatal stunting, but in light of Barker's findings and the vast amount of literature that has followed his original 1990 paper, it seems likely that the increased risk of morbidity and mortality for shorter people may be consequences of prenatal

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[38] Boersma and Wit, 'Catch-up Growth', pp. 647-648; Stinson, 'Growth Variation', pp. 451-452.
[39] Proos, 'Growth', pp. 647-649.

predictive adaptive responses.[40] This conclusion is supported by the rising percentage of deaths from cancer in WHO global mortality estimates, especially among wealthy nations, in relation to mortality associated with cardiovascular disease suggesting that prenatally programmed cardiovascular defects are decreasing with improved environmental conditions.[41] Despite this, there is strong evidence that infectious diseases and inflammation in the postnatal period compromise cardiovascular and other organ functioning.[42] However, before completely ruling out the adaptive nature of the response, one must consider the alternative to stunting in the face of a nutritional or disease insult: the child continues to grow in the poor environmental conditions and needs to consume more and more calories to continue growing. When these calories are not available, the child would be more susceptible to disease and begin to starve with horrible consequences. The stunted child would therefore have a higher relative level of fitness than the child who continued to grow.

A second adaptive framework for growth stunting in response to a poor nutritional and disease environment actually evolved as an adaptive trait for sexual maturation. Menarche in women usually occurs towards the end of the pubertal growth spurt. Despite the fact that menarche would be programmed to arrive earlier by a poor prenatal nutritional environment, Gluckman and Hanson have argued that menarche can be delayed during periods of poor nutrition in the postnatal environment. This was an immediate adaptive response by the female to postpone reproduction hoping that environmental conditions would improve before she incurred the high energetic cost of pregnancy.[43] It would also have the unintended consequence of delaying or slowing the pubertal growth spurt and lowering final adult

[40] Fogel, *Escape from Hunger*, pp. 23-27; Barker, 'Maternal Nutrition', pp. 807, 812; Barker, 'Fetal'.
[41] World Health Organization, *Global Burden*, pp. 11-13, 25.
[42] Crimmins and Finch, 'Infection', p. 501.
[43] Gluckman and Hanson, 'Evolution', p. 9.

height. These two adaptive responses provide a useful framework in which to understand environmental and genetic influences on height.

The most important environmental factors affecting growth are those that influence the energy and nutrient consumption of the child. In this sense, general food calorie consumption and a balanced diet are essential for maintaining the basal metabolic rate and sustaining growth. There are different negative effects from protein deficiencies and general shortfalls in dietary energy in part because growth hormones respond differently to each form of poor nutrition.[44]

However, other factors such as disease, work, and climate can also affect energy and nutrient consumption. Chronic undernutrition hinders the immune system, which requires significant energy to fight a disease. Even if a child were not particularly undernourished before contracting a disease, the immune response to the disease would raise his/her energy requirements so that the child must consume more food than before to stay alive and remain healthy.[45] In addition, diarrhoea can significantly decrease dietary energy and nutrient absorption further exacerbating the problems of malnutrition.[46] Child labour can also influence growth patterns because the child's physical activity level (PAL) will be higher if it is required to expend energy on work.[47] Finally, climate can also influence growth because if a child lives in a cooler climate, he/she will have to expend higher amounts of energy to maintain his/her body temperature during cold winters.[48] All of these environmental factors can trigger an immediate adaptive response and slow growth if they are sufficiently taxing upon the energy intake of the child.

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[44] Shetty, 'Malnutrition and Undernutrition', p. 524; Dauncey and Pell, 'Genetic Regulation', pp. 143-144; Noguchi, 'Protein Nutrition', p. s241.
[45] Schaible and Kaufman, 'Malnutrition and Infection', p. 806.
[46] Marino, 'Water', pp. 1930-32; Caulfield *et al.*, 'Undernutrition', p. 197.
[47] Steckel, 'Heights and Human Welfare', p. 10.
[48] Komlos, 'Anthropometric History', pp. 178-9.

Genetic influences on height are complex and poorly understood because the specific genetic mechanisms that drive growth have not been discovered. Silventoinen et al. found that genetic factors accounted for ninety percent of the variation in heights among affluent Caucasian people but that environmental factors accounted for a greater proportion of variation in height among non-affluent populations.[49] Historians, anthropologists, and economists have evaded the large degree of genetic influence by comparing mean heights of large representative samples of a population. This methodology is sound unless different ethnic groups have different genetic height potentials assuming they were exposed to similar environmental conditions. However, this does not appear to have been the case. Eveleth and Tanner and others have compared affluent populations from various ethnic groups to see whether their final heights and growth curves are similar. Europeans, Africans, Indo-Mediterraneans, and Native Americans tend to have similar growth curves and final heights while East Asians are slightly shorter in stature and experience an early pubertal growth spurt.[50] Thus, it is reasonable to compare heights of most populations, but judgements are best made in relative terms, comparing affluent and poorer subgroups within one population.

Clearly, genetic and environmental influences cannot be seen as separate spheres of influence on growth and final adult height. They are both a part of a wider evolutionary context. Adaptive mechanisms are built into human physiology to adapt to poor nutritional and disease conditions in both the prenatal and postnatal growth periods. Anthropometric historians can benefit from understanding the conditions that lead to evolutionary change and evaluating what the benefits and costs of any adaptation could be.

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[49] Silventoinen *et al.*, 'Genetic Regulation', p. 292; Stinson, 'Growth Variation', p. 456.

[50] Stinson, 'Growth Variation', pp. 454-57; Ulijaszek, 'Secular Trends', pp. 43-45; Eveleth and Tanner, *Worldwide Variation*, pp. 222-40.

4.2 Applying the Adaptive Framework: The Peculiar Growth Trajectory of Slaves in Antebellum America and the Caribbean

4.2.1 Background on the growth of slaves in the antebellum South

The previous section set out an adaptive framework for understanding children's growth and attempted to explain how some of these mechanisms might have worked. This section seeks to demonstrate the utility of this framework by using it to reinterpret the growth pattern of slaves in antebellum America and in the Caribbean. The analysis will build upon Steckel's original pioneering research as well as more recent debates about slave children's health.

Steckel was the first to study the heights of slave children and compare them with modern standards. To do this, he drew upon a large number of ship manifests created to monitor the coastwise slave trade after the Atlantic slave trade was abolished in 1807. Steckel found that slave children had extremely low birth weights and were very stunted in early life with males at 3.23 standard deviations below modern standards and females at 2.89 standard deviations below modern standards (recalculated according to 2006/7 WHO standards) at age 5.5. However, by the time that the slave children had stopped growing after age 21, the average child was only 0.81 and 0.67 standard deviations below modern growth standards for boys and girls respectively.[51] This is a massive gain in height relative to modern standards, much larger than any gain that has been measured for similarly deprived populations, including slave populations in the Caribbean analysed by Higman.[52] Steckel argues that the children began experiencing catch-up growth early in childhood, but most sustained catch-up growth occurred after age 16.5 for boys and 13.5 for girls.[53] Explaining the poor growth outcomes at younger ages and improving health outcomes

[51] Steckel, 'Peculiar Population', pp. 724-725. These Z-scores were calculated from the heights that Steckel reported using the WHO 2007 growth reference.
[52] Prentice *et al.*, 'Critical Windows', pp. 914-916; Higman, *Slave Populations*, pp. 534-535.
[53] Steckel, 'Peculiar Population', pp. 724-726.

by the time slaves reached adulthood has been more difficult. Steckel explained this ‘catch-up growth’ by arguing that slave owners had different incentives to invest in children versus adults. Until children could join the productive workforce, after approximately age 10, slave owners fed children low cost and low nutritional quality grains, only providing meat and protein for children after they started working the fields.[54] Steckel also points out that slave mortality rates after age 10 were relatively low and stable, suggesting that the catch-up growth after age 10 would not be influenced by survival bias.[55]

Pritchett and Freudenberger have argued that the slave heights in coastwise manifests were upwardly biased compared to the rest of the slave population because masters preferred to sell and ship taller slaves. This bias was especially prominent among the children in the slave manifest, but was not quite so important for adults.[56] However, Komlos and Alecke questioned Pritchett and Freudenberger’s claims by arguing that the insatiable demand for slaves in the ‘New South’, Louisiana and Mississippi, meant that traders did not have to be picky when selecting slaves to transport. In addition, slaves in Maryland were taller than the slaves in the coastwise manifest, so they argue there was no clear upward bias in the coastwise manifest.[57] Pritchett later argued that the incentives to ship taller slaves were strongest for young children and diminished with age.[58] This is confirmed by a later study, which showed that slave children shipped alone were taller than slave children shipped with their mothers.[59] Thus, it seems that the average height of slave children in the population

[54] Steckel, ‘Peculiar Population’, pp. 735-736.
[55] Steckel, ‘Peculiar Population’, pp. 732-733. However, higher mortality rates that declined sharply to the age of six suggest that some of the early catch-up, reported below, could be due to survival bias.
[56] Pritchett and Freudenberger, ‘A Peculiar Sample’, pp. 125-126.
[57] Komlos and Alecke, ‘Economics’, pp. 455-457.
[58] Pritchett, ‘Interregional Slave Trade’, pp. 83-85.
[59] Calomiris and Pritchett, ‘Preserving Slave Families’.

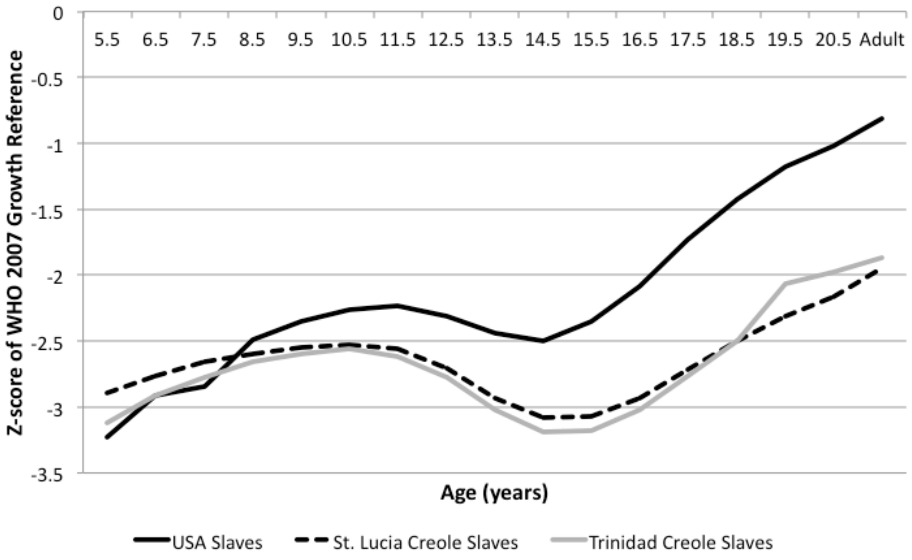
was lower than the figures that Steckel reports especially at younger ages. This means that Steckel underestimated the children's catch-up growth, which was even greater than what is reported above.[60]

Coelho and McGuire have also challenged Steckel's conclusions arguing that slave children's slow growth can be better explained by hookworm exposure rather than poor nutrition. They argue that because children were kept near slave quarters during the day and did not have good control over their bowels, they were at much higher risk of becoming infected with hookworm than adults who spent most of the time in the fields away from the unsanitary living quarters. Thus, when children began working around the age of ten, their exposure to hookworm and their hookworm burden decreased significantly, and they were able to attain high levels of catch-up growth. They estimated that hookworm could account for 31 per cent of the shortfall in children's heights.[61] Steckel challenged their claims in a response, arguing that they overestimated the effect of hookworm and that constant levels of childhood mortality among slaves aged seven and above suggest that improvements in the disease environment could not explain slave children's remarkable catch-up growth.[62]

Steckel's analysis is generally sound, but it should be pointed out that by using percentiles to understand growth trajectories, he is only able to describe the relative catch-up growth of the population not the absolute catch-up, which is best measured using a Z-score; this is because a population moving from the 1st percentile to the 2nd percentile of modern growth standards has made a much larger gain in absolute height than a population moving from the 49th percentile to the 50th percentile.[63] The

[60] Pritchett, 'Interregional Slave Trade', pp. 83-85; Bodenhorn *et al.*, 'Problems', pp. 29-33.
[61] Coelho and McGuire, 'Diets', pp. 239-241.
[62] Steckel, 'Diets', pp. 249-254.
[63] Wang *et al.*, 'Limitations', p. s180.

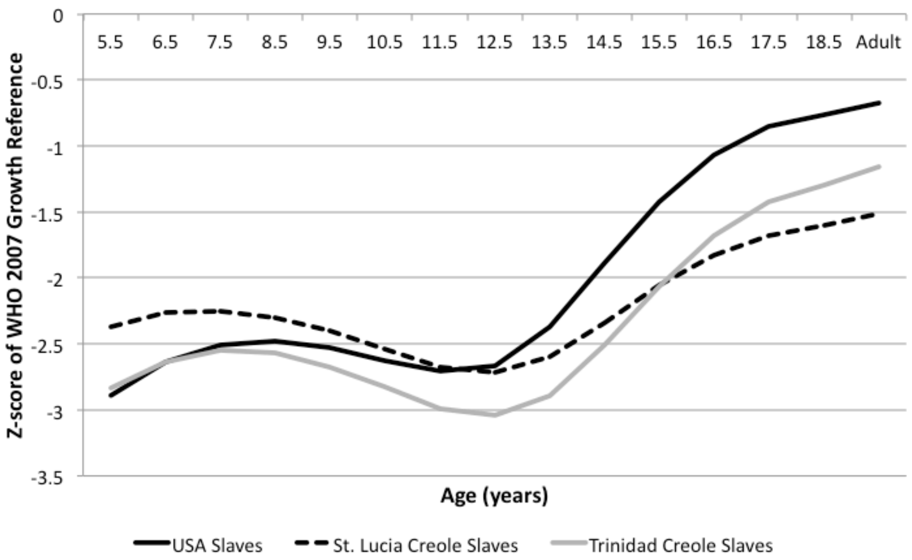
Figure 4.1: Heights of slave boys in the US and Caribbean reported as Z-scores of the WHO 2007 reference.



Notes: The Z-scores were calculated based on the WHO 2007 growth reference from the Preece-Baines smoothed figures reported in Steckel, 'Growth Depression'.

Sources: Steckel, 'Growth Depression', pp. 117, 122.

Figure 4.2: Heights of slave girls in the US and Caribbean reported as Z-scores of the WHO 2007 reference.



Notes and Sources: see figure 4.1.

difference between percentile change and Z-score change is important because it leads Steckel to understate the catch-up growth that occurs for American slaves before the age of 10 (figures 4.1 and 4.2). It also leads Steckel to be somewhat dismissive of the catch-up growth of slaves in the Caribbean when their catch-up was actually quite impressive.[64]

4.2.2 Slave children's growth in an adaptive framework

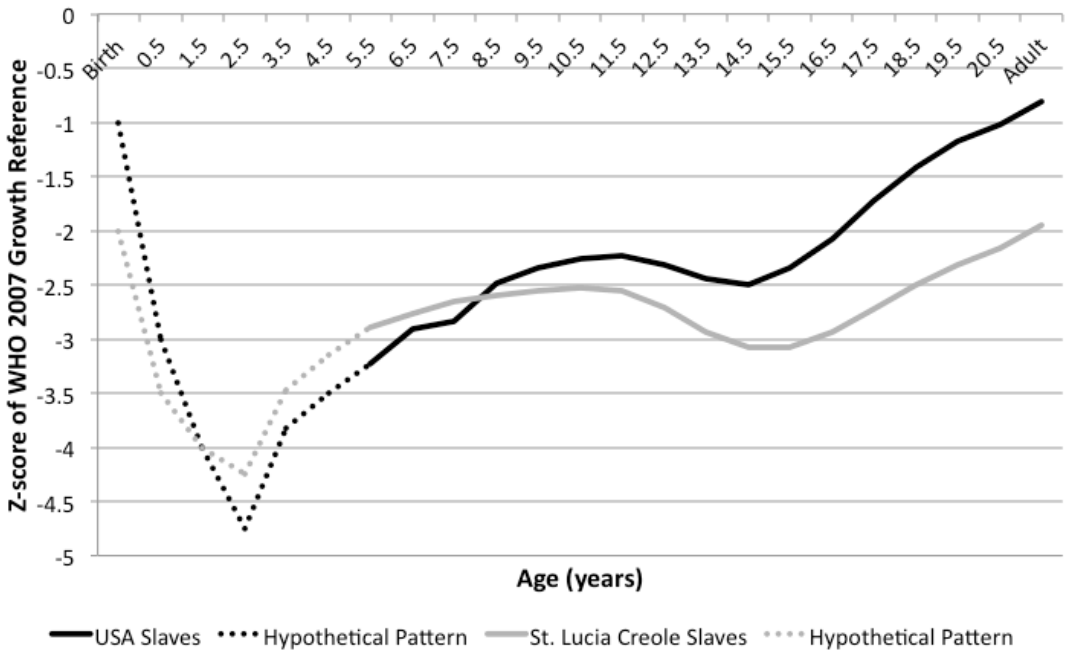
Although Steckel and Coelho and McGuire's arguments are interesting, there is quite an intriguing puzzle hidden in their extensive work. In another paper, Steckel argues that slaves had the lowest average birth weights of any population ever studied, yet American slaves experienced incredibly dramatic catch-up growth, managing to reach the 27th percentile of modern standards for height.[65] If Barker and Gluckman and Hanson's arguments that prenatal conditions are extremely important for future growth and may even trump catch-up growth are correct, then this is a real conundrum that needs to be solved, especially since modern populations with similar birth weights do not catch-up like the slaves did.

However, an interpretation of slave children's growth in an adaptive framework would better explain the pattern of growth that Steckel observes (see figure 4.3 for a schematic view). I will first present the framework for American slaves before also applying it to slaves in the Caribbean as a robustness check. The argument turns around one key revision of Steckel's research on slave health, namely that slave birth weights were not extremely low as he argued. Thus, the argument would follow that adult slave women had relatively good nutrition and health once they entered the labour force.[66] This ensured that the prenatal conditions in the womb were fairly good for the growing foetus, though obviously exposure to malaria, hookworm, and the strenuous labour slaves had to perform would have still made the conditions less than ideal. Thus, relatively good conditions *in utero* provoked a

[64] Steckel, 'Peculiar Population', p. 728; Higman, *Slave Populations*, pp. 534-535.
[65] Steckel, 'Birth Weights'.
[66] Steckel, 'Peculiar Population', pp. 736-740.

predictive adaptive response. Slave foetuses developed as if conditions in the postnatal period would closely mirror the conditions faced by their mothers in adulthood; they were programmed for a tall stature and a relatively high metabolism. However, after the children were born, they experienced a brutal mismatch between the prenatal and postnatal environment: conditions were far worse for the children in

Figure 4.3: Hypothetical and observed growth patterns of slave boys in the antebellum US South and the Caribbean



Notes: The Z-scores were calculated based on the WHO 2007 growth reference from the Preece-Baines smoothed figures reported in Steckel, 'Growth Depression'. Hypothetical growth trajectory predicted from adaptive framework (see text).

Sources: Steckel, 'Growth Depression', pp. 117, 122.

the postnatal period than the prenatal period. The combination of a high metabolism set in the prenatal period and poorer nutritional and disease conditions in the postnatal period took a striking toll on the children's health and prompted an immediate adaptive response in the children, slowing their growth rate to much slower rates than children in modern populations. This is corroborated by evidence that the children were severely stunted when the first reliable estimates of their height are available at age three and four.[67] The children first started experiencing catch-up after age 3.5, perhaps because their immune systems became better adapted to the disease environment.[68] But, persistently poor conditions likely also triggered the immediate adaptive response in the children to delay the pubertal growth spurt since their level of nutrition was still quite low in early adolescence. Thus, the second bout of catch-up growth was sparked by the children's entry into the labour force, which provided them with a more ample and balanced diet, most importantly including meat. These two positive shocks forced the children back onto the healthier growth trajectory that was set during the prenatal period, allowing them to experience rapid catch-up growth. The immediate adaptive response to delay the pubertal growth spurt also meant that the growth continued for a much longer period than would occur in modern populations.

This new interpretation is built on a few key assertions about slavery in antebellum America that have to be carefully justified in order for it to make sense: first, slave women had to be healthy relative to women in other historical populations; second, conditions for slave children had to be very bad in infancy and early childhood; third, slave children's birth weights could not have been as low as Steckel estimated; and finally, catch-up growth could not have occurred on the scale observed if the children experienced poor conditions in the prenatal period. I will deal with each of these in turn.

The first assertion that must be proven in order for the adaptive framework explanation of slaves' growth to hold true is that slave women had to have been

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[67] Steckel, 'Birth Weights', p. 178.

[68] Prentice *et al.* found catch-up growth between the ages of 3 and 7 in Gambian children. They believed 'that a combination of the normal postnatal maturation of the children's immune systems and the development of a broad repertoire of adaptive responses against previously encountered pathogens reduces the frequency and severity of growth-impairing infections'. Prentice *et al.*, 'Critical Windows', p. 914.

healthy relative to other historical populations. At the time that Steckel wrote his article, there were no other studies of female stature in the nineteenth century, which precluded him from comparing the heights of adult female slaves with other women in the past. However, there have been many studies of female stature in the last thirty years, which suggest that American female slaves were substantially taller than working class women in Britain and Ireland. American slave women aged 25-50 were 158.9 cm tall, much taller than female convicts transported to Australia—156.6 cm for rural English women, 154.3 cm for urban English women, 155.7 cm for rural Irish women and 155.3 cm for urban Irish women—and women imprisoned in the Newgate prison in London born in the early nineteenth century.[69] In addition, it is likely that the nutrition of slaves was superior to their European counterparts in the early nineteenth century since their master had strong incentives to keep them well fed.[70] Finally, Steckel, himself, argues that while there were substantial differences in mortality rates of slaves and other Americans in childhood, these had largely disappeared by age 20-24.[71] It is thus credible that aside from their heavy labour, female slaves experienced fairly good conditions relative to other historical populations. This does not mean that slave women were healthy or fit relative to modern populations. It only means that the conditions that pregnant slave woman and their developing children experienced *in utero* were superior to the conditions that slave children faced in the first few years of life.

[69] Johnson and Nicholas, 'Health', pp. 211, 219; Nicholas and Oxley, 'Living Standards', p. 733.

[70] Steckel, 'Peculiar Population', pp. 439-741; Fogel and Engerman, *Time on the Cross*, vol. I, pp. 109-115; vol. II, pp. 90-91. Sutch disputed Fogel and Engerman findings of good slave diets, arguing that the diet only provided enough energy for slaves to carry out their required tasks, but he does argue that it was enough for adult slaves to maintain their general health. Sutch, 'Treatment', pp. 359-360, 382-386. Kiple and Kiple also dispute that adult slaves had adequate nutrition arguing that they were deficient in iron and calcium, but it is unclear how much worse this would have been relative to other populations. Kiple and Kiple, 'Slave Child Mortality', p. 287.

[71] Steckel, 'Dreadful Childhood', pp. 427-429.

The second key assertion is that the environmental and nutritional conditions that slave children faced in infancy had to be exceptionally bad so that children were worse off than they were *in utero*. There is substantial evidence to support this claim. Steckel, himself, writes that 'it is doubtful that populations of the past could have been much, if any, worse off than slaves as young children'.[72] First, slave children were weaned incredibly early, probably around three months and certainly within one year. Early weaning not only deprived slave children of key nutrients and protein but also made them more susceptible to diseases since they were not receiving anti-bodies through their mothers' milk and could be served contaminated food.[73] Second, slave children were given a very poor diet of corn, hominy and fat, lacking in protein and micronutrients necessary for growth. This poor diet left slave children especially prone to protein-calorie malnutrition. Slave infants also suffered from acute deficiencies in calcium, magnesium, and iron, which greatly increased infant mortality. These deficiencies were exacerbated by the slaves' dark skin pigment, which prevented the synthesis of vitamin D required for absorbing and storing calcium.[74] Finally, slave children were left unsupervised during the day, increasing their exposure to diseases especially in the cramped and unsanitary dwellings in which they were forced to live. Thus, they likely experienced high levels of morbidity from malaria, hookworm, diarrhoea, and respiratory diseases despite the fact that they may have had some level of immunity to hookworm and malaria.[75] Clearly, environmental and nutritional conditions for slaves in infancy and very early

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[72] Steckel, 'Birth Weights', p. 740.
[73] Steckel, 'Birth Weights', p. 732; Steckel, 'Dreadful Childhood', p. 449; Klein and Engerman, 'Fertility Differentials'; Kiple and Kiple, 'Slave Child Mortality', p. 288.
[74] Steckel, 'Birth Weights', p. 189; Kiple and Kiple, 'Slave Child Mortality', pp. 285-286, 289, 296-297.
[75] Savitt, *Medicine and Slavery*, pp. 57-73; Kiple and Kiple, 'Slave Child Mortality', pp. 298-299; Coelho and McGuire, 'Biology'; Coelho and McGuire, 'Diets'.

childhood were horrendous and could easily have been worse than the conditions they faced in the prenatal period.

Third, it seems fairly likely that Steckel significantly underestimated slaves' birth weights. Because there is very little reliable evidence on slaves' birth weights, Steckel estimated their birth weights by assuming that the linear relationship between birth length (or height) and birth weight in poor modern populations would be the same as in historical populations.[76] All in all, this is not a bad assumption given the paucity of historical data. One might wonder whether the relationship is really linear, but the r-square in the regression was very high. However, because it is very difficult to measure height for children who cannot walk, Steckel used the average heights of three and four-year-olds relative to modern standards to predict the slaves' birth weights. This assumption is slightly more problematic because it requires the children to have followed the same growth trajectory from birth until that point; they cannot have experienced any catch-up growth or stunting relative to their prenatally programmed growth trajectory. This would seem unlikely given the evidence presented above that suggests that infancy and early childhood were periods of extremely poor nutrition and health for slave children. Thus, it seems plausible that slave children would have become severely stunted by the time they reached the age of three or four, especially since growth velocities are highest before the age of three.[77]

In addition, the birth weights that Steckel predicted were incredibly low. At 2,320 grams, they are a full 1,180 grams below the modern standard of 3,500 grams.

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[76] Steckel, 'Birth Weights', p. 181.

[77] Boersma and Wit, 'Catch-up Growth', p. 647. Steckel reports that children ages one and two were even shorter relative to modern standards than children aged three and four. However, as Steckel notes, taking proper measurements for children who cannot stand is very difficult. Therefore, it is likely that the average heights for ages one and two significantly understate the children's actual length. Steckel, 'Birth Weights', p. 177.

Of the poor populations that Steckel uses to predict the birth weight only one population, the Lumi of New Guinea, had a birth weight below 2,840 grams.[78] Some more recent studies of birth weights in other New Guinea tribes have shown how persistently low birth weights are there. Despite health interventions by the government and missionaries between 1969 and 1989, the Au tribe experienced stagnant and low birth weights just over 2,600 grams. Although there are many environmental reasons that birth weights could be so low, one must also consider the fact that there may be some genetic trait that contributes to these persistently low birth weights.[79]

If we consider the factors contributing to low birth weights that Steckel mentions, 30 grams of the 1,180 gram deficit could be explained by lower average height of slaves relative to modern populations; 100 grams could be explained by the presence of sickle cell anaemia among populations of African descent; and another 250 grams could be explained by maternal exposure to malaria, but this still leaves 800 grams of the deficit.[80] Steckel attributes this 800 grams to the hard labour that slave women were forced to carry out during their pregnancies. However, high energy expenditure was unlikely to have a large direct effect on birth weights as long as slave women received reasonably adequate nutrition, and this generally seems to have been the case.[81] Work posture may also have been important since most of slave women's work picking cotton was in an upright position. Standing in an upright posture would have reduced blood flow to the placenta, hindering nutrients and oxygen from

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[78] Steckel, 'Birth Weights', p. 181.
[79] Tracer *et al.*, 'Two Decade Trends', pp. 486, 492-493.
[80] Steckel, 'Birth Weights', pp. 185-188.
[81] One possible doubt about this statement would be that slave women's nutritional status declined during the third trimester of pregnancy because the calorie costs of pregnancy were incredibly high (475 kcal per day) and because slave owners may have given them less food because they were less productive, only picking 76 per cent as much cotton as non-pregnant slave women in the month before a child's birth. Humphries, 'Lure', p. 13; FAO, 'Human Energy Requirements', p. 59; Steckel, 'Birth Weights', p. 188.

reaching the foetus and thus lowering slave children's birth weights.[82] However, it seems unlikely that slaves' work could have such a large effect on birth weight for two reasons. First, the largest measured effect of strenuous work during pregnancy on birth weight was a deficit of 210 grams, far lower than 800 grams.[83] And second, in a meta-analysis of 34 studies that measured the influence of maternal work on birth weight, Kramer found 'the effect of maternal work on intra-uterine growth [to be] uncertain'. A negative effect was certainly consistent with biological principles, but Kramer seemed to believe that maternal work would be most detrimental if the mother were malnourished.[84] Thus, it seems likely that slave children had substantially higher birth weights than Steckel estimated.

Finally, the magnitude of the catch-up growth that the slave children achieved is unprecedented and would seem implausible if slave children were exposed to such terrible conditions *in utero*. The slave boys in Steckel's sample experienced a 2.4 standard deviation increase and the girls a 2.2 standard deviation increase in height-for-age relative to modern standards. In comparison, the Boston and London children presented in the next chapter who were among the poorest in their respective communities only rarely achieved catch-up growth of one standard deviation relative to the modern mean (see figure 5.15 and table 5.9) and the average catch-up was much lower. These relatively low levels of catch-up occurred despite the fact that the intervention that they experienced, entering the schools, provided a much better disease and nutritional environment than entering the workforce did for slaves. This lower rate of catch-up is due, in part, to the fact that we cannot observe the children at adulthood, so it is possible that they could have experienced type B catch-up growth and caught up even more. However, modern experimental studies have tested this

[82] Kramer, 'Determinants', p. 696.
[83] Tafari *et al.*, 'Effects', p. 222; Steckel, 'Birth Weights', p. 187.
[84] Kramer, 'Determinants', pp. 696-697; Coelho and McGuire, 'Diets', p. 239.

more robustly. Comparing the catch-up between age four and adulthood for children in India, Guatemala and the Philippines, Prentice *et al.* found that the average amount of catch-up growth was 0.72 standard deviations relative to the modern mean. In addition, they only observed catch-up growth between 0.17 and 0.28 height-for-age Z-scores when testing the effect of supplementing the diets of malnourished children.[85] Finally, Indian girls adopted in Sweden in the second half of the twentieth century, probably the most optimal conditions imaginable, only experienced type A catch-up growth of 1.55 standard deviation relative to modern standard in two years.[86] Thus, it is clear that the catch-up growth of American slaves was truly remarkable, especially considering that the intervention sparking catch-up growth occurred in the first half of the nineteenth century when even the best nutritional and environmental conditions were far below modern levels.

The slaves' catch-up growth is even more puzzling because there is substantial evidence that low birth weight children exposed to a poor environment *in utero* have a lower capacity for catch-up growth. For example, low birth weight[87] Indian children adopted in Sweden had significantly lower catch-up growth. In addition, although the Indian girls experienced rapid type A catch-up growth after their move to Sweden, they also experienced early onset of the pubertal growth spurt and menarche and did not reach heights significantly taller than their counterparts in India. This pattern has been observed with malnourished children from other countries adopted in developed countries as well.[88] Thus, it seems that for these adopted children poor conditions in the prenatal period triggered a predictive adaptive response that lowered metabolism and height potential and accelerated maturation. Further poor conditions in early

[85] Prentice *et al.*, 'Critical Windows', pp. 915-916.
[86] Proos, 'Growth', p. 647.
[87] Below 2,000 grams.
[88] Proos, 'Growth', pp. 647-649.

childhood led to additional stunting as many of the children were malnourished and suffering from chronic diseases before being adopted. However, when the children were adopted and given the best nutrition and health care available, they experienced rapid type A catch-up growth that restored them to their prenatally determined growth trajectory. Thus, they had an earlier age at menarche than Swedish girls who were not deprived *in utero* and their Indian counterparts,[89] who had experienced an immediate adaptive response in early adolescence to delay the pubertal growth spurt. Although the adopted children experienced type A catch-up growth, they were not able to continue to grow at relatively high velocities into their early twenties. This evidence is corroborated by the fact that low birth weight children tend to be less responsive to hormones controlling growth.[90]

The direct implications of these studies for slaves' growth is slightly difficult to comprehend since the effectiveness of the intervention for the Indian girls was substantially greater than the effectiveness of the intervention for the slaves. Gluckman and Hanson also emphasize that the postnatal immediate adaptive response to delay maturation until conditions improve is probably more powerful than the prenatal predictive adaptive response to poor nutrition *in utero* to advance maturation.[91] However, the evidence presented above suggests that catch-up growth may be limited for children who have experienced poor prenatal conditions and have a low birth weight, especially if they experience an intervention that would spark type A catch-up growth. Thus, the low average birth weight of American slaves seems inconsistent with their incredibly high level of catch-up growth. Their unique pattern of growth would make more sense if slave children developed and set their metabolism and growth trajectory in a relatively good uterine environment, then faced

[89] Proos, 'Growth'.
[90] Gluckman and Hanson, 'Consequences', 8.
[91] Gluckman and Hanson, 'Evolution', p. 9.

severe deprivation in infancy before experiencing rapid catch-up growth once they had adapted to the disease environment and their diets improved after they entered the workforce.

4.2.3 Caribbean slave children's growth: A robustness check

The adaptive framework seems plausible in explaining the growth pattern of American slaves, but can it also explain the similar trajectory of Caribbean slaves, who in many ways suffered worse conditions?[92] Explaining why Caribbean slaves would also experience substantial catch-up growth is more difficult. In terms of maternal health, slave women in the Caribbean were substantially shorter than their American slave counterparts and shorter than or equal to women in England and Ireland. Women born in St. Lucia and Trinidad were 153.3 cm and 155.6 cm tall respectively, and slave women born in Africa were 1-2 cm shorter.[93] Caribbean slave women were also forced to work long hours and were given rum as part of their rations.[94] Infant mortality rates were incredibly high in St. Lucia and Trinidad, 583 and 479 deaths per 1,000 according to model life tables, suggesting that birth weights were quite low since birth weight is the strongest predictor of perinatal mortality.[95] These are much higher than even Steckel's upper bound estimate of 350 deaths per 1,000 based on his predicted birth weights.[96] All of these things may suggest that birth weights in the Caribbean were lower than in the US. However, in terms of child health, slave mothers tended to wean their children at later stages in the Caribbean

[92] Even after the abolition of the Atlantic slave trade in 1807, almost all slave populations in the Caribbean had negative rates of natural increase. Higman found that this was due to a combination of high mortality and low fertility among slaves. Higman, *Slave Populations*, pp. 374-378.

[93] Steckel, 'Growth Depression', p. 122; Higman, *Slave Populations*, p. 281.

[94] Steckel, 'Peculiar Population', p. 729; Higman, *Slave Populations*, pp. 205, 211. Steckel shows that alcohol consumption levels were lower for slaves in the US.

[95] Higman, *Slave Populations*, p. 319; Floud *et al.*, *Changing Body*, p. 16; Wrigley, 'British Population', p. 73.

[96] Steckel, 'Peculiar Population', p. 733.

than in the US, which may have given the Caribbean slave children an advantage if they survived the first month of life.[97] These practices may have contributed to the lower levels of childhood and adolescent mortality in the Caribbean when compared with the antebellum American South.[98] The diets of slaves in the Caribbean and in the US South were fairly similar with nutrition improving after slaves entered the workforce in both places.[99] Thus, it seems likely that slave birth weights in the Caribbean were lower than in the US South, but conditions in childhood were slightly better.

Placing Caribbean slave children's growth in the adaptive framework (figure 4.3), low birth weights seem to have limited the catch-up potential of Caribbean slaves even when conditions improved.[100] Thus, slaves in the Caribbean achieved substantial catch-up growth because their material conditions did improve across their growing years, but their potential for catch-up was limited by the prenatal predictive adaptive response, which set their growth trajectory and metabolism at a lower level. In addition, it appears that Caribbean slaves, at least in St. Lucia, were better off than US slaves from ages 3.5 to 7.5. This difference would be even greater if Pritchett's suspicions of sample selection bias were true for Steckel's coastwise manifest sample, i.e. the population mean height at young ages was even lower than the sample mean, because the Caribbean records were not subject to the same bias.[101] The Caribbean children's advantage could have been caused by a better disease environment in childhood, but it could also suggest that the mismatch between the prenatal and

[97] Klein and Engerman, 'Fertility Differentials'; Higman, *Slave Populations*, pp. 353-354.
[98] Higman, *Slave Populations*, pp. 654-657; John, 'Plantation Slave Mortality', pp. 170-171; Steckel, 'Peculiar Population', p. 733; Steckel, 'Slave Mortality', p. 92.
[99] Kiple and Kiple, 'Deficiency Diseases', pp. 200-203; but see Higman, *Slave Populations*, pp. 204-205 for a more sceptical opinion.
[100] This is corroborated by the fact that US slaves' height increments (cross-sectional height gain per year) were substantially higher than Caribbean slaves' height increments across the growing years (see table 4.3). Steckel, 'Growth Depression', pp. 116, 122; Prentice *et al.*, 'Critical Windows', p. 914.
[101] Bodenhorn *et al.*, 'Problems', pp. 31-33; Pritchett, 'Interregional Slave Trade', pp. 83-85.

postnatal environment was not as great for Caribbean slaves. Although conditions were still probably worse in the postnatal period than the prenatal period, the difference was smaller, which meant that Caribbean slave children did not fall behind modern standards as quickly as American slave children. Their metabolism better matched their postnatal experience. Clearly, an adaptive framework for growth can be incredibly instructive when trying to understand the growth trajectories of different populations.

4.3 Explaining Historical Patterns of Children's Growth in an Adaptive Framework

With the lessons of the previous case study in mind, we can now attempt to apply the adaptive framework to changes in the pattern of growth over the past 150 years. Unfortunately, this discussion will have to be rather speculative because a lot more primary work remains to be done on how the growth trajectories of children have changed over time.[102] However, a perusal of the secondary literature does allow for the development of some preliminary stylized facts that could guide a more systematic and robust analysis.

The first stylized fact is that at least from the mid-nineteenth century onward, birth weights in parts of the western world were already much higher than in a wide range of developing countries today. Although there are no reliable national birth weight figures for historical periods, it is possible to infer population levels from stillbirth rates and observed birth weights for sub-populations. Stillbirth rates and perinatal mortality are closely linked to birth weight because 'the stillbirth rate at an average birth weight of 2,500 grams . . . is between ten and thirty times higher than

[102] I hope to do more work on this in the future.

the rate at an average of 3,500 grams'.[103] Thus, declining stillbirth, neonatal and endogenous infant mortality rates in England from the early eighteenth to the early nineteenth century suggest that maternal health improved substantially over that period.[104] Stillbirth rates were also quite low in Belgium in the nineteenth century with 35.9 and 35.7 stillbirths per 1,000 live births in Tilleur (1847-1880) and Sart (1812-1900) respectively.[105] These figures are lower than the 40-50 stillbirths per 1,000 live births that Wrigley predicted for England in the mid nineteenth century.[106] In addition, where birth weight evidence is available, it seems that in the second half of the nineteenth and early twentieth centuries, birth weights in North America had already reached their modern levels (table 4.1). Birth weights in Europe seem to have improved over the twentieth century somewhat, but they were already at a relatively high level. If we use a low birth weight (LBW) percentage of 10 per cent to distinguish developed from developing countries as Ward suggests, then clearly Edinburgh, Vienna and African Americans in Boston showed room for improvement in the late nineteenth and early twentieth centuries.[107] Melbourne also had LBW percentage above 10, but McCalman *et al.* used a higher LBW cut-off of 2,722 grams, artificially inflating their percentage.[108] However, despite a lot of variation, these birth weights were much higher than those reported for a number of developing countries in the 1980s (table 4.2). Birth weights in India and Pakistan were the lowest with means around 2,750 grams and a LBW rate of 30 per cent. Some developing countries did perform better, though, with relatively high birth weights in China, Chile, and

[103] Wrigley, 'British Population', p. 73.
[104] Wrigley, 'British Population', p. 71; Floud *et al.*, *Changing Body*, p. 16.
[105] Oris *et al.*, 'Infant and Child Mortality', p. 362
[106] Wrigley, 'British Population', p. 71.
[107] Ward, *Birth Weight*, p. 133-135; Goldin and Margo, 'Poor at Birth', p. 377; Costa, 'Unequal at Birth', pp. 1005-1006.
[108] McCalman *et al.*, 'A Health Transition', p. 1076.

Iraq.[109] However, the fact that the historical samples that Ward measured were in the upper part of the 1980s birth weight distribution suggests that children in North America and Europe were likely never exposed to the worst intra-uterine conditions now present in the developing world.

Table 4.1: Birth weights of children in historical populations compared with children of like populations born in the 1970s and 1980s.

	Historical			Modern (1970s-80s)		
Country/Place	Years	Mean Birth Weight (g)	LBW (%)	Years	Mean Birth Weight (g)	LBW (%)
North America						
Boston, USA						
Whites	1872-1900	3,409	5.9	1974-77	3,480	3.6
Blacks	1872-1900	3,094	12.3	1974-77	3,230	7.7
All	1872-1900	3,397	6.2	1977	3,299	7.4
New York, USA	1910-1931	3,463	5.5	--	--	--
Philadelphia, USA	1848-1873	3,403	8.1	--	--	--
Montreal, Canada	1851-1905	3,375	5.7	1988	3,303	6.3
Europe						
Vienna, Austria	1865-1930	3,097	12.9	1978	3,320	5.8
Dublin, Ireland	1869-1930	3,282	8.0	1978-79	3,473	4.4
Edinburgh, Scotland	1847-1920	3,132*	15.2	1974	3,062*	7.7
Three Cities, Norway	1860-1920	3,400-3,500	--	--	--	--
Australia						
Melbourne	1857-1900	--	13.7§	--	--	--

Notes: All samples reflect mainly working class populations. LBW means low birth weight, a birth weight under 2,500 grams. *Scottish mean birth weight includes both live births and stillbirths, driving down the mean figure. § The low birth weight cut-off for the Melbourne study was 6 lbs. (2,722 grams), so 2,500 gram LBW percentage would likely be lower.

Sources: New York – Costa, 'Unequal at Birth', p. 992; Philadelphia – Goldin and Margo, 'Poor at Birth', p. 365; Norway – Rosenberg, 'Birth Weights', p. 281; Melbourne – McCalman *et al.*, 'A Health Transition', p. 1076; All Others – Ward, *Birth Weight*, p. 134.

The second stylized fact is that children in the past had later pubertal growth spurts than healthy children in the present. The 2007 WHO growth reference predicts that boys and girls should reach the peak of the pubertal growth spurt at ages 13.125 and 10.875 respectively. Steckel has calculated precise age at the peak of the pubertal growth spurt for a number of historical populations and found that all of the

[109] Kramer, 'Determinants', p. 665.

populations had much later pubertal growth spurts than modern populations.[110] Thus, there has been a transition over the past 100 years where the pubertal growth spurt has occurred earlier in children of both sexes.

Table 4.2: Birth weights of children around the world in the 1980s.

Country/Place	Mean Birth Weight (g)	LBW (%)
North America		
USA	3,299	6.9
Canada	3,327	6.0
Europe		
Czechoslovakia	3,327	6.2
France	3,240-3,335	5.6
Germany (FDR)	3,356	5.5
Hungary	3,144-3,162	11.8
Italy	3,445	4.2
Norway	3,500	3.8
Sweden	3,490	4.0
United Kingdom	3,310	7.0
Latin America		
Brazil	3,170-3,298	9.0
Chile	3,340	9.0
Colombia	2,912-3,115	10.0
Guatemala	3,050	17.9
Mexico	3,019-3,025	11.7
Africa		
Egypt	3,200-3,285	7.0
Kenya	3,143	12.8
Nigeria	2,880-3,117	18.0
Tunisia	3,210-3,376	7.3
United Republic of Tanzania	2,900-3,151	14.4
Zaire	3,163	15.9
Asia		
China	3,215-3,285	6.0
India	2,493-2,970	30.0
Indonesia	2,760-3,027	14.0
Iran	3,012-3,250	14.0
Iraq	3,540	6.1
Japan	3,200-3,208	5.2
Malaysia	3,027-3,065	10.6
Pakistan	2,770	27.0

Sources: Kramer, 'Determinants', p. 665.

The third stylized fact is that type B catch-up growth, catch-up growth through the extension of the growing years, was somewhat common in historical populations. Table 4.3 shows the catch-up growth for Steckel's various samples in terms of the

[110] Steckel, 'Growth Depression', p. 127. Steckel used the Preece-Baines model to smooth and predict the age at maximum growth for these populations. This was standard procedure at the time, but later analysis has found that the Preece-Baines model is better at predicting the pubertal growth spurt in boys than in girls. Thus, the evidence presented here should be taken as very preliminary. Zemel and Johnston, 'Application'.

percentile change calculated from the height-for-age percentiles that Steckel reports and in terms of Z-scores of the 2007 WHO growth reference.[111] These two measures are fairly similar for the most part, but it is important to remember, as noted above, that a one-percentile change does not reflect the same amount of actual height change across all of the deciles.[112] It is thus clear that many historical populations were experiencing catch-up growth, though it is important to note that the catch-up growth measured could also be a selection effect if children in the upper age range were more likely to come from prosperous backgrounds.[113] This is especially problematic for some of the school samples and for girls in particular since their education was less of a priority for families in the nineteenth century. Thus, the catch-up growth for girls in England, Boston, Milwaukee, and Sweden may be at least in part driven by the fact that only wealthier girls remained in school until 18 or 19.

Keeping these three stylized facts in mind, we can now attempt to interpret the differing growth trajectories of historical populations and draw some wider lessons about historical growth patterns. The fact that birth weights in the Western World were already quite high in the second half of the nineteenth century suggests that the negative consequences of low birth weight were not as strong in these countries as they are in developing countries today. Thus, the predictive adaptive response to lower metabolism and growth was likely not as powerful a restraint on children's growth in North America and Europe 150 years ago as it would be in India today. This may also suggest that negative consequences of these predictive adaptive responses, such as higher risks of heart disease and diabetes, may be more prominent in developing countries in the present and future than they were in developed

[111] Steckel, 'Growth Depression', pp. 116-120, 122-124.
[112] Wang *et al.*, 'Limitations', p. s180; Steckel, 'Percentiles', p. 158.
[113] Steckel, 'Peculiar Population', p. 728.

Table 4.3: Growth characteristics of 13 historical populations.

Location	Class	Time Period	Type B Catch-up Growth: Percentile Change (Steckel) Min	Percentile Change (Steckel) Max	WHO Z-score Change Min	WHO Z-score Change Max	Catch-up?	Growth Characteristics: Age at Max Growth (Steckel)	Average Interval over 10 (cm/year)	Max Interval over 10 (cm/year)	Earliest Height Z-score	Final Height Z-score
Panel A. Boys												
USA	Slaves	1808-61	25.7	26.9	1.54	2.42	Yes	14.8	4.2	5.9	-3.23	-0.81
Trinidad	Creole Slaves	1813	3.0	3.4	0.73	1.25	Yes	15.0	3.7	4.8	-3.12	-1.87
St. Lucia	Creole Slaves	1813	2.0	2.3	0.60	0.94	Yes	14.3	3.6	4.9	-2.89	-1.95
Phillipines	School Children	1900s	--	--	-0.31	0.16	No	15.0*	3.3	7.1	-1.82	-2.13
Russia	Factory Workers	1880s	1.0	2.9	0.20	0.31	No	16.1	3.5	6.2	-1.82	-1.62
Stuttgart	Middle Class	1772-94	10.6	11.7	0.70	0.73	Yes	15.8	3.7	5.4	-1.86	-1.16
England	Labouring Classes	1870s	3.3	7.2	0.44	0.52	Yes	15.9	3.6	5.6	-1.81	-1.32
England	Non-labouring Classes	1870s	21.4	21.4	0.60	0.60	Yes	15.1	3.7	6.7	-1.14	-0.54
Stuttgart	Aristocrats	1772-94	2.2	6.5	0.13	0.26	No	14.7	3.5	5.9	-1.19	-1.06
Moscow	Middle Schools	1889-90	-3.8	0.6	-0.10	-0.01	No	14.4	3.4	6.7	-0.81	-0.91
Sweden	School Children	1883	-8.8	11.4	-0.18	0.28	No	15.8	3.5	6.8	-0.46	-0.64
Panel B. Girls												
USA	Slaves	1808-1861	26.8	27.9	1.81	2.22	Yes	13.3	3.91	6.2	-2.89	-0.67
Trinidad	Creole Slaves	1813	12.1	12.7	1.39	1.67	Yes	13.5	3.68	5.3	-2.83	-1.16
St. Lucia	Creole Slaves	1813	3.9	5.0	0.74	0.86	Yes	12.4	3.3	5.1	-2.37	-1.51
England§	Labouring Classes	1870s	--	--	1.19	1.38	Yes	12.1	3.6	9.1	-1.83	-0.51
Russia	Factory Workers	1880s	-0.3	0.3	0.27	0.27	No	14.5	2.9	4.4	-1.81	-1.54
Phillippines	Schoolchildren	1909	--	--	-0.50	-0.12	No	12.0*	2.6	7.6	-1.63	-2.13
Italy	Upper Class	1870s	1.4	2.1	0.35	0.35	No	13.3	3.0	7.0	-1.58	-1.23
Boston	Irish Parents	1875	8.3	12.6	0.61	0.70	Yes	12.4	3.2	5.5	-1.56	-0.86
Boston	American Parents	1875	4.2	8.5	0.40	0.52	Yes	12.1	3.1	6.3	-1.39	-0.87
Milwaukee	American Parents	1881	13.5	16.6	0.70	0.76	Yes	11.5*	3.2	6.3	-1.33	-0.57
Sweden	Schoolchildren	1883	18.7	26.8	0.74	0.88	Yes	12.5	3.4	5.6	-1.07	-0.33

Notes: Minimum catch up growth was calculated by subtracting the adult percentile or Z-score by the maximum percentile between age 5.5 and 9.5. Maximum catch up growth was calculated by subtracting the adult percentile or Z-score by the minimum percentile between age 5.5 and 9.5. All growth series are from Steckel except for the Filipino children. * denotes that age at max pubertal growth was calculated from the cross-sectional height intervals rather than by the Preece-Baines model.

Sources: Steckel, 'Growth Depression', pp. 116-124; Bobbit, 'Growth', pp. 6-7.

countries in the past. Reports of age-standardized prevalence of diabetes around the world support this suspicion.[114] Good prenatal conditions in the North America and Europe also allowed these populations to experience greater catch-up growth if conditions improved. Thus, in a meta-analysis of child growth patterns past and present, these European populations should be considered as between developing and developed countries today in terms of their health status.

The delay in the timing of the pubertal growth spurt in the past suggests that children in the past must have been making immediate adaptive responses to delay maturation in response to poor nutrition or high levels of morbidity. However, determining what these conditions were is more difficult. Table 4.3 presents Steckel's results for samples of children where the adult height is known along with a sample of Filipino children from the early twentieth century. There are two main patterns worth highlighting with regard to the timing of the pubertal growth spurt. First, although there is only rarely information on class for children from the same society and period, it does appear that boys and girls from higher classes seem to have an earlier age of maximum growth during the pubertal growth spurt: middle class schoolboys in Stuttgart reached their age of maximum growth 1.1 years later than aristocratic boys; the boys of factory workers in Moscow reached their age of maximum growth 1.6 years after their counterparts in middle schools; boys of the labouring classes in England experienced maximum growth 0.8 years after their non-labouring households; and finally girls with Irish parents, who were on average more working class than girls with American parents, reached their pubertal 0.3 years later. The fact that even children of the highest classes had later pubertal growth spurts may also

[114] Diamond, 'Double Puzzle', p. 601.

suggest that exposure to diseases rather than nutrition was the most important factor in triggering the immediate adaptive response.

In addition, simple Pearson correlation coefficients suggest that there is no relationship between the earliest height Z-score or the final adult height Z-score and the age at maximum growth during the pubertal growth spurt for boys.[115] Thus, the class effect does not hold across the entire sample. However, for girls there is a negative correlation of -0.45 between the earliest height Z-score and the timing of the pubertal growth spurt. These preliminary correlations should not be over-interpreted because they are based on a very small sample of different growth patterns, but they suggest that the link between nutritional status and the pubertal growth spurt may be more powerful in girls than in boys. This is consistent with the adaptive framework because the cost of reaching sexual maturity earlier is greater for girls because of the high-energy costs of pregnancy and lactation. In fact, the mechanism controlling the timing of the pubertal growth spurt may be different for boys and girls. This is corroborated by the relatively low correlation of 0.44 between the age of maximum growth of girls and boys from the same populations in Steckel's original article. These findings highlight the need to study boys and girls growth patterns separately so that we can understand how certain conditions may affect the growth of girls and boys differently.

It is also important to attempt to explain why certain groups in table 4.3 experienced catch-up growth when others did not. In order to do this, panels A and B of table 4.3 are divided into groups by their earliest height-for-age Z-score and the amount of catch-up growth achieved. The first group, which contained slaves in the Americas and working class English girls, had a low initial height, but still achieved a

[115] The earliest height-for-age Z-score did vary across the different samples, but all of the earliest Z-scores preceded the pubertal growth spurt. They were taken for ages 5.5-9.5 for boys and ages 5.5-8.5 for girls.

great deal of catch-up growth. These children clearly experienced some kind of intervention where their material circumstances improved dramatically across their growth period. However, as mentioned above, the extent to which they could catch-up relative to modern standards was limited by their birth weights. If the children had adapted to relatively good conditions *in utero*, then they could experience large amounts of catch-up growth like American slaves. However, if maternal health practices were less ideal, as they were in the Caribbean, then children's catch-up growth was limited despite improving conditions. English working class girls are an outlier in this group, and as mentioned above their fast catch-up growth may reflect changes in the sample at higher ages rather than actual catch-up growth.

The second group had relatively low initial height levels and did not experience catch-up growth. These children likely had low birth weights and did not experience an intervention that would allow them to escape their prenatally determined growth trajectory. They did, however, have a later age at maximum growth than modern populations, suggesting that continued exposure to poor nutrition or infection triggered immediate adaptive responses that delayed maturation. Children falling into this category included Filipino school children and the children of Russian factory workers.

The third group consists of populations of children who had relatively high height-for-age Z-scores at earliest measurement and experienced moderate levels of catch-up growth across their growing years. Again, we must be cautious when interpreting the Z-score change as catch-up growth because the increase in height-for-age Z-scores measured for these children may be a product of the changing nature of the samples across ages. However, it is possible that without the limitations put on catch-up growth by poor conditions *in utero*, these children were able to experience some additional catch-up growth over their growing years.

The fourth and final group, only present for boys, consisted of children who were tall, at least for historical populations, relative to modern standards and did not experience any catch-up growth. These children likely had relatively high birth weights, and although they experienced some bad conditions that led to a delayed pubertal growth spurt, they were able to compensate for this delay by growing for a longer period of time. This group's growth trajectory suggests that evidence that boys or girls continued growing well into their twenties is not necessarily evidence of catch-up growth. The Swedish schoolboys reported in panel A were still growing at the age of 20, but they did not experience any catch-up growth from their earlier trajectory. Thus, anthropometric historians should use caution when interpreting growth continuing into the twenties in for instance military records as catch-up growth.[116]

Hopefully, it is clear from the reinterpretation of historical growth patterns in this section that analysing growth patterns in an adaptive framework can provide some useful predictions about how populations will respond to initial conditions *in utero* and nutritional and disease insults in the postnatal period. These predictions are not necessarily novel or surprising in and of themselves, but they are strengthened when placed in a unified adaptive theory based in evolutionary biology.

4.4 Conclusion

This chapter has introduced a new theoretical framework for interpreting the pattern of children's growth in populations past and present. Utilizing new biological

[116] One must also be careful with interpreting age dummy variables in multiple regression analysis since scholars studying growth cessation normally use one-year dummies, which may have small sample sizes and be influenced by sample selection.

theories of adaptive responses in relation to growth, the adaptive framework consists of two prenatal and two postnatal adaptive responses triggered by good or bad conditions. First, in the prenatal period, acute malnutrition may prompt an immediate adaptive response in the foetus to slow its growth until maternal nutrition improves. Second, conditions *in utero* spark a predictive adaptive response whereby the metabolism and growth trajectory of the growing foetus are linked to the expected conditions in the postnatal period. If there is a poor environment *in utero* the foetus develops with a lower metabolism and lower growth trajectory so that it is better adapted to growth in poor conditions after birth. As we have seen above, problems arise when there is a mismatch between conditions in the prenatal and postnatal period because the prenatally programmed metabolism and growth trajectory are not ideal for the postnatal environment. Third, in the postnatal period, malnutrition or chronic infections can trigger an immediate adaptive response to delay or slow growth. On the other hand, an improvement in conditions can spark catch-up growth, either a period of faster than normal growth or an extension of growth into later ages, moving the child back onto his/her former growth trajectory. Finally, poor nutrition can also elicit an immediate adaptive response to delay the pubertal growth spurt until conditions improve. All of these responses are adaptive in the sense that they increase the probability that a child will survive to reproductive age and reproduce. However, they are not without their costs. Poor nutrition *in utero* has been linked to heart disease and diabetes in later life and shorter children and adults have higher mortality risks at all ages.

This framework was then employed to reinterpret the growth of slaves in the US and Caribbean. Slaves in the US South and the Caribbean, surprisingly, appear to have experienced a mismatch between the prenatal and postnatal environment where the postnatal environment was substantially worse than the prenatal environment. This mismatch was greatest for US slaves because maternal health and thus birth weights were relatively good there. The mismatch caused slave infants to become severely stunted in their first few years of life because their prenatally programmed metabolism was set too high, but as their immune adapted to the disease environment and they received better food, they regained their former growth trajectory and experienced rapid catch-up growth. Caribbean slaves did not experience the same level of catch-up growth because they had lower birth weights, which limited their ability to respond to improving conditions. They were restricted by their metabolism and growth trajectory set in the prenatal period. Therefore, it seems that placing children's growth in an adaptive framework can be a very helpful way of understanding growth patterns in the past.

Finally, the chapter introduced three stylized facts of children's historical growth experience: birth weights were relatively high in North America and Europe at least since the mid-nineteenth century; historical populations experienced the pubertal growth spurt at a later age than modern populations; and catch-up growth through the extension of the growing years was not uncommon in historical populations. With these three stylized facts in mind, I attempted to interpret different historical growth patterns using the adaptive framework.

This analysis of historical growth patterns helps to clarify some important issues that should be addressed in the future. First, the link between birth weights, maternal health and catch-up growth highlights the important role maternal health and the conditions a foetus is exposed to *in utero* play in determining growth outcomes. Thus, researchers should focus on measuring the relative health status of men and women and explaining any differences that may exist. Unfortunately, historical records of male height have defined large periods of anthropometric history because there is such a dearth of sources with information on female stature. After putting anthropometric history in an adaptive perspective, this male centred view is not just a one sided perspective of living standards as many feminists have argued; it is a fundamentally skewed view because maternal conditions play such a strong role in determining growth and height potential. Horrell, Meredith and Oxley's work showing how the relative bargaining position of men and women in the household has large consequences for the allocation of household resources and women's health status is a good model to follow in the regard.[117] In addition, more studies are needed on how environmental conditions during pregnancy affect the growth pattern and final adult height. Baten and Murray have tested this relationship using real wage data for prisoners in nineteenth century Bavaria, but this research could obviously be expanded to other periods and geographic areas.[118]

Second, mismatches between the prenatal and postnatal environment can create substantial health problems for children. If prenatal conditions were substantially better than postnatal conditions especially in the first couple of years of life, as was the case for American slaves, then the children would experience dramatic stunting in the first couple of years of life because the children's metabolism was set too high for their environment. This mismatch could have modern corollaries when famine may cause postnatal conditions to be worse than prenatal conditions or when the disease environment favours high levels of morbidity and mortality in infancy and early childhood. However, the consequences for a mismatch where prenatal conditions were worse than postnatal conditions could also have health consequences. If metabolism was set low in the prenatal period but resources were more abundant

[117] Horrell *et al.*, 'Measuring Misery'; Meredith and Oxley, 'Blood and Bone'; Horrell and Oxley, 'Bargaining'.
[118] Baten and Murray, 'Heights', pp. 365-67.

thereafter, then the children would have an increased risk of developing childhood obesity and its associated health consequences. Diamond has suggested a similar mechanism as part of the cause of the rising obesity and type 2 diabetes of Pacific Islanders.[119]

Third, although there were clear class distinctions in the timing of the pubertal growth spurt, the fact that all groups experienced a later pubertal growth spurt than modern populations suggests that insults that could cross class boundaries, such as disease, were more important in triggering an immediate adaptive response to delay the pubertal growth spurt. Morbidity and chronic diseases such as hookworm, diarrhoea and malaria in particular may have influenced the growth patterns of populations as much as nutrition. Thus, more work needs to be done showing how bouts with particular diseases affected children's growth and how the ecology and prevalence of diseases in different geographic areas affected children's growth. Bleakley's work on the eradication of malaria and hookworm from the US South could serve as a model, though it is probably not possible to collect county level information on children's growth.[120]

Fourth, understanding growth in an adaptive framework highlights the need for a greater focus on gender inequality and gender differences in growth during childhood.[121] Factors influencing the pattern of female growth and final adult height may be quite different than those of men, not just because women were treated differently than men in past societies but because different factors might trigger adaptive responses in women and men and there may be biological differences in their adaptive responses. A meta-analysis of all known historical and modern studies

[119] Diamond, 'Double Puzzle'.
[120] Bleakley, 'Disease and Development'; Bleakley, 'Economic Effects'.
[121] Osmani and Sen, 'Hidden Penalties', pp. 115, 118-19; Horrell *et al.*, 'Measuring Misery', pp. 114-16.

on children's growth might be a good starting point to make further progress on this issue.

Clearly, applying adaptive models to anthropometric history validates some older insights and raises new questions about factors affecting children's growth and later health. A clear focus in the future on foetal and maternal health, gender inequality, morbidity and mismatches between prenatal and postnatal environments will hopefully help historians formulate a more accurate and balanced account of children's health and growth in the past.

CHAPTER FIVE:

HEALTH, GENDER AND THE HOUSEHOLD: CHILDREN'S GROWTH IN THE MARCELLA STREET HOME, BOSTON, MA AND THE ASHFORD SCHOOL, LONDON, UK

Over the past fifteen years numerous studies by nutritionists, paediatricians, development economists and economic historians have shown that nutritional deprivation and disease exposure *in utero*, in infancy, and in childhood can have serious consequences for later health, cognitive development, productivity, and earnings.[1] Barker's famous hypothesis suggests that nutritional deficits *in utero* caused developing children to 'permanently change their physiology and metabolism' in ways that directly related to later life risks of heart disease, stroke, hypertension, and diabetes.[2] Earlier, Waaler also found that heights and weights of children and adults were directly related to mortality risk. Children and adults who were stunted, underweight or obese had significantly higher mortality risk than taller adults in a normal weight range.[3] From a historical perspective, Almond has shown that exposure to the 1918 flu pandemic *in utero* led people of that cohort in the United

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[1] Floud *et al.*, *Changing Body*, pp. 15-29.
[2] Barker, 'Fetal'; Barker, 'Maternal Nutrition'; Almond and Currie, 'Killing Me Softly'.
[3] Waaler, 'Height', p. 49.

States to have lower educational attainment, income and socioeconomic status than birth cohort born directly before and after the pandemic.[4] Thus, evidence is mounting that poor nutrition *in utero*, in infancy and in childhood have grave long-run effects on human capital formation, productivity and life expectancy.[5]

These concerns have reaffirmed the importance of maternal health for the health of entire populations. In fact, Osmani and Sen have developed a model, which directly relates relative female deprivation to foetal health and the health of the general population. They argue that a male-bias in access to household resources, education and health care in childhood generally leads to poor female health. Poor conditions for girls in childhood predisposes women to a less healthy adulthood, and if the deprivation continues, women would not be able to provide an ideal uterine environment for foetal development for their children. Thus, poor maternal health could perpetuate lower health outcomes for subsequent generations of both girls and boys.[6] Placing this model in the context of historical Britain and America, if relative female deprivation was a feature of these societies, it could have slowed the progress of improving health across the second half of the nineteenth and twentieth centuries.

Along these lines, this chapter seeks to understand whether girls were less healthy than boys in the US and Britain at the end of the nineteenth and beginning of the twentieth centuries by measuring the growth of boys and girls in two government run schools: the Marcella Street Home in Boston, Massachusetts (1889-98) and the Ashford School of the West London School District in London, England (1908-16). These data sources are particularly interesting because the children's heights and weights were recorded at entry and discharge from the schools, providing longitudinal

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4 Almond, 'Is the 1918 Influenza Pandemic Over?'.

5 Strauss and Thomas, 'Health over the Life Course'; Prentice *et al.*, 'Critical Windows'; Almond and Currie, 'Killing Me Softly'; Floud *et al.*, *Changing Body*, pp. 15-29, 176-177.

6 Osmani and Sen, 'Hidden Penalties'.

growth information for many of the children. Thus, it is not only possible to measure the children's deprivation cross-sectionally as Steckel, Harris and others have done for other populations, but it is also possible to measure and compare the children's longitudinal growth while in the schools relative to modern standards.[7] This paper uses the differences in boys' and girls' catch-up growth in each school to argue that girls were unhealthy relative to boys before entering the schools.

The chapter will proceed as follows: I will first briefly describe the historical literature on gender discrimination in health and resource allocation outcomes. Second, I will describe the data sources and their representativeness. I will then proceed to establish that these children met the two preconditions for catch-up growth: their biometric measures were substantially below modern standards before entering the institutions and that entry into the institutions was a positive health intervention that could spark catch-up growth. Finally, I will establish that the children in both schools were experiencing catch-up growth relative to modern standards and that girls were experiencing faster catch-up growth than boys. There are three possible explanations for the greater catch-up growth in girls relative to boys: girls could have received better treatment in the schools, girls could have a greater natural propensity for catch-up growth, or girls could have been deprived relative to boys before entering the institutions. A close study of the conditions in the institutions and of the scientific literature on catch-up growth allows me to tentatively reject the first two possible explanations in favour of the third. Explaining why girls were in poorer health than boys is more difficult, but it seems reasonable to infer that this gender gap may have been caused by gender discrimination in the allocation of household resources.

[7] As far as I am aware, this is the first study to measure children's longitudinal growth using historical data. Steckel, 'Peculiar Population'; Floud *et al.*, *Height*, pp. 163-182.

5.1 Gender Differences in Health and Gender Discrimination in Nineteenth and Twentieth-century Britain and America

The influence of gender discrimination on health and resource allocation outcomes in the past has been measured in three main ways: excess female mortality at various ages, discrimination in household allocation of resources measured in household budgets, and by differential influences of environmental factors on men and women's biological standard of living (height or BMI). These indicators generally present a relatively rosy picture of gender discrimination in Britain and the US relative to the more substantial differences that are commonly found in Asia. However, there is mixed evidence that women were not reaching equal outcomes to men in nineteenth and early twentieth century Britain and America.

Evidence on female mortality presents a mixed story of gender discrimination in Britain and America depending on the age range and specific locations studied. Sex ratios of infant deaths are often used as a measure of son preference in modern and historical populations. For as of yet unknown biological reasons, male births outnumber female births at a ratio of about 1.06 to 1, and males are more vulnerable to respiratory infections, accidents of childbirth, and X-chromosome linked diseases in the first year of life, implying a sex ratio of infant mortality of around 1.10 under non-discriminatory conditions.[8] The sex ratios of infant deaths in South and East Asian countries with strong son preferences tend to be below unity, suggesting that either selective infanticide is committed against girls or 'mortal disadvantaging or neglect' is commonplace.[9] However, there is very little evidence that families in Europe or the US at any point in history where mortality records exist practiced selective infanticide or mortally neglected female infants and children. The sex ratios of children at birth at different parities are equal in western populations in contrast to

[8] Waldron, 'Sex Differences', pp. 64-66; Alter *et al.*, 'Gender Differences', p. 329.
[9] Lynch, 'Why', pp. 252-4.

Asian populations with strong male preferences.[10] The sex ratios of infant deaths were always above unity in England from the earliest point in time when differentials could be calculated.[11] Likewise, the sex ratio of infant deaths was 1.19 in Boston and 1.13 in Philadelphia from 1884-90, and the sex ratio for the entire United States as reported by the census bureau in the Eleventh Census of 1890 was 1.26.[12] Vinovskis also found that life expectancy at birth was slightly higher for girls than boys in Massachusetts in 1860.[13] These results do not change substantially across time or across rural and urban counties, though a more thorough analysis of the trends would be welcomed and is beyond the analysis here.[14]

However, sex differentials in mortality above age 1 provide a more complex picture. Woods and Shelton show that in the mid nineteenth century UK there was excess female mortality between the ages of 10 and 40 in Britain but by the 1890s there was only excess female mortality between the ages of 10 and 15. Surprisingly though, excess female mortality was more prevalent and applied to larger age groupings in designated 'healthy districts' both at mid-century and in the 1890s.[15] McNay *et al*. also found that the overall mortality level was negatively correlated with excess female mortality of women aged 10-19 and 20-44, i.e. healthier districts with lower mortality had higher levels of excess female mortality controlling for a host of other factors. However, they also found that excess female mortality was related to economic structure. Higher excess female mortality was found in agricultural districts, districts with high levels of female literacy, and districts where phthisis was

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[10] Lynch, 'Why', pp. 254-5.
[11] Hinde, 'Sex Differentials', p. 5.
[12] Billings, *Vital Statistics of Boston and Philadelphia*, pp. 126, 158; Billings, *Report on Vital and Social Statistics in the United States at the Eleventh Census: Part III Statistics of Deaths*, p. 10.
[13] Vinovskis, 'Mortality Rates', p. 211.
[14] See other censuses and the Massachusetts 'Reports of Births, Marriages and Deaths', which began in 1842 and continued into the interwar period.
[15] Woods and Shelton, *Atlas*, pp. 134-135.

a more common cause of death for women. Lower levels of excess female mortality existed in districts with high shares of female employment in agriculture, domestic service and trade, high female in-migration, and larger shares of females dependent on poor relief.[16] Thus, it is clear that women's health and longevity was influenced by economic circumstances and that part of this excess female mortality could have been caused by gender discrimination in the allocation of resources in the household.[17]

Harris has disputed some of these findings arguing that there is little evidence that 'females suffered systematic neglect in childhood or that such neglect resulted in sex-specific differences in mortality rates'. He argues that higher ratios of female to male deaths aged 0-14 in the mid-nineteenth century relative to modern ratios were caused by the epidemiological environment. Girls were more susceptible to certain infectious diseases than boys, so as mortality declined for children beginning in the mid-nineteenth century, girls benefited relative to boys in this decline. Likewise, a shift-share analysis of causes of mortality shows that 98.6 per cent of the mortality decline between 1851/60 and 1979/95 was associated with factors that affected boys and girls equally. Only 3 per cent of the decline could be explained by gender specific factors. However, there is strong evidence that adult women suffered more than their adult male counterparts, leading to excess female mortality.[18] Harris's analysis is interesting and useful but not entirely convincing. It is true that the vast majority of health improvements would have affected boys and girls in a similar manner, but this does not disprove that there was a gap between mortality rates in the mid nineteenth century. In addition, we do not necessarily know why girls would have been more likely to die of certain diseases than boys. Presumably part of this difference could

[16] McNay *et al.*, 'Excess Female Mortality', pp. 669-673.
[17] McNay *et al.*, 'Excess Female Mortality', p. 670; Woods and Shelton, *Atlas*, pp. 134-135; Anderson, 'Social Implications', p. 19.
[18] Harris, 'Gender', (2008), p. 193-197.

have been associated with poorer female nutrition if girls were discriminated against in the allocation of household resources.

There has been less research on excess female mortality in the United States, but generally the literature finds that female and male mortality rates were very similar until the Civil War when excess male mortality became the norm. There are a few cases in the eighteenth and nineteenth centuries where excess female mortality has been observed.[19] Vinovskis calculated lower female life expectancies in Salem, Massachusetts for ages 0-29 in 1840-42, but female life expectancies were almost always higher in Salem in 1818-22, 1828-30, and 1859-61. Female life expectancies were also slightly lower than male life expectancies for ages 1-29 in all of Massachusetts in 1860.[20] However, in general these difference were quite small, suggesting that if female deprivation occurred, it did not have a substantial impact on mortality rates. Thus, overall the evidence on excess female mortality suggests that there may have been some gender discrimination in the allocation of household resources affecting girls in their growing years, at least in Britain, but the prevalence of excess female mortality varied based on the economic context of a particular district and changed over time.

Historians have also measured differences in the allocation of resources in the household. The two main studies, one from the US and the other for England, both used the 'Cost of Living of Industrial Workers in the United States and Europe 1888-1890' survey conducted by the US Department of Labor on working class households. Horrell and Oxley found no clear and consistent pattern of gender bias in resource allocation in the household across their entire sample from England. There were differences in allocation by sector with girls slightly favoured (though the

[19] Pope, 'Adult Mortality', pp. 290-291; Haines, 'The White Population', p. 339.
[20] Vinovskis, 'Mortality Rates', p. 207, 211.

coefficients were insignificant) in households situated in textile regions, boys favoured in households in metal-producing households, and girls favoured in coal-mining families. Rather than confirming the simple hypothesis that children with the most labour market opportunities in the various sectors would be favoured with additional expenditure, they argued that three key elements seemed to be important in the allocation of resources: employment opportunities; inducements to try to retain valuable children in the household; and the relative worth of both children if both were or were not working.[21] Horrell and Oxley also found that girls received fewer calories and grams of protein in their diet daily than boys, but it was unclear whether this gap was larger than the biological difference in calories required caused by sexual dimorphism.[22] Using the portion of the Department of Labor survey collected in the US, Logan followed a similar methodology to Horrell and Oxley and came to a somewhat similar conclusion. Logan could not reject the efficient allocation of resources in the family; there was not bias against girls. However, he argues that equal allocation of resources did not mean that parents were acting in an egalitarian manner. Instead, parents allocated resources equally to boys and girls because 'the future higher earnings of boys were offset by their higher probability of leaving the household'.[23] Thus, evidence on household resource allocation from late-nineteenth-century Britain and the US suggests that girls were not discriminated against. A caveat to these findings, however, is that most of the households surveyed in Britain and the US in the 1888-90 survey were from the wealthier parts of the working class, those employed full time in factories or large establishments.[24] Poor families may have faced more difficult decisions about allocating scarce resources.

[21] Horrell and Oxley, 'Crust', pp. 513-4, 518.
[22] Horrell and Oxley, 'Crust', p. 510; Schneider, 'Real Wages'; FAO, 'Human', pp. 26-7.
[23] Logan, 'Family Allocation', pp. 20-23, 31 quote.
[24] Haines, 'Poverty', in Hershberg (ed.), *Philadelphia*, pp. 245-9; Horrell and Oxley, 'Crust', p. 499.

A final method of measuring gender discrimination in the allocation of household resources is to look carefully at the differences in the anthropometric measures (heights and BMI) of women and men. Nicholas and Oxley studied the height differences between English men and women transported to Australia before 1840. They found that women's heights in rural areas fell across the birth cohorts between 1790 and 1820 relative to the heights of women born in urban areas and relative to the heights of men. They argue that diminishing employment opportunities for women in agricultural regions left rural women relatively disadvantaged in the allocation of household resources compared to their urban and male contemporaries.[25] Their results have been challenged on two fronts in the literature: Jackson argued that they did not properly account for the changes in the age structure of the sample over time, and Harris has argued that they mischaracterized the patterns of female employment, which are uncertain and may not have declined until after the 1850s.[26] In a response to Jackson, Nicholas and Oxley argue that they did properly account for the changing age structure of convicts, and although Harris is right that the precise trends in female labour force participation across the eighteenth and nineteenth centuries are unclear, it would be difficult to argue that the decline in spinning in the late eighteenth century (see chapter 2) did not strongly influence women's total employment in the economy. It seems unlikely that straw plaiting, lace-making and handloom weaving could have replaced all of the cottage industry employment that was being used in spinning, especially when considering how much wool and flax was being spun according to Muldrew's figures.[27] Earnings in spinning were also higher than in other activities, making the disappearance of spinning even more

[25] Nicholas and Oxley, 'Living Standards', (1993), pp. 735-40.

[26] Jackson, 'Heights'; Harris, 'Anthropometric History', p. 71-73; Harris, 'Gender', (2008), pp. 172-177; Harris, 'Gender', (1998), pp. 414-418.

[27] Muldrew, 'Th'ancient Distaff', p. 520; Burnette, *Gender*, p. 42-48.

detrimental for women's bargaining power in the household.[28] Thus, Nicholas and Oxley provide at least tentative evidence that there were gender differences in health outcomes in the early nineteenth century.

Harris also studied children's growth in the early twentieth century based on his sample of mean heights of children at different ages collected by School Medical Officers during the first half of the twentieth century. Harris finds that when compared with British growth standards, girls' heights tended to be at higher percentiles of modern standards from ages 4-5 to 7-9 but that boys overtook girls by the age of 12-13. Similarly, when looking at the average height of children at a specific age over time, girls tended to be at a slightly higher percentile than boys across the first half of the twentieth century. He argues that the female advantage likely existed because girls are biologically more resistant to adverse conditions than boys and that these biological factors made it difficult to use height to measure gender differences in health.[29] He later extended this analysis to a number of European countries finding similarly that there was no evidence of female disadvantage apart from famine conditions during World War II in Oslo.[30] Sommerfelt and Arnold conducted a similar study based on young children's cross-sectional anthropometric measures taken in the late 1980s and early 1990s in 34 developing around the world. They generally found that there were 'relatively small differences between boys and girls in terms of prevalence of stunting, underweight and wasting' despite the fact that some of the countries had clear male biases in other indicators.[31] Dercon and Singh compared children's height-for-age, weight-for-age and BMI-for-age across genders at older ages, 8, 12 and 15, for Ethiopia, Peru, India (Andhra Pradesh) and Vietnam.

[28] Muldrew, 'Th'ancient Distaff', pp. 507-511; Wall, 'Some Implications', p. 332.
[29] Harris, 'Gender', (1998), pp. 425-429.
[30] Harris, 'Anthropometric History', pp. 65-71.
[31] Sommerfelt and Arnold, 'Sex Differentials', pp. 151-152.

In all but a few cases, they found pro-female bias in terms of nutritional status.[32] These mixed results both in history and today highlight the complexity of considering gender differences in health and the need for new methodologies to study it further.

Horrell, Meredith and Oxley have added BMI and weight to the picture for historical populations. They found that women in the Surrey House of Correction in Wandsworth, South London in the third quarter of the nineteenth century tended to gain weight while in prison while men lost weight. Likewise, women aged 25 and older had consistently lower BMIs than their male counterparts. These findings suggest that women were living under conditions of relative deprivation before entering the House of Correction.[33] Oxley and Meredith have conducted a similar study for the Paisley House of Correction near Glasgow but have found surprisingly different results. Women in Paisley appear to have had higher BMIs than their male counterparts. They posit that women's greater labour market opportunities in Glasgow allowed them to bargain for a larger share of household resources or at least benefit from food given to them at work.[34] These two studies on British prisoners suggest that woman did not always face discrimination and that bargaining models of resource allocation in the household may best describe the reality of Victorian Britain. To my knowledge there has not been similar anthropometric research explicitly studying gender differences in children's stature and growth conducted for the United States, so this paper adds especially to that literature.

To sum up then, there is mixed evidence of poor relative female health and gender discrimination in the allocation of household resources. These results, however, are complicated by the fact that most of the studies have focused on relatively affluent groups in society such as school children or full-time employed

[32] Dercon and Singh, 'Nurition', pp. 5-7.
[33] Horrell *et al.*, 'Measuring Misery', pp. 110-12, 114-5.
[34] Meredith and Oxley, 'Blood and Bone'.

workers. Thus, this study adds to the literature by studying boys and girls longitudinal growth and by focussing on the working poor.

5.2 The Samples

5.2.1 The Marcella Street Home, 1889-1898

Before discussing the methods and results in detail, it is first necessary to provide some institutional context for the Marcella Street Home and the Ashford School and discuss the samples and representativeness. The Marcella Street Home was founded in 1876 in Roxbury, which had been annexed by Boston in 1868, on the western edge of Boston.[35] The Home was formed to house pauper and neglected boys who were resident at the Deer Island House of Reformation at the time. Pauper and neglected girls were incorporated into the Home in 1881 after the construction of new buildings to accommodate them.[36] Boys and girls continued to be housed in separate departments throughout the life of the institution. The home was mixed race but only a small number of children in the school were black. The Home had a school from its beginning where children were taught basic subjects, including reading and writing.

The heights and weights of children were not systematically recorded in the Marcella Street Home until 1889 and continued to be recorded until the institution closed in 1898 when all the children in the institution could be placed in foster homes. It is not exactly clear why the administrators began keeping these records in 1889; for instance, there is no change in the superintendent that year. However, the fact that the results of the anthropometric measures were never reported in the annual reports of the institution suggests that they were recorded purely to track the children's growth. Thus, the figures are unlikely to have been deliberately skewed to depict the

[35] 'Twentieth Annual Report of the Board of Directors for Public Institutions', pp. 27-8, 66-7.
[36] 'Twenty-fifth Annual Report of the Board of Directors for Public Institutions', pp. 92-3.

institution in a better light or influence policy in the institution or outside of it. The register includes the heights and/or weights of 475 children born between 1873 and 1898 with some children entering and leaving the institution multiple times. In addition to their height and weight, it is necessary for the children's birthdate to be recorded in order to calculate Z-scores for the children's anthropometric measurements relative to modern standards. Height and BMI Z-scores could be calculated for 103 girls and 248 boys, but fewer than this number had their heights and weights recorded at entry and exit from the institution. The amount of time children remained in the home varied from zero days to 8.4 years with an average stay of 1.3 years.[37]

The children were drawn from all over Boston, including South Boston and Roxbury. The Board of Visitors described the children in the home as follows in 1894:

> The population is supplied from two sources, — first, from the ranks of pauperism, and second, from the courts, which place children, found to be criminally neglected by their parents, under the legal guardianship of the city. Among the pauper children are a small number whose parents are obliged by unavoidable poverty to temporarily place them in the Home, and a very large number of unfortunate children born of dissolute, inebriate parents, who sacrifice even natural affection to better indulge an insatiable thirst for drink, while shirking the responsibility of caring for their offspring during the years of helplessness.[38]

The difference between pauper children and neglected children is key in this case because the one surviving register, the one used in this chapter, only recorded the neglected children. There was likely a separate register for the pauper children, but it does not survive. This presents a real selection bias problem that is difficult to assess and overcome. Contemporary newspaper articles suggest that most children were sent to the institution because their parents were drunkards. For instance, the Boston Daily Advertiser reported July 15, 1881 that 'Catherine Mitchell was arrested and brought before the police court in Roxbury as a common drunkard. In her rooms were found

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[37] CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001.
[38] 'Report of the Board of Visitors to the Public Institutions [1894]', p. 43.

her three children, five, three and a half and two years of age, *all intoxicated* [sic]. The society sent them to the Marcella-street home'.[39] A year later, the same newspaper published a speech given by Robert Treat Paine, Jr. in which he lamented the 'river' of neglected children that had to be sent to the home but acknowledged that 'perhaps they are more fortunate than those children who are still kept in a home where the father and mother both drink'.[40] The speech was given to a temperance society, so the stress on alcohol may be somewhat exaggerated, but it still highlights the nature of the neglect for which children were sentenced to the home. It also presents clear evidence that household resources were being syphoned off for the parents' benefit, not their children.

The question, then, is how would neglected children compare to children in general and to the poor children that are represented in the West London School District. This is a difficult question to answer because there is only limited information about the children and their parents. Pinpointing the social class of the children is difficult because the mother and father's occupations were not recorded in the register. However, there is information about the parents' immigration status. According to the Eleventh Census taken in 1890, 65.9 per cent of children under five in Boston had at least one parent born in a foreign country, 29.4 per cent had native born parents, 3.2 per cent were foreign born, and 1.5 per cent were black (Table 5.1).[41] In the Marcella Street Home 62.8 per cent of white sentenced inmates had parents born outside the USA, 21.9 per cent had native-born parents, 9.4 per cent of white children were foreign-born, and 6.0 per cent were black. While broadly similar, white children with native parents were significantly under-represented in the sample

[39] 'Cruelty to Children', *Boston Daily Advertiser*, 15 July 1881.
[40] 'A Public Meeting of the Citizen's League', *Boston Daily Advertiser*, 16 November 1882.
[41] Unfortunately, the data were not broken down further by age. I have followed the census in excluding the immigration status of black children's parents so that the number would be comparable. Billings, *Vital Statistics of Boston and Philadelphia*, pp. 116-17.

and white foreign-born children and black children were significantly over-represented in the sample. Thus, it appears that the poor and lower classes of immigrants and African Americans are over-represented among the sentenced children.

Table 5.1: Race and immigration status of the children's parents in the 1890 census for Boston and in the Marcella Street Home, 1889-1898.

	US Census 1890 (Boston children under 5)		Marcella Street Home		
	n	per cent	n	per cent	t-statistic
Native White Children with a Foreign-Born Parent	26,360	65.90%	241	62.76%	-1.27
Native White Children with Both Parents Native	11,742	29.35%	84	21.88%	-3.54
White Foreign-Born Children	1,294	3.23%	36	9.38%	4.12
Black Children	605	1.51%	23	5.99%	3.69
Total (for which immigration status or race is known)	40,001	100.00%	384	100.00%	

Notes: One sample proportion t-test. T-statistics above 1.97 or below -1.97 are statistically significant.

Sources: Billings, *Vital Statistics of Boston and Philadelphia*, pp. 116-17; CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001.

Another concern about using a register of neglected children is that the children might have had poorer health than poor children in Boston let alone the average child in Boston. This concern can be tested by comparing the Marcella Street Home children with other, more or less contemporaneous populations of children. In the early 1870s, the physiologist Henry Pickering Bowditch conducted a study on the growth of Boston school children, incorporating the heights and weights of 13,691 boys and 10,895 girls. He reported the mean height and later calculated percentiles for his sample. Bowditch's sample included both children whose parents were native and children whose parents were foreigners with a specific comparison of children of parents of native origin and Irish origin. The sample also included a fairly wide range of occupations, though children whose fathers were skilled labourers, which included many middle class professions, or belonged to the mercantile professions were likely over-represented relative to unskilled labourers (Table 5.2).[42] However, Bowditch's sample does provide a good reference population with which to compare the neglected children in the Marcella Street Home.

Table 5.2: Origin of parents and father's occupations in the Bowditch sample of heights and weights of Boston school children in the 1870s.

Panel A: Origin of Parents in the Bowditch Sample						
	Boys		Girls		All Children	
	n	per cent	n	per cent	n	per cent
American Origin	4,327	31.60%	3,681	33.79%	8,008	32.57%
Irish Origin	5,235	38.24%	3,623	33.25%	8,858	36.03%
American and Irish Origin	570	4.16%	418	3.84%	988	4.02%
German	752	5.49%	585	5.37%	1,337	5.44%
One or Both English	1,061	7.75%	979	8.99%	2,040	8.30%
Other Foreign or Unknown Origin	1,746	12.75%	1,609	14.77%	3,355	13.65%
Total	13,691	100.00%	10,895	100.00%	24,586	100.00%

Panel B: Father's Occupations of Children in the Bowditch Sample						
	Native Fathers		Irish Fathers		All Fathers	
	n	per cent	n	per cent	n	per cent
Professional	386	9.50%	18	0.35%	404	4.40%
Mercantile	1,404	34.56%	428	8.34%	1,832	19.93%
Skilled Labour	1,655	40.73%	1,749	34.10%	3,404	37.03%
Unskilled Labour	618	15.21%	2,934	57.20%	3,552	38.64%
Total (where father's occupation known)	4,063	100.00%	5,129	100.00%	9,192	100.00%

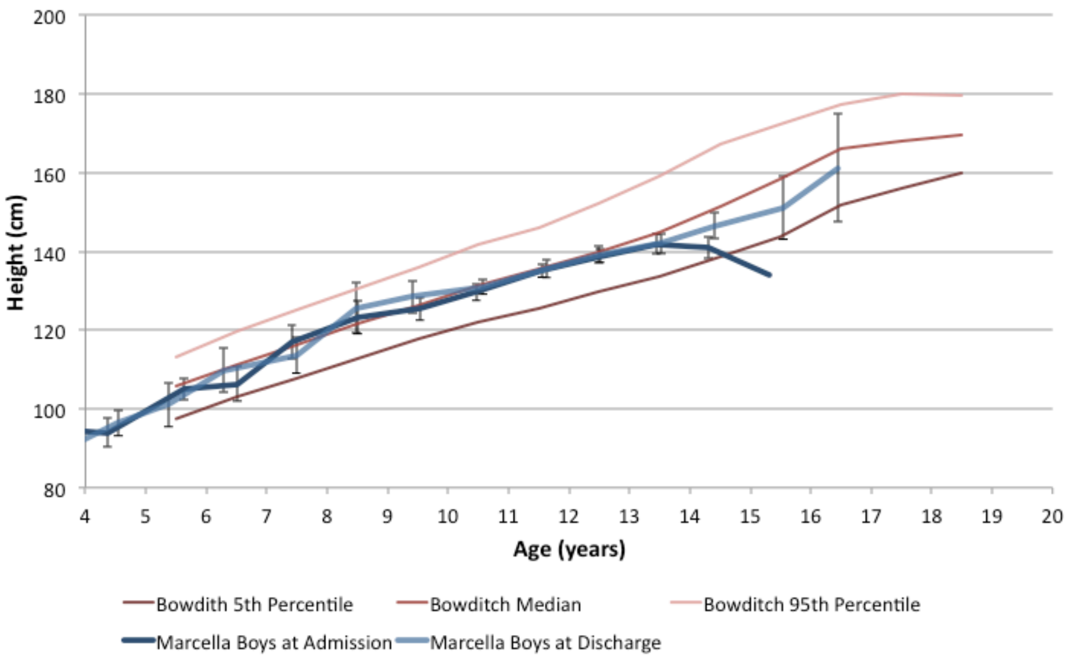
Sources: Bowditch, *Growth*, (1877), pp. 40-45; Bowditch, *Growth*, (1879), pp. 38-45.

Figures 5.1 and 5.2 graph the mean height of boys and girls upon admission and discharge from the Marcella Street Home with 95 per cent confidence intervals for each age against the median, 5th percentile and 95th percentile of height from the Bowditch sample. Surprisingly, the Marcella Street Home boys were at about the same height as the average schoolboy in Boston in the 1870s, and the girls were only slightly shorter than their middle class counterparts from the 1870s. Thus, the sentenced inmate children in the Marcella Street Home in the 1890s were not deprived relative to the Bowditch sample taken in the early 1870s. There are several possible explanations for this result. First, although the sentenced inmates had been neglected by their parents, they may have been more representative of the wider

[42] Bowditch, *Growth*, (1879), p. 35-36.

population of Boston children than the pauper inmates. However, a second and more likely possibility is that improving sanitation and hygiene and increasing income provided children with better health and nutrition shifting the distribution of children's heights upward between the 1870s and 1890s. Thus, although the sentenced inmates were about the same height as children in 1870s, they were still deprived relative to children in the 1890s.

Figure 5.1: Comparison of heights of boys in the Marcella Street Home (1889-98) with Bowditch's sample of Boston schoolboys measured in the 1870s.

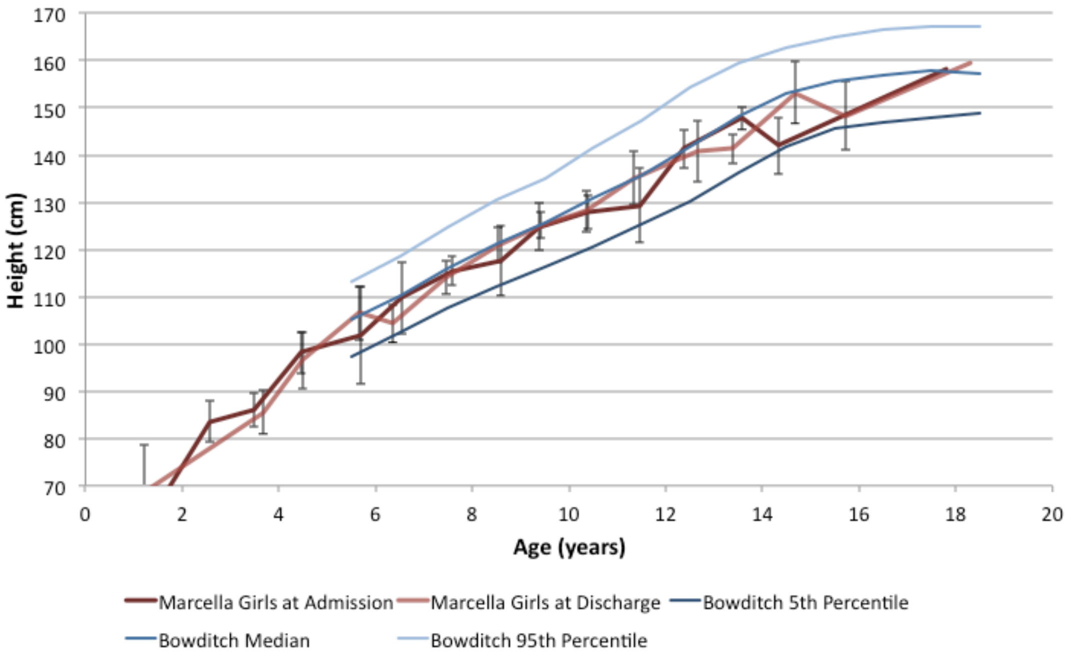


Notes: Error bars are 95 per cent confidence intervals for the mean height of boys at each age.

Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; Bowditch, *Growth of Children*, (1891), p. 482.

In the end, despite the selection bias in the Marcella Street Home sample, it seems unlikely that the selection would influence boys and girls differently. Likewise, there is no evidence in annual reports of the home or in other reports of the administration overseeing the home that girls were more mistreated than boys because of the abuse that they experienced. If there were any discrimination in the allocation of household resources or in the general treatment of girls, this would be the remnant of attitudes of the larger society or perhaps class that the children were a part of rather than a specific result of the abuse.

Figure 5.2: Comparison of heights of girls in the Marcella Street Home (1889-98) with Bowditch's sample of Boston schoolgirls measured in the 1870s.



Notes: Error bars are 95 per cent confidence intervals for the mean height of girls at each age.

Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; Bowditch, *Growth of Children*, (1891), p. 488.

5.2.2 The Ashford School of the West London School District, 1908-1916

The West London School District was founded in 1868 to accommodate poor children from the London parishes of Fulham, Hammersmith, Paddington, St. George and later Westminster. The school was a residential school housing up to 800 students located in Ashford, Middlesex well outside of London. The school sat on a 70-acre site, which included six acres for the buildings along with an attached farm. Boys and girls aged six and above were kept in separate wings of the main building at the school, and the rest of the younger children were housed in a separate building until November 1911 when the West London School District opened the Park School to house the younger children. There were two detached infirmaries, one for general diseases and the other for infectious diseases.[43] The board of managers employed a very large staff to supervise the children, educate them, maintain the buildings, and produce food on the farm.

The information on children resident in the Ashford School of the West London School District was drawn from the Medical Officer's Report Book, covering the years 1908 to 1916. Again, there is no indication why the institution began recording the children's anthropometric measures, but the administrators also never mentioned the measurements in the 2,000 pages of minutes during this period, so it seems that the figures were probably not adulterated. Overall, 1,914 children born between 1892 and 1909 were collected from the register. Height and BMI Z-scores could be calculated for 642 girls and 833 boys, 1475 in total, providing a larger and more robust sample than the Marcella Street Home. This sample decreased substantially when measuring longitudinal growth though because not all children were measured at discharge. The children's ages varied from 8 months to 18.31 years old with most falling between 5 and 15. The amount of time each child was resident in the Ashford school ranged from zero days to 8.98 years with an average of 1.46 years, slightly longer than the length of stay in the Marcella Street Home.

The children resident in the Ashford School were generally the children of workhouse inmates. The children were generally admitted into the school every two weeks, which meant that they could have been kept in a workhouse for several weeks before entry. Unfortunately, there is even less information about the children's parents than there was for the Marcella Street Home. The only data that was included in the Medical Officer's Report Book was the child's name, parish of residence, and

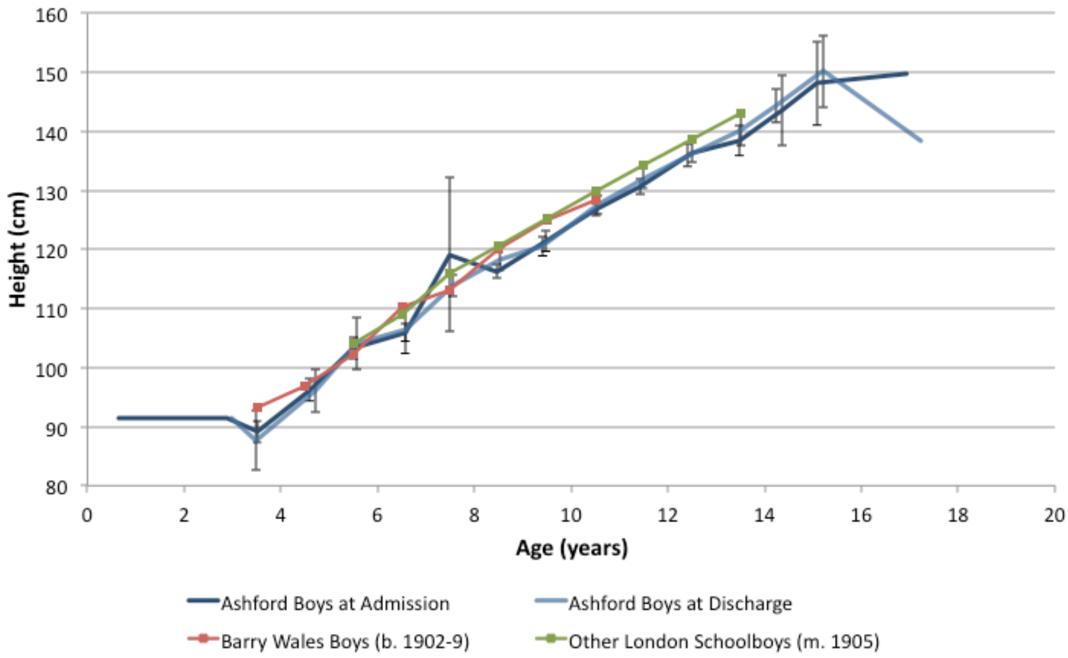
[43] Monnington and Lampard, *Poor*, pp. 8-9; LMA, Signed Minutes of the Board of Management (SMBM) 1911, WLSD/27, pp. 177-8.

biometric measurements. There is slightly more information about the children available in other registers collected by the Ashford School administration, but they do not include the most telling variables such as father's occupation and linking the two registers would require a lot of effort. Other studies on the workhouse though can provide a first glance at what the characteristics of these children were. Workhouse children tended to be orphans, deserted children, illegitimate children or children whose parents were also in the workhouse.[44] They were representative of the working poor of West London generally.

It is also possible to compare the anthropometric measures of the children in the Ashford School with their contemporaries. Figures 5.3 and 5.4 compare the heights of boys and girls in the Ashford School with age cohorts of children measured in Barry, Wales, a leading coal port in Britain and in London. E. G. Habakkuk examined the medical cards of elementary school children born between 1902 and 1909, presenting the average heights of boys and girls at each age. His sample was quite substantial with 5,819 boys and 5,504 girls measured.[45] Cameron reports the average heights of 18,686 school children measured in London in 1905.[46] A comparison between the Barry, London and Ashford School children suggests that the Ashford children were somewhat shorter than their Welsh and Londoner counterparts, though the gap was really quite small, especially when both are compared relative to modern standards. The small difference between the Ashford children and the other samples suggests that while the children in the Ashford School were somewhat smaller, they were not completely destitute. Unfortunately, with the limited information available about the children in the Ashford School, this is the most sophisticated analysis of representativeness that can be completed.

[44] Wood, *Poverty*, pp. 98-100.
[45] Habakkuk, 'Statistical Study', pp. 295-98.
[46] Cameron, 'Growth', p. 507.

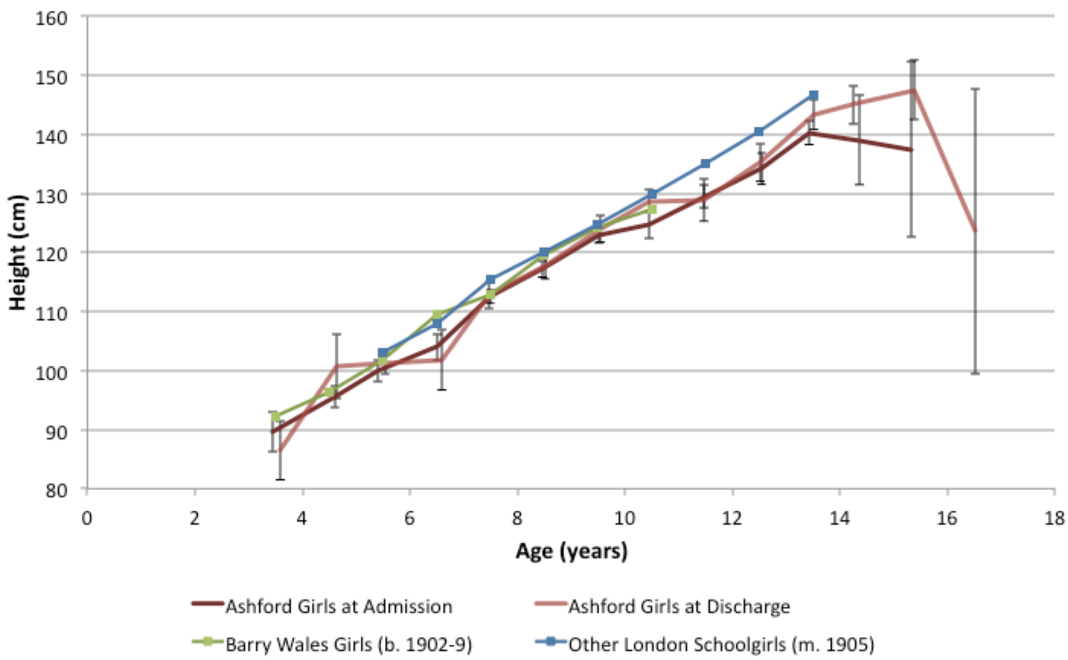
Figure 5.3: Comparison of heights of boys in the Ashford School (1908-16) with samples of schoolboys from Barry, Wales (1902-9) and London (1905).



Notes: Error bars are 95 per cent confidence intervals for the mean height of boys at each age.

Sources: LMA, West London School District, Medical Officer's Report Book, WLSD/435; Habakkuk, 'Statistical Study', p. 300; Cameron, 'Growth', p. 514.

Figure 5.4: Comparison of heights of girls in the Ashford School (1908-16) with samples of schoolgirls from Barry, Wales (1902-9) and London (1905).



Notes: Error bars are 95 per cent confidence intervals for the mean height of girls at each age.

Sources: see figure 5.3.

5.3 Growth References, Growth Curves and Measuring Catch-up Growth

5.3.1 The 2006/7 World Health Organization's (WHO) Growth References

In order to compare the growth of children across countries and time periods, it is necessary to compare the children's anthropometric measures not only with contemporary populations but also with modern standards or references for the growth of children living under optimal conditions. In this dissertation, I will rely upon the World Health Organization (WHO)'s 2006 growth standards for preschool children ages 0-5 and the 2007 WHO growth references for preadolescent and adolescent children ages 5-19 in order to compare the relative deprivation of children and to understand how children's growth patterns were different historically than the ideal today.

There has been much debate over the last fifty years about whether an international, prescriptive growth standard is realistic and useful.[47] Growth *standards* are meant to be prescriptive, to indicate the rate and level of growth of children 'that has been associated empirically with specified health outcomes and the minimization of long-term risks of disease'. Growth *references*, on the other hand, represent the growth of a specific population and are meant merely as a point of comparison rather than as a recommendation for growth. The general consensus in the medical profession is that young children's growth does not vary across sub-populations, so it would be possible to construct a growth standard for children at all ages by sex.[48] This has been strongly affirmed for children under the age of 5 by the WHO Multicentre Growth Reference Study (MGRS), which compared the growth of children aged 0-5

[47] Eveleth and Tanner, *Worldwide Variation*, pp. 15-16; Butte *et al.*, 'Evaluation', pp. s170-s171; Wang *et al.*, 'Limitations', pp. s180-s182; Seidell *et al.*, 'Cross-sectional Growth References', pp. s189-s191; Haas and Campirano, 'Interpopulation Variation', pp. s212-s216.

[48] Butte *et al.*, 'Evaluation', p. s171, quote p. s171.

in Brazil, Ghana, India, Norway, Oman and the US.[49] However, the consensus is more disputed for children over the age of five. Eveleth and Tanner challenged this in both editions of their book *Worldwide Variation in Human Growth*, arguing that people of East Asian origin (Japanese people form the reference category) reach puberty earlier than European and African populations and end up shorter overall.[50] However, it is not clear whether the reference populations used by Eveleth and Tanner are really comparable, especially since all three populations were still experiencing a secular increase in height at the time of measurement. Haas and Campirano tried to eliminate this problem by comparing only the tallest subsample of populations around the world. They still found that East and South Asians were shorter than the 1977 NCHS reference and Northern Europeans were taller.[51] This does suggest that there may be some differences in the growth pattern and final height potential across human subpopulations. However, the children studied in this chapter are almost exclusively European or Americans of European descent, so using the WHO growth references should not pose methodological problems.

In the past, most historians have relied upon the 1977 United States National Center for Health Statistics (NCHS) reference for infant, preschool, preadolescent and adolescent children. The Center for Disease Control (CDC) normalised these NCHS charts, and these CDC adaptations were recommended by the WHO for use as an international reference for child growth in 1978.[52] These standards form the basis of Steckel's calculations of height percentiles for children in historical populations published in *Historical Methods*.[53] Steckel modified the 1977 NCHS reference for historical populations for two main reasons. First, historical populations faced greater

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[49] WHO MGRS, 'Assessments'; and see also Habicht *et al.*, 'Height and Weight Standards'.
[50] Eveleth and Tanner, *Worldwide Variation*, pp. 180-4.
[51] Haas and Campirano, 'Interpopulation Variation', pp. s215-8; Butte *et al.*, 'Evaluation', p. s171.
[52] Wang *et al*., 'Limitations', p. s176.
[53] Steckel, 'Percentiles'.

deprivation than modern populations and were therefore clustered in the lower percentiles. He therefore provided percentiles below the 5th percentile, which was the lowest presented in the 1977 NCHS references. He also provided standard deviations for heights at specific ages so that exact percentiles could be calculated under assumptions of normality instead of using linear interpolation between percentiles, which was commonly done before. Second, Steckel adjusted the variance of the height distributions, following Healy (1962) because the ages of children in historical populations are often grouped in one-year age categories, which would naturally have greater variances than exact age estimates. These differences were more important in infancy and early childhood than in adolescence because children grow fastest early in life and the variance on their growth is smaller before the adjustment.[54]

Despite Steckel's careful work with the 1977 NCHS references, I believe it is best to incorporate the 2006/7 WHO standard/reference unadjusted.[55] These references differ from the 1977 references in a number of ways. Steckel began his percentiles with children aged three, but because the samples employed in this chapter contain younger children, I will discuss the development of the infant and early child growth standards. The NCHS growth standard for infants and children aged 0-23 months developed in the late 1970s was based on the Ohio Fels Research Institute Longitudinal Study from 1929-75. The children in the study were similar in terms of socioeconomic, genetic and geographic factors and were also fed primarily on infant formula during early development.[56] These infant and early child NCHS growth standards were criticized for focusing only on Americans of European descent in one community. In addition, children in the Fels study were only measured every three

[54] Steckel, 'Percentiles', pp. 158-61.
[55] Steckel's variance adjustment is not required for the data presented in the chapter because the children's birthdates were included in the documents, allowing their exact age to be calculated.
[56] de Onis and Yip, 'WHO Growth Chart', pp. 75-6; de Onis *et al.*, 'Time'.

months, which was not considered frequent enough to capture the state of growth in infancy. The statistical techniques used for smoothing had also become out-dated, and curves reflecting the growth of breast-fed children were preferred.[57] In order to overcome these problems, the WHO established and implemented the Multicentre Growth Reference Study (MGRS) between 1997 and 2003. The MGRS surveyed children in socioeconomic conditions favourable to growth aged 0-5 years in six countries: Brazil, Ghana, India, Norway, Oman and the US. The MGRS collected longitudinal anthropometric measures for 1,737 children at 21 points in the first 24 months and cross-sectional anthropometric data for 8,440 children aged 18-71 months.[58] In addition, the most advanced smoothing techniques were employed to set the percentiles and Z-scores.[59] Because of the inclusion of multi-ethnic sample sites, a strict longitudinal structure for early ages, and the precision of the smoothing techniques employed, the new 2006 WHO Child Growth Standard presents a marked improvement on the earlier NCHS standard and seemed appropriate to use for comparisons with historical populations.

The growth reference for school-age children and adolescents changed less drastically between 1977 and 2007. Both references are based on the same data drawn from three separate samples of non-obese US children taken from 1960-1975.[60] Beginning in the mid 1990s, scholars had called for a school-age and adolescent reference that incorporated non-stunted, healthy samples from a number of countries rather than just relying on the US data. Although, as mentioned above, the consensus opinion confirmed by the WHO Multicentre Growth Reference Study was that subpopulations had similar growth patterns, especially before the age of five, many

[57] WHO, *WHO Child Growth Standards*, pp. 1-2; de Onis and Yip, 'WHO Growth Charts', pp. 77-82.
[58] WHO, *WHO Child Growth Standards*, pp. 3-5.
[59] WHO, *WHO Child Growth Standards*, pp. 7-10.
[60] Wang *et al.*, 'Limitations', p. s177; de Onis *et al.*, 'Development', p. 660-1; de Onis and Yip, 'WHO Growth Chart', p. 76.

studies suggested that there could be differences between growth patterns across subpopulations for children over five.[61] de Onis *et al.* attempted to find additional datasets from around the world when constructing the 2007 school-age and adolescent growth references, but the heterogeneous methodologies of the studies made it impossible to combine them and still maintain consistency with the 2006 infant and preschool-age growth standards. Therefore, they continued to only use the US data. In addition, both growth references for 5-18 year olds are based on cross-sectional rather than longitudinal data. Therefore, the reference 'does not express growth as a velocity percentile – it gives no clue as to whether or not a given rate of percentile crossing is unusual; there is no adjustment for regression to the mean, whereby smaller children tend to grow faster; and the rapid changes in velocity due to puberty and variability in timing of puberty are not captured by cross-sectional data'.[62] Most scholars would have preferred that the 2007 reference combine both cross-sectional and longitudinal data, but again this was not possible given the paucity of longitudinal studies spanning the ages 5-18.[63] Although there are some problems with using only cross-sectional data to construct the growth references, most experts appear to take a more optimistic position about the references than Wang *et al*. The WHO 2006/7 references have been widely accepted around the world as a benchmark for rich, healthy children as well as poor, malnourished children and have often been used to measure catch-up growth.[64]

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[61] Butte *et al.*, 'Evaluation', pp. s170-1; Wang *et al.*, 'Limitations', pp. s180-2; Seidell *et al.*, 'Cross-sectional Growth References', pp. s196-8; Haas and Campirano, 'Interpopulation Variation'; WHO MGRSG, 'Assessment'.

[62] Wang *et al.*, 'Limitations', pp. s177.

[63] de Onis *et al.*, 'Development', pp. 660-1.

[64] The WHO 2006/7 growth references have been endorsed by the European Childhood Obesity Group, the International Pediatric Association, the UN Standing Committee on Nutrition, and the International Union of Nutrition Science. See also Butte *et al.*, 'Evaluation'; Wang *et al.*, 'Limitations'; Ulijaszek, 'International'; Eveleth and Tanner, *Worldwide*, pp.15-16; Adair, 'Filipino Children'; Dercon and Singh, 'Nutrition'; Singh *et al.*, 'School Meals'.

The new 2007 WHO references for school-age children and adolescents have three main advantages. First, although percentiles are more readily understood by the average, non-statistical historian and the public, Z-scores are a much better method for measuring anthropometric differences from modern standards. Z-scores provide a continuous rather than ordinal variable; as Steckel notes, they can easily capture the extremes of a distribution that would be difficult to capture using percentiles; they can be compared easily across age and sex; and finally, Z-scores are a better measure of longitudinal growth over time than percentiles. It should also be noted that a one unit increase in Z-scores reflects a constant absolute change in anthropometric indicators, while a one percentile increase has different absolute values depending on where the percentile is in the distribution.[65] Second, the cut-off points for stunting, underweight, overweight, and obese in the early NHCS references changed at different ages and were sometimes measured in percentiles and sometimes in Z-scores. This meant that children who would be considered underweight at age 9.99 might be considered within a normal range at age 10.01.[66] The new WHO growth standards were developed so that both the infant and early child standard and the school-age and adolescent reference used the same cut-off points for stunting, underweight, overweight, and obesity across all ages and so that the infant and early child growth standard would transition more or less seamlessly with the school-age and adolescent reference.[67] Finally, because the 1977 NCHS reference was based on children from the United States, the thresholds for overweight and obese were set too high for global populations. This also meant that the threshold for underweight was set too high, overestimating the number of children at risk.[68] The new WHO

[65] Wang *et al.*, ‘Limitations’, p. s180; Steckel, ‘Percentiles’, p. 158.
[66] Wang *et al.*, ‘Limitations’, pp. s179-80.
[67] de Onis *et al.*, ‘Development’, pp. 663-664.
[68] Wang *et al.*, ‘Limitations’, pp. s182-s184.

standard/reference adjusts for this, lowering the absolute cut-off points, and also uses BMI-for-age as the primary indicator of underweight or overweight rather than the confusing weight for height measures used in the 1977 NCHS standards.[69]

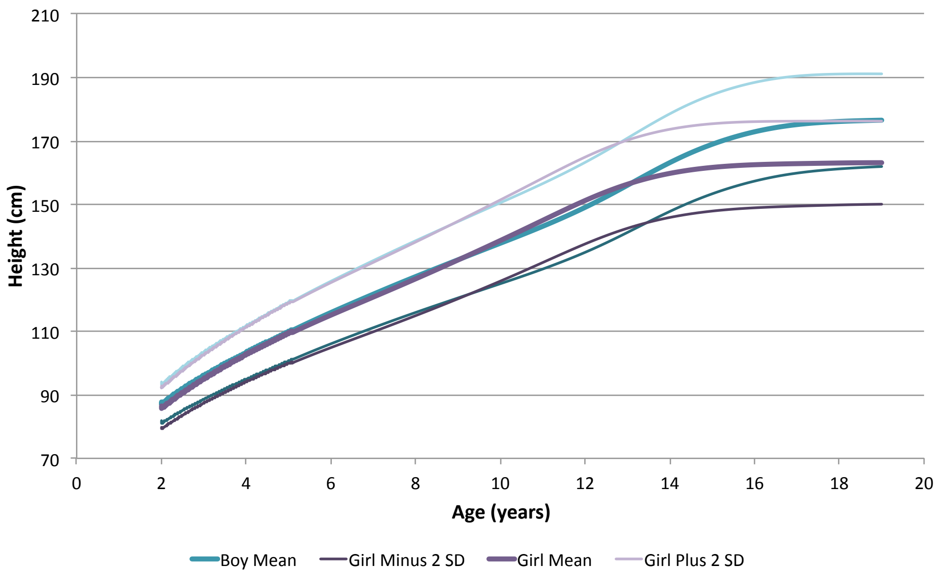
5.3.2 Height, Weight and BMI Growth Curves for Boys and Girls

Figure 5.5 shows the WHO growth curve for height across the range of growing ages. It suggests that on average boys and girls have similar heights until girls begin to overtake boys during their pubertal growth spurt. The boys then overtake girls later on when they experience their own pubertal growth spurt. The timing of these growth spurts is more easily discerned when looking at a graph of height intervals over time, i.e. the growth between one-year cohorts in cross-section (Figure 5.6). From these figures it is clear that girls experience a pubertal growth spurt beginning around age seven, peaking around age eleven and declining swiftly thereafter. Boys have a later, more distinctive pubertal growth spurt, which begins around age ten, reaching its peak at age 13 and declining thereafter. As was mentioned in the previous chapter, the timing of these growth spurts tends to be delayed in malnourished populations and will be of interest when measuring catch-up growth later in the paper. It is important to note that the growth intervals in Figure 5.6 are measured using cross-sectional rather than longitudinal measurements of children's heights. If individual children had been measured longitudinally, there would have been a more pronounced acceleration of growth during the pubertal growth spurt. Thus, the more gradual growth spurt for girls in the cross-sectional

[69] de Onis *et al.*, 'Development', pp. 664-665.

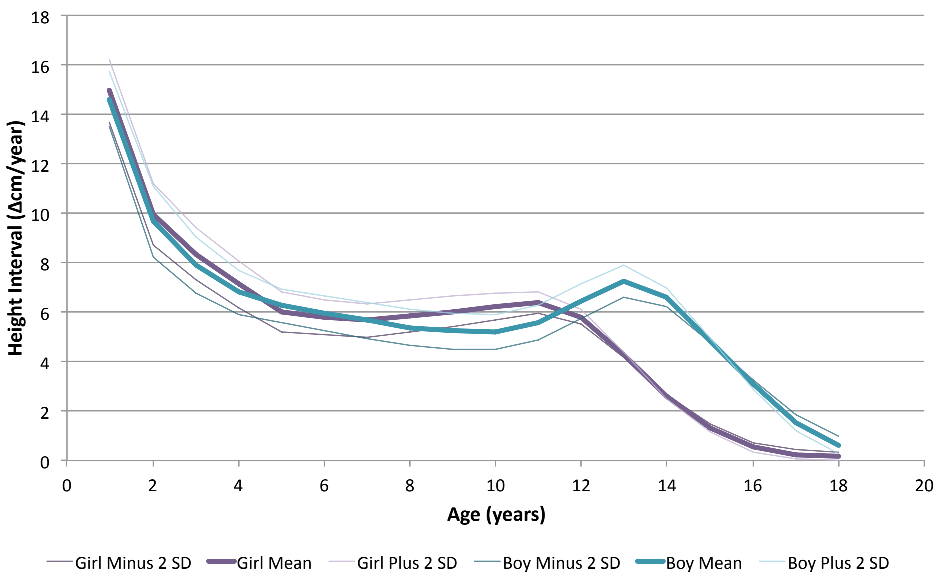
height interval graphs reflects higher variance in the timing of the pubertal growth spurt rather than a slower, less distinct growth spurt than men.[70]

Figure 5.5: WHO 2006/7 height-for-age standards for modern, healthy children. Mean heights with standard for +2 and -2 standard deviations around the mean.



Sources: de Onis *et al.*, 'Development'; WHO, *WHO Child Growth Standards*; data drawn from http://www.who.int/growthref/en/.

Figure 5.6: Growth velocity (height intervals) for modern children according to the WHO 2006/7 growth references.



Sources: de Onis *et al.*, 'Development'; WHO, *WHO Child Growth Standards*; data drawn from http://www.who.int/growthref/en/.

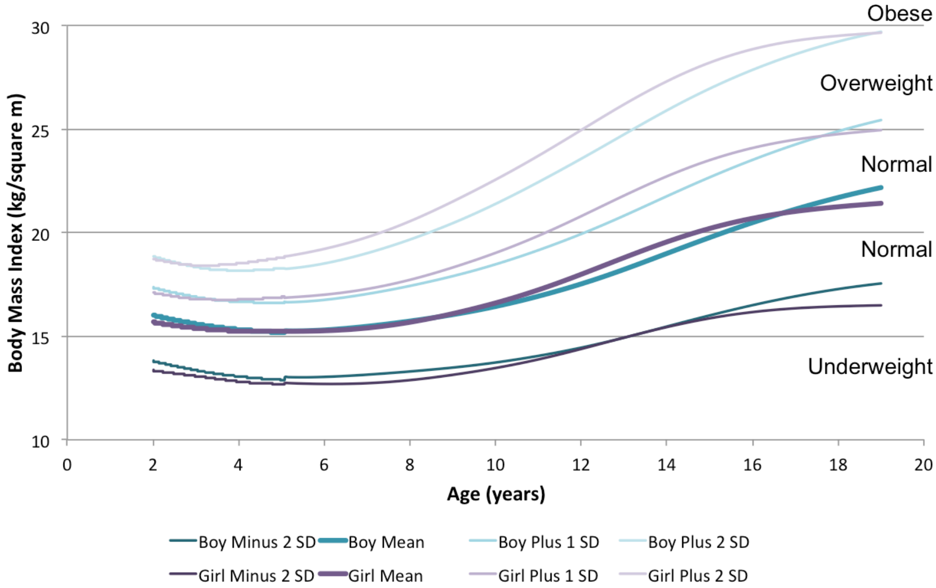
[70] Eveleth and Tanner, *Worldwide Variation*, p. 10; Cole, 'Statistical Considerations', p. s242.

The WHO also defined weight-for-age standards for children up to age ten. After age ten the relationship between weight and age is no longer straightforward or useful as a measurement of deprivation. The curves generally increase over time, but otherwise have fewer problems with interpretation than the height-for-age standards. The BMI-for-age WHO growth references are more complicated. As can be seen in Figure 5.7, BMI-for-age standards decline until the age of 3.5 to five and then increase thereafter. The nadir of these curves is called the adiposity rebound, the point at which children begin putting on weight relative to height. The BMI standards are designed so that children with a BMI-for-age that is two standard deviations below the mean are considered underweight. Children between two standard deviations below the mean and one standard deviation above the mean are considered to have a normal BMI-for-age. Children between one standard deviation above the mean and two standard deviations above the mean are considered overweight, and children over two standard deviations above the mean are considered to be obese. The growth references for these three measures, then, will form the basis of the analysis conducted in the rest of the dissertation.

5.3.3 Catch-up Growth through the Life of Daniel O'Brien

Traditionally, when anthropometric historians have measured children's growth in the past they have either studied pooled cross-sectional data of children's heights or they have analysed the aggregate statistics published by experts. Steckel pioneered these methodologies to study slave children as we have seen in the previous chapter, but they were quickly applied in Britain as well. Floud *et al.* studied boys enlisted in the Marine Society in London and in the elite military academy of

Figure 5.7: WHO 2006/7 BMI-for-age standards for modern, healthy children.



Sources: de Onis *et al.*, 'Development'; WHO, *WHO Child Growth Standards*; data drawn from http://www.who.int/growthref/en/.

Sandhurst from the mid-eighteenth to mid-nineteenth centuries.[71] Likewise, Harris used the aggregate statistics on children's stature recorded for certain ages in the school medical officers' report books around Britain to study children's health in the twentieth century as was already mentioned above.[72] In these initial studies and in follow ups, the authors tracked changes in stature at particular ages over time and compared the children's height to modern standards for growth. More recently, Hatton and his co-authors have used Harris's panel data on children's heights as well as the Boyd-Orr sample collected for 1937-39 to analyse the influence of the disease environment and family size on child health.[73] These studies have provided some interesting findings about the secular trends in stature over time and the multi-causal factors influencing growth, but they have been limited by the cross-sectional nature of the data. This study is unique, then, because it makes use of longitudinal

[71] Floud *et al.*, *Height*, pp. 163-182.
[72] Harris, *Health*, pp. 84-89.
[73] Hatton, 'Infant Mortality'; Hatton and Bray, 'Effects'.

measurements of children's heights and weights, which allows us to make better inferences about growth.

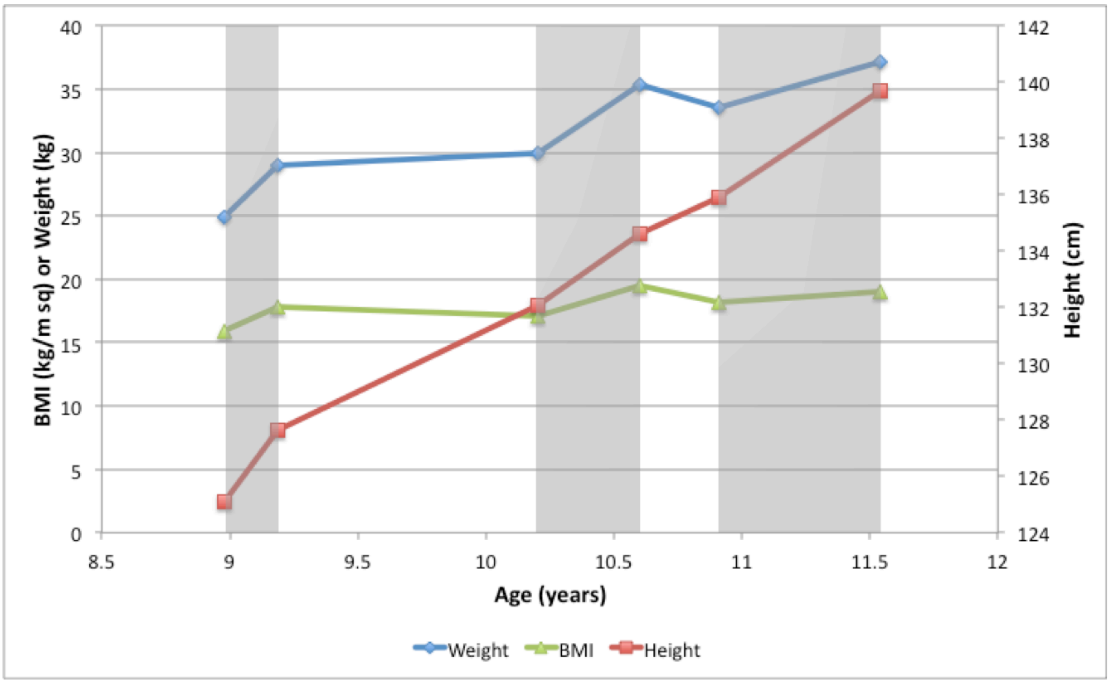
The focus of the chapter is to measure the catch-up growth in terms of height, weight, and BMI experienced by children in the two schools. As mentioned in the previous chapter, there are three types of catch-up growth. Type A catch-up growth is a period of faster than normal growth that occurs when children who are malnourished or exposed to chronic diseases are moved into a better nutritional and disease environment. For type A catch-up the degree of catch-up growth depends on the length of the intervention and on the relative deprivation of the child before the intervention.[74] Type B catch-up growth, discussed at length in the previous chapter, occurs when growth continues at normal rates beyond the growing years of modern populations, allowing children to grow closer to modern standards. Type C catch-up growth is a combination of type A and type B.[75] This chapter will only measure type A catch-up growth because the children are not observed at adulthood, so there was no way of measuring their type B catch-up growth.

Perhaps an example of a child in the Marcella Street Home will help to clarify a typical pattern of catch-up growth? As shown in Figure 5.8, Daniel O'Brien entered and left the Marcella Street Home three times between 1892 and 1894 (the grey shaded periods). When looking at his absolute height, weight, and BMI, Daniel gained weight while in the home and lost weight while outside of the home; the same is true of BMI. In terms of height, his height continued to increase across the observable period, but his height growth was faster while in the Home than outside of the Home. All of this evidence suggests that Daniel was experiencing catch-up

[74] Adair, 'Filipino', p. 1140-1141; Tanner, 'Catch-up'; Eveleth and Tanner, *Worldwide*, pp. 192-193; Gluckman and Hanson, 'Consequences', p. 9; Prentice *et al.*, 'Critical Windows', p. 915.

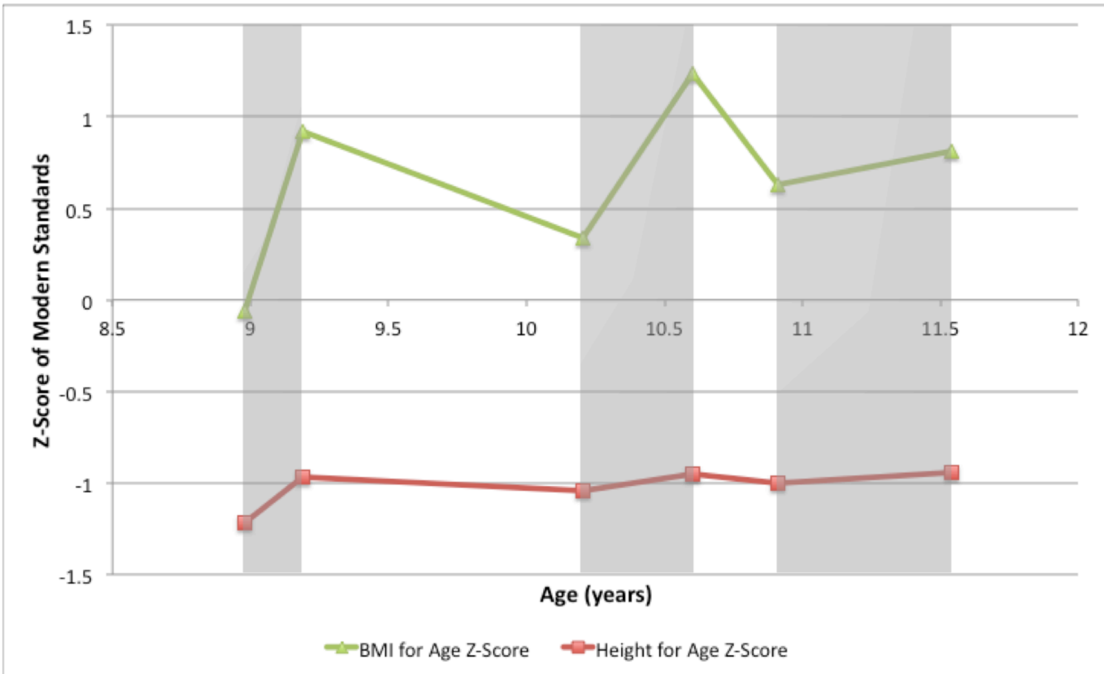
[75] Boersma and Wit, 'Catch-up Growth', pp. 647-648.

Figure 5.8: Height, weight and BMI growth of Daniel O'Brien in the Marcella Street Home, Boston Massachusetts, 1892-4.



Sources: City of Boston Archives (CBA), Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001.

Figure 5.9: Height and BMI growth as Z-scores of modern standards of Daniel O'Brien in the Marcella Street Home, Boston Massachusetts, 1892-4.



Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001.

growth inside of the Home. We can refine these patterns by expressing Daniel's growth in terms of Z-scores of modern standards (Figure 5.9). Unfortunately, only his height and BMI-for-age Z-scores can be calculated because weight-for-age Z-scores do not extend beyond age ten. Expressing Daniel's growth in Z-scores of modern standards makes the previous pattern even clearer. Daniel's height increased relative to modern standards while he was in the home and decreased while he was outside the home. The changes in BMI-for-age were even greater with Daniel experiencing nearly a one standard deviation of modern standards increase in BMI-for-age during his first stay in the Marcella Street Home. Daniel's figures show strong evidence that there could be catch-up growth among children in the Marcella Street Home and by extension in the Ashford School.

5.4 Preconditions for Catch-up Growth

In order for catch-up growth to occur there are two key preconditions. First, the children must be substantially below modern standards before the catch-up period begins. Second, there must be a positive intervention that improves nutrition and decreases the disease load allowing catch-up growth to occur. The rest of the paper introduces the datasets, explains that these preconditions are met, and establishes that children were catching-up to modern standards. Importantly, it measures differences in catch-up growth between boys and girls.

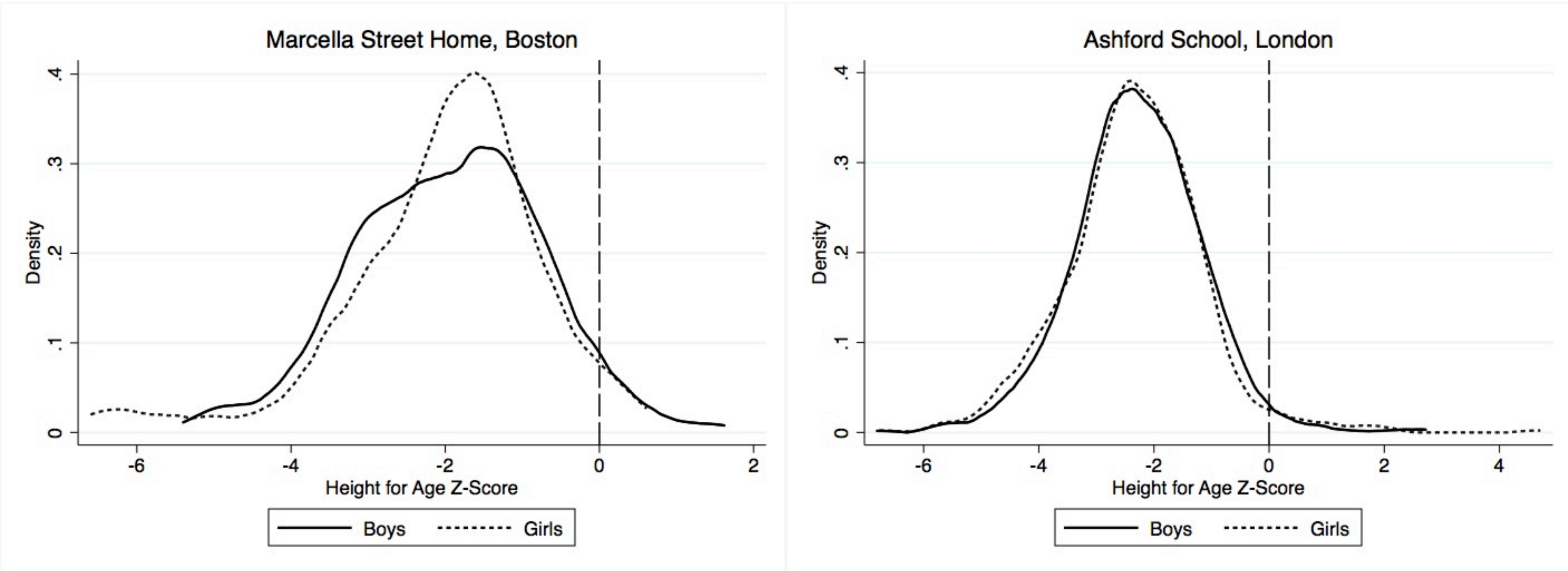
5.4.1 Relative Deprivation of Children

Before discussing the longitudinal growth of children in the Ashford School and Marcella Street home, it is first necessary to understand how the children compare to modern children. The children's growth was different in two key aspects than modern populations: the absolute level of height or weight at any given year was lower and the children also seemed to follow a different growth curve both in terms of BMI and height.

Figure 5.10 shows the raw distributions of boys and girls heights at admission to both institutions as Z-scores of modern standards (table 5.3 presents the descriptives). In both the Ashford School and the Marcella Street Home, the mean Z-scores of children's heights for age were at or slightly below two standard deviations below the mean of modern standards. In other words, with a median Z-score of -2.3, half of the children in the Ashford School had levels of height-for-age that would only occur in the bottom one per cent of a modern population. These children were clearly very deprived. The distributions of boys and girls were very similar in the Ashford School but were different in the Marcella Street Home. This difference in the Marcella Street Home is not driven by the boys sentenced for truancy who had a different socioeconomic background than the other children because the distributions remain different if these children are removed.

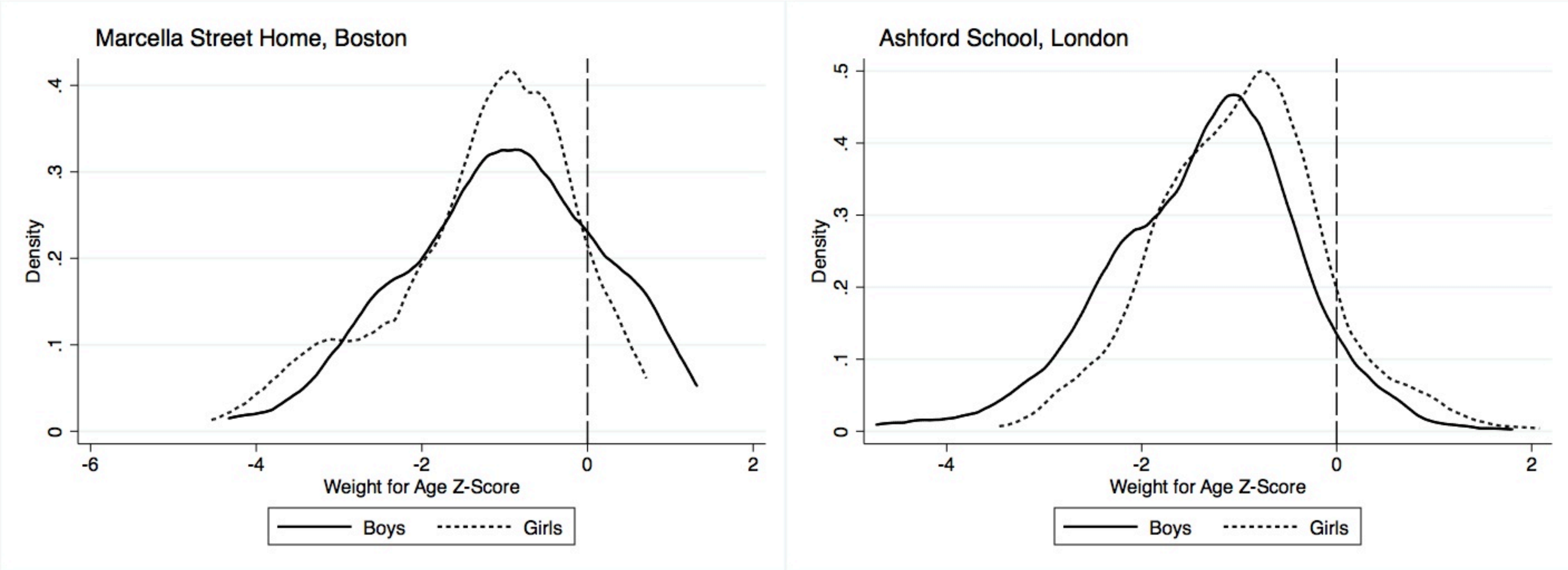
The children were also behind modern standards in terms of weight-for-age, which could only be calculated for children under 10 years old because the reference becomes less useful after that point. Figure 5.11 displays the distribution of weight-for-age Z-scores for boys and girls in both schools. For weight-for-age the means of the distributions were at or slightly below -1, suggesting that the children were better off in terms of weight-for-age than they were for height-for-age. However, they were still deprived relative to modern standards and might have been expected to make a catch-up in weight-for-age scores.

Figure 5.10: Height-for-age Z-score distributions for children at admission to each school.



Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; London Metropolitan Archives (LMA), West London School District, Medical Officer's Report Book, WLSD/435.

Figure 5.11: Weight-for-age Z-score distributions for children at admission to each school.



Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; LMA, West London School District, Medical Officer's Report Book, WLSD/435.

Table 5.3: Descriptive statistics for anthropometric measures at admission of children in the Marcella Street Home and Ashford School as Z-scores of WHO 2006/7 references.

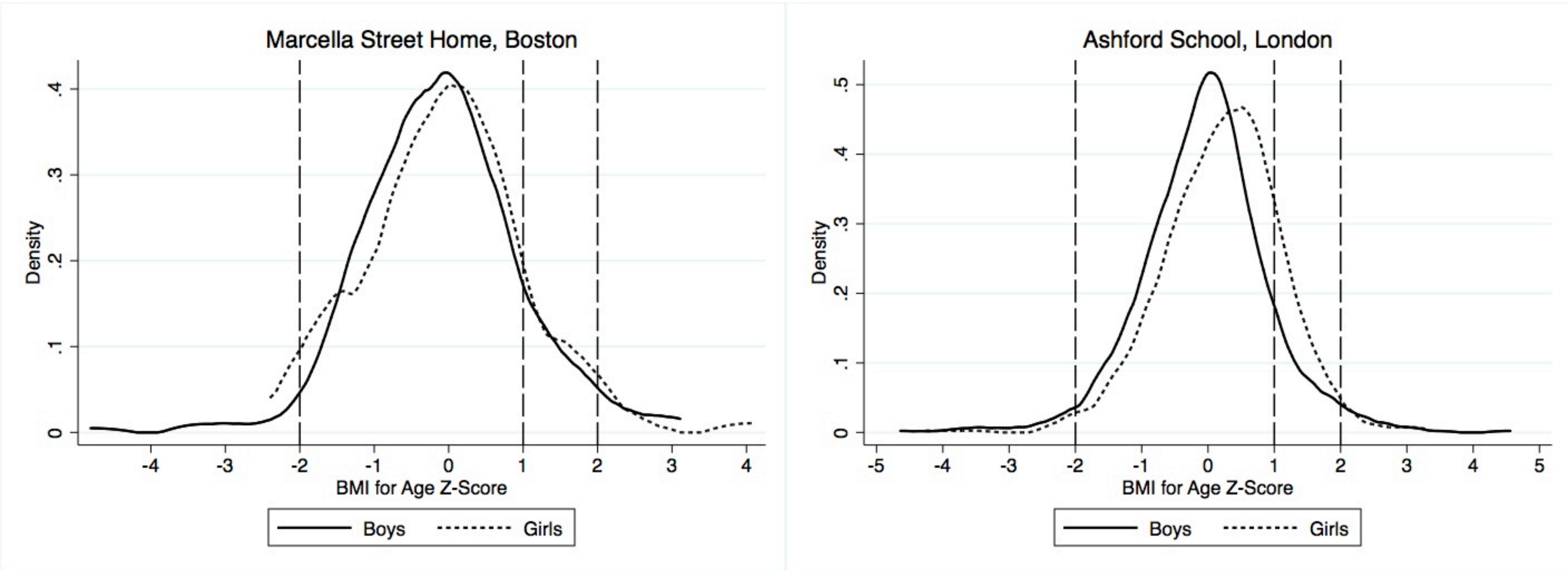
	Marcella Street Home, Boston		Ashford School, London	
	Boys	Girls	Boys	Girls
Height-for-age Z-Score				
mean	-1.95	-2.07	-2.26	-2.37
% over zero	4.10%	2.94%	1.96%	2.54%
Weight-for-age Z-Score				
mean	-1.02	-1.270	-1.35	-0.99
% over zero	23.81%	11.84%	5.98%	10.76%
BMI-for-age Z-Score				
mean	-0.11	0.03	-0.08	0.21
% under -2 (underweight)	2.46%	2.94%	1.59%	1.27%
% between -2 and +1 (normal)	84.83%	82.36%	87.87%	81.42%
% between +1 and +2 (overweight)	9.84%	10.78%	8.33%	15.56%
% over +2 (obese)	2.87%	3.92%	2.21%	1.75%

Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; London Metropolitan Archives (LMA), West London School District, Medical Officer's Report Book, WLSD/435.

Finally, in terms of BMI-for-age, the children in both schools were mostly in the normal BMI range between two standard deviations below the mean and one standard deviation above the mean (Figure 5.12). In addition, ten to fifteen per cent of children were classified as overweight or obese. The means of the distributions were close to zero. Thus, the evidence on BMI-for-age, if read naively, suggests that the children in both schools were healthy. We would therefore not expect to find catch-up in BMI.

However, there are several reasons why this evidence should not be interpreted in such a straightforward manner. First, BMI (weight in kilograms divided by height in meters squared) as a measure is not able to distinguish the composition of the body that leads to higher weight. Muscle and bone are denser than fat tissue, so if these children weighed more relative to their height because they had built up a lot of muscle tissue through working, a heavier BMI would not necessarily mean that the

Figure 5.12: BMI-for-age Z-score distributions for children at admission to each school.



Notes: The dashed vertical lines show the cut off points for different weight categories: under -2 is underweight, -2 to 1 is normal, 1 to 2 is overweight, and over 2 is obese.

Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; LMA, West London School District, Medical Officer's Report Book, WLSD/435.

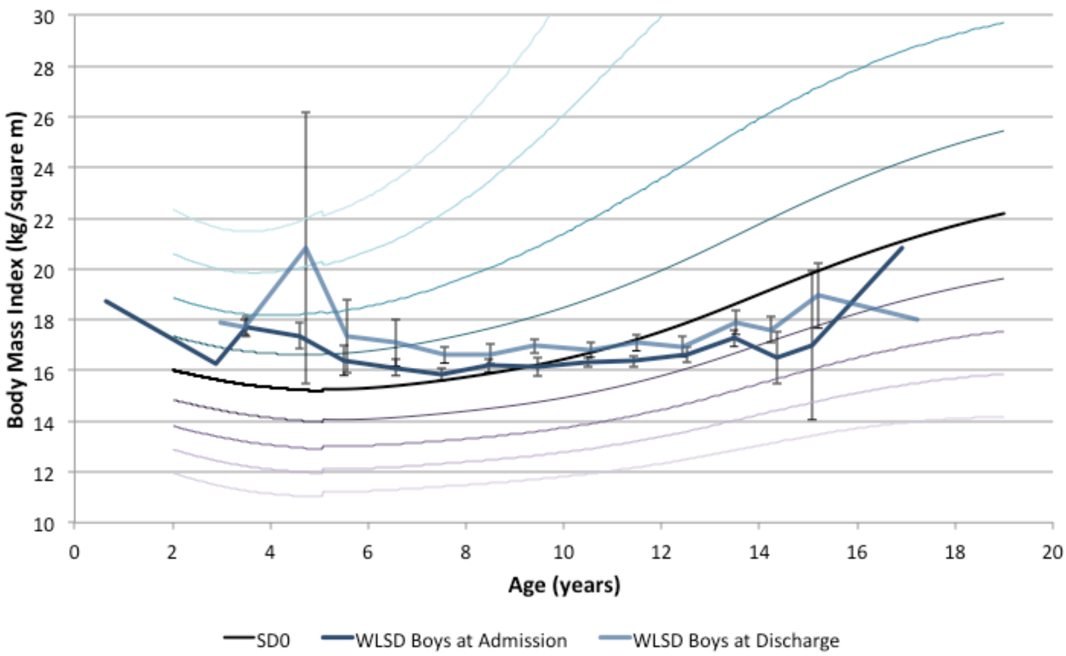
children had the high body fat percentages that we now associate with overweight and obese individuals. Second, BMI is a good measure of welfare for adults who have stopped growing because their heights, the denominator in the BMI calculation, do not change. Thus, changes in BMI only reflect changes in their mass, not their height. However, children grow in both measures. This is partially what gives the BMI growth curve its strange shape (see the previous chapter); mean BMI-for-age decreases to the adiposity rebound around age five in modern populations and then begins increasing thereafter. If a child had a sudden spurt of growth, such as catch-up growth, their BMI would likely decrease even though their growth spurt would be a very good sign that they were in good health. Thus, the interpretation of BMI levels and changes in BMI for children is not as clear or intuitive as similar levels and changes in height and weight.

Finally, the interpretation of BMI-for-age is complicated because it appears that children in history may have had a different BMI growth curve than children growing up in the late twentieth century. The BMI growth curves for children in the Ashford School and Marcella Street Home compare well with the BMI growth curves collected by some of the first anthropometricians of the late nineteenth century, Henry Pickering Bowditch and the anthropometric committee in Britain.[76] The mean BMI of historical children tended to be above the mean BMI of modern standards until the age of ten or eleven when it permanently fell below modern standards (Figures 5.13-5.14). The curves thus tended to be quite flat with the only increases in BMI taking place after the age of 15. In addition, the adiposity rebound, the nadir of the mean BMI growth curve, took place later in historical populations at around age seven or eight. The differences between the historical and modern BMI growth curve are

[76] Bowditch, 'Growth', (1891), pp. 482, 485, 489, 491; Farr *et al.*, 'Report', p. 180.

particularly problematic because they suggest that there might be differences in the measured BMI growth in the short run and the long run. In the short run, children could put on a substantial amount of weight in a relatively short period of time in anticipation of gains in height, increasing their BMI. But if children are only observed in the long-run, as is often the case in this chapter, then their BMI growth relative to modern standards would likely be negative.

Figure 5.13: Comparison of modern BMI-for-age growth curves with the observed BMI-for-age cross-sectional growth curves for boys in the Ashford School.

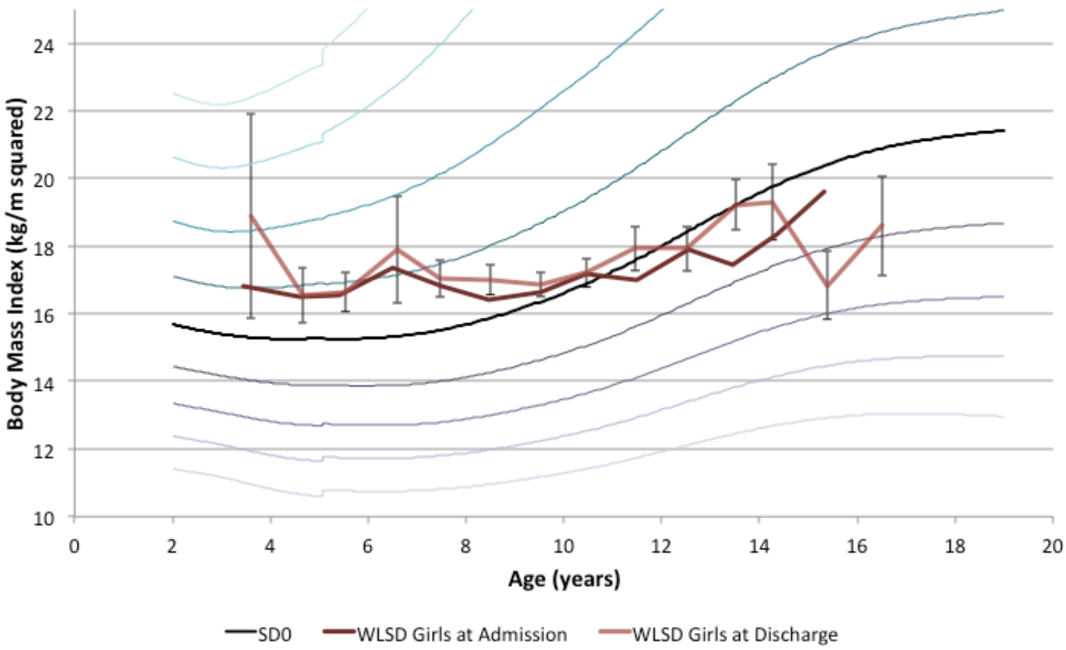


Notes: The black solid line represents the mean BMI-for-age growth curve of the WHO 2006/7 growth references. The parallel lines above and below the mean are standard deviations from the mean. 95 per cent confidence intervals are provided around the mean BMI of boys in the Ashford School at each age.

Sources: LMA, West London School District, Medical Officer's Report Book, WLSD/435; de Onis *et al.*, 'Development'; WHO, *WHO Child Growth Standards*; growth references drawn from data at http://www.who.int/growthref/en/.

Children in the past may have had higher BMI values than children in the present for a number of reasons. First, good heating in a home was costly, so children and adults likely needed a higher fat content in their body to help protect them from

Figure 5.14: Comparison of modern BMI-for-age growth curves with the observed BMI-for-age cross-sectional growth curves for girls in the Ashford School.



Notes: The black solid line represents the mean BMI-for-age growth curve of the WHO 2006/7 growth references. The parallel lines above and below the mean are standard deviations from the mean. 95 per cent confidence intervals are provided around the mean BMI of girls in the Ashford School at each age.

Sources: LMA, West London School District, Medical Officer's Report Book, WLSD/435; de Onis *et al.*, 'Development'; WHO, *WHO Child Growth Standards*; growth references drawn from data at http://www.who.int/growthref/en/.

the cold. In addition, without antibiotics and modern medicinal practices, when children became ill, they were often sick for weeks at a time. The illness would sap the child's resources in two ways. First, many chronic digestive diseases such as diarrhoea prevent the body from absorbing the nutrients consumed, so the child would only be able to draw energy from a fraction of the food he/she consumed. Second, the immune system requires enormous amounts of energy to fight off a disease, so the child would have to expend most of its energy on fighting the disease rather than growing or developing.[77] Finally, Waaler's study of Norwegian longitudinal biometric and health records makes clear that mortality risk is not related to BMI in a two dimensional way. Instead, mortality is related in a three dimensional framework

[77] Floud *et al.*, *Changing Body*, pp. 11-12.

to both height and weight independently. Both shorter people and thinner people suffer a higher mortality risk relative to individuals of average height and weight independent of whether their BMI falls within today's acceptable range.[78] Therefore, although these children appear to fall into the normal range for BMI, they are both stunted, two standard deviations below the modern mean height-for-age, and wasted, one standard deviation below the modern mean weight-for-age, which suggests that they will have a higher mortality risk and are therefore less healthy than children in modern populations.

5.4.2 A Positive Health Intervention: The Marcella Street Home, 1889-98

Having shown that the children in both schools were deprived relative to modern standards, the first precondition for catch-up, I must now establish that the conditions in both schools were substantially better than the conditions children were facing in either city before they entered the schools. If this were the case, then the children's entry into the institution could be considered a positive intervention that could spark catch-up growth. I will begin by describing the diet, hygiene and sanitary conditions in the Marcella Street Home before moving on to the Ashford School.

The diet in the Marcella Street Home was rather monotonous during the first half of the 1890s. It consisted of cocoa or milk and bread for breakfast; soup with some meat, bread, and potatoes for dinner, and cocoa or milk, bread and sometimes cheese for supper. This diet was scrutinized in November 1896 by an expert committee formed to investigate the dietaries in all of the public institutions managed by the city of Boston. The committee found the diet to be 'not well suited to growing

[78] Waaler, 'Height, Weight and Mortality'; Floud *et al.*, *Changing Body*, pp. 57-72.

children.'[79] The new superintendent, Michael J. Dwyer, who took over abruptly from White under mysterious circumstances in October 1896, noted 'that the diet of the inmates, while apparently sufficient in quantity, was lacking in quality, variety and service'.[80] Dwyer immediately implemented some of the recommendations of the expert committee, and two published dietaries in 1897 and 1898 show improvement in a number of regards: molasses, cornmeal, and oatmeal were introduced at breakfast; vegetables and fruit became staples at dinner and meat portions may have increased as well; and cheese or butter and a dessert were added to the supper menu.[81]

Unfortunately, the quantity of the various foods given to the children was only reported once for November 1896, and it seems that the quantities reflect a dietary somewhere in between the old diet criticized by the expert committee and the implementation of the final dietary sometime in 1897. This November 1896 diet was intermediary because it included molasses, which was not a part of the older diet and was one of the first additions to the diet, but did not include the fruit and vegetables, which were added in the final diet. However, the November 1896 diet can be compared with the recommended diet put forth by the expert committee (Table 5.4). Overall, the changes seem rather small. The committee recommended to increase the average daily consumption of eggs, butter, sugar, dried fruit, potatoes, and fresh vegetables, while they recommended a decrease in the consumption of milk (down 33 per cent). The amount of meat increased slightly, but it was already quite high in the older diet. It is not possible to recalculate the number of calories in the diet using

[79] 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 14-5.
[80] 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 115.
[81] 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 14-5, 116; 'Annual Report of the Children's Institutions Department for the Year 1897', pp. 20-1.

Table 5.4: Actual and Recommended Diet for Children in the Marcella Street Home.

Food	Actual Diet Observed November 1896 (ounces)	Diet Recommended by Experts (ounces)
Meat and fish (fresh or salted)	6.71	7
Eggs	--	0.75
Cheese	0.24	*
Milk	24.02	16
Butter and lard	0.19	1.3
Flour, cornmeal, crackers	14.13	11
Oatmeal, hominy, rice	1.44	2
Peas, beans	1.12	2*
Tapioca, sago, cornstarch	0.1	--
Sugar	1.08	3
Dried Fruits	--	0.75
Potatoes	4.8	6
Fresh vegetables	--	4
Apples	--	--
Molasses	0.5	--
Protein (grams)	95	93
Fat (grams)	55	77
Carbohydrates (grams)	380	389
Total Calories	2,459	2,692

Notes: *Peas, beans and cheese were combined into one category in the recommended diet.
Sources: 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 184-96.

modern and better techniques[82] because no recipes are given for the various foods. However, by the expert committee's own calculations based on Atwater factors, the value of protein and carbohydrates in the diet remained approximately the same, while the amount fat increased from 55 to 77 grams per day and the total calories increased from 2,459 to 2,692 calories per day, a 9.5 per cent increase. The committee acknowledged that their recommendations of food for children were high. In fact, they were substantially higher that the energy requirements calculated by Atwater and

[82] See Schneider, 'Inescapable Hunger', pp. 2-6; chapter 3.

cited in the report for children aged 7-10: 2,025 calories, 75 grams of protein, 60-75 grams of fat, and 249-283 grams of carbohydrates.[83] They justified the high food expenditure by arguing that the children had 'probably been under-nourished, and must be brought to a good *physical* condition before good *moral* results may be expected [sic]'. They also argued that Carroll D. Wright had estimated that children 8 to 10 needed 75 per cent as much food as an adult, and that the children's diet corresponded to three-quarters of the requirements of a moderately active man.[84] Anecdotal evidence that the quality of the flour purchased to make bread increased and that officers stopped skimming the milk so that the inmates and officers consumed the same bread and milk suggests that there was a marked increase in the quality of the diet.[85] Thus, it is clear that the committee was actively trying to promote healthy diets for children in these institutions.

However, the 2,459 calorie diet, which was in place before the dietary changes, was not a bad diet, especially considering that the average age at entry into and discharge from the home was 9.04 and 10.34 respectively and very few children remained in the home beyond the age of 16. Boys and girls growing at modern height velocities do not require more than 2,459 calories per day until they are 12 and 14 respectively.[86] Thus, an average calorie intake across all children of 2,459 calories was undoubtedly more than they were receiving outside the home and was substantial enough to allow them to experience catch-up growth. The 95 grams of protein in the diet would have also provided plenty of protein considering that Allen's respectability

[83] 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 184-96.
[84] 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 188.
[85] A switch to higher fat content in milk and more refined flour would have made the increase in total calories even larger when accounting for digestion costs: Schneider, 'Inescapable Hunger', pp. 2-5. 'Annual Report of the Children's Institutions Department for the Year 1897', p. 20; 'Annual Report of the Institutions Commissioner for the Year 1896-7', p. 116.
[86] Schneider, 'Real Wages', p. 4; FAO, 'Human', pp. 26-7.

basket provides 112 grams of protein for an adult male.[87] It should also be noted that there is no indication in the annual reports from the home that girls were fed less than boys. Sometimes the girls received slightly different foods, but there is no reason to believe that this would put them at a disadvantage for growth.

The Marcella Street Home seems to have been quite a sanitary institution given the standards of its time. Both superintendent A. B. Heath (in post 1885-94) and his successor William A. White (in post 1894-6) were physicians, and so they understood the importance of sanitation. The board of visitors had this to say of sanitary conditions in the home in 1894:

> Personal cleanliness is insisted upon. The children wash three times daily, and bathe frequently; clean towels are supplied for each washing, and good white soap provided. An admirable feature of the boys' washroom is the arrangement of hot and cold water faucets so placed that the children can wash under a stream of water, thus lessening the risk of communicating eye and skin diseases. The common institution practice which formally prevailed of sleeping in underclothes worn during the day has been amended for the girls, they being now supplied with night-gowns.[88]

Heath also proudly wrote in his report for 1892 that many children entered the home in deplorable condition with ophthalmia, chronic eczema, and other ailments but were nursed back to health in the hospital to be totally cured.[89]

It is also possible to compare mortality rates for children in the Marcella Street Home with children in Boston as a whole. This, however, is not a simple task. Although child deaths are reported in the annual reports for the entire period that the Home was open, monthly totals of children are needed in order to calculate the exposure risk that children faced in the home. The age breakdown of the children is also not reported, so I will compare the calculated rates with those of children aged 5-10 and 10-15 in Boston. However, it is possible to calculate the death rates for each year and compare these with similar information on deaths in Boston. Table 5.5

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[87] Allen, *British Industrial Revolution*, pp. 36-37; Schneider, 'Real Wages', p. 102; see chapter 1.
[88] 'Report of the Board of Visitors to the Public Institutions [1894]', p. 44.
[89] 'Annual Report of the Public Institutions Department, for the Year 1892', pp. 90-1.

shows the mortality rate of children in the Marcella Street Home and the associated rates in Boston in the same years. The rates in the Marcella Street Home fluctuate more than the rates in Boston, but this is likely just an artefact of the small number of deaths in the Home. The average mortality rate for children in the home across the period (8.2 deaths per thousand) is slightly lower than the average mortality rate of children aged 5-10 in Boston (8.9 deaths per thousand) but higher than the average mortality rate of children aged 10-15 (3.9 deaths per thousand). Since the average age of children to the Home was 9.04 at entry and 10.34 at discharge, the death rate was likely higher in the Home than in the population of Boston as a whole.

However, there are two important points to consider before judging the home too harshly. First, the children in the Marcella Street Home were of lower socio-economic status than the average child in Boston. Although the data do not exist, it is fairly safe to assume that working class children suffered from higher mortality rates than their middle and upper class counterparts. Therefore, the mortality rates in the Marcella Street Home might be better than the mortality rates for working class children in Boston. Second, Superintendent Heath mentioned in the annual reports that some of the twenty deaths that occurred between 1884 and 1890 were caused by diseases the children already had before entering the institution.[90] Thus, if it were possible to control for fatalities from diseases contracted at the Marcella Street Home, the mortality rate would be substantially lower. Thus, it seems plausible to assume that conditions were much more sanitary in the Home than in the houses and neighbourhoods where the children lived before entering the Home.

[90] 'Twenty-Eighth Annual Report of the Board of Directors for Public Institutions for the City of Boston, for the Financial Year 1884-85', p. 171; 'Annual Report of the Department of Public Institutions for the Year 1894', p. 128.

Table 5.5: Mortality rates in the Marcella Street Home compared with child mortality rates in Boston, 1884-1890

		Annual Mortality Rate (deaths per thousand)		
Year	Number of Child Deaths (MSH)	Marcella Street Home (MSH)	Boston Children (5-10)	Boston Children (10-15)
1884-85	4	8.16		
1886	2	5.13	8.01	3.67
1887	4	10.13	9.08	4.19
1888	6	15.18	9.13	4.22
1889	3	7.23	10.66	3.42
1890	1	2.69	7.82	3.75
Average		8.04	8.94	3.85

Notes: The population of Boston aged 5-10 and 10-15 was held constant across the years at the 1890 levels. If the population were growing, this would make the early death rates underestimates of the actual mortality rates. Since we observe a slightly increasing trend for child mortality rates in Boston, we can assume that the child death rates were nearly constant.

Sources: Mortality in MSH – 'Twenty-Eighth Annual Report of the Board of Directors for Public Institutions for the City of Boston, for the Financial Year 1884-85', p. 177; 'Twenty-Ninth Annual Report of the Board of Directors for Public Institutions for the City of Boston, for the Year 1885', p. 140; 'Thirtieth Annual Report of the Board of Directors for Public Institutions for the City of Boston, for the Year 1886', p. 181; 'Thirty-First Annual Report of the Board of Directors for Public Institutions for the City of Boston, for the Year 1887', p. 151; 'Thirty-Second Annual Report of the Board of Directors for Public Institutions for the City of Boston, for the Year 1888', p. 146; 'First Annual Report of the Commissioners of Public Institutions of the City of Boston, for the Year 1889', p. 136; 'Annual Report of the Department of Public Institutions [for the Year 1890]', p. 104.

Monthly number of children in MSH (population at risk) – 'First Annual Report of the Commissioners of Public Institutions of the City of Boston, for the Year 1889', pp. 129-132; 'Annual Report of the Department of Public Institutions [for the Year 1890]', p. 99.

Mortality and population in Boston – 'Annual Report of the Registrar of the Births, Marriages, and Deaths in the City of Boston, for the Year 1886', p. 14; 'Annual Report of the Registrar of the Births, Marriages, and Deaths in the City of Boston, for the Year 1887', p. 13; 'Annual Report of the Registrar of the Births, Marriages, and Deaths in the City of Boston, for the Year 1888', p. 14; 'Annual Report of the Registrar of the Births, Marriages, and Deaths in the City of Boston, for the Year 1889', p. 10; 'Forty-Ninth Report . . . of Births, Marriages, and Deaths in the Commonwealth', p. 65.

In the mid 1890s the opinion of the Commissioners of Public Institutions, who oversaw the Home, began to change. The key problems with the institution were the dilapidated buildings and its proximity to the city stables and swill shops. This is first mentioned in the Commissioner's report for 1894, but was quickly followed by assurances that 'this institution is in most excellent condition'.[91] In subsequent years, the rhetoric became more assertive with Superintendent Dwyer (in post 1896-1898)

[91] 'Annual Report of the Public Institutions Department, for the Year 1894', p. 21.

writing at the beginning of 1897 that 'the odors permeating our entire institution from this nuisance are at times nauseating'.[92] The swill plant was finally closed later that year, only one year before the institution itself closed.[93]

The increasingly harsh rhetoric was also noted in regard to sanitation improvements, particularly in the boys section of the home. White oversaw the installation of new modern flush-toilets in the hospital and lower floors in the second half of 1895, but this did not prevent his successor, Dwyer, from criticizing the plumbing further and building additional toilets and new showers for the children in 1897.[94] Dwyer also mentioned that the boys were less clean than the girls, and the secretary of the medical staff reported that 'over one hundred and fifty boys use accommodations sufficient for not more than a tenth of that number'.[95] This might suggest that the boys were experiencing worse conditions in the home than their female counterparts. However, it is impossible to verify whether poor hygiene and overcrowding created a higher disease load for boys because disease incidence was not reported separately by sex in the medical officers' reports.

Between the change in diet, the removal of the swill plant, and the construction of new toilet systems and showers, it may seem that the Home improved drastically after Dwyer took over in 1896. These improvements were certainly beneficial, but Dwyer's condemnation of the old system has to be tempered against a changing political climate after 1895. At this point and into 1896, Josiah Quincy, the grandson and great-grandson of former mayors, was elected mayor of Boston. Quincy believed that the city government could do more to serve the interests of its poorer inhabitants and took a greater interest in the Home and all of the public institutions

92 'Annual Report of the Public Institutions Department, for the Year 1896', p. 120.
93 'Annual Report of the Children's Institutions Department for the Year 1897', p. 15.
94 'Annual Report of the Public Institutions Department, for the Year 1895', p. 139; 'Annual Report of the Children's Institutions Department for the Year 1897', p. 15.
95 'Annual Report of the Public Institutions Department, for the Year 1896', pp. 115, 127.

more generally, visiting the Marcella Street Home personally at least twice.[96] Mayor Quincy started reforming the institutions quite quickly. The mayor was likely responsible for removing Superintendent White from his position in October 1896 and replacing him with Dwyer. The mayor's office denied that White had been removed in a statement two weeks before Dwyer took over the Home, but it appears that this was merely the mayor's response to a press leak of his plans.[97] The mayor also promoted legislation that eventually changed the administrative structure of the public institutions department, establishing separate departments to manage institutions for children, the insane, paupers, and criminals. This was meant to rationalize the administrative structure, but it also gave Quincy the power to appoint unpaid trustees to oversee the new departments.[98] Thus, it is not surprising that the tone of the reports shifts to match Quincy's political agenda.

The descriptions of the Marcella Street Home morph from the Commissioners of Public Institutions describing the home as in excellent condition in early 1895 to the following hyperbolic description by the Trustees for Children in early 1898:

> In the heart of our city, surrounded by a wooden fence 10 feet high, with barbed wire on its top, stands a large building which . . . became the Marcella-street Home, the institution to which Boston sends the children whose parents are unable to care for them, and the children of those whose cruelty and neglect have caused the courts to send them there. . . . On one side of this high fence are the city stables, breeding rats, on another a dump, where until last year, city swill was deposited. In this prison, under lock and key, these innocent children, deprived of their homes through no fault of their own, are expected to grow up into self-respecting citizens.[99]

Therefore, it is possible that Dwyer and the trustees sharpened their rhetoric on the Home because they favoured a system where neglected and poor children were placed with foster families rather than being raised in an institution; as mentioned before, the

[96] 'Comr. Marshall Active', *Boston Daily Advertiser*, 4 December 1896; 'Dr. White Not Removed', *Boston Daily Advertiser*, 16 October 1896; 'Mayor Josiah Quincy III, Served 1896-1899', biography on http://www.celebrateboston.com/biography/mayor/josiah-quincy-the-third.htm.

[97] 'Dr. White Not Removed', *Boston Daily Advertiser*, 16 October 1896.

[98] 'In Three Groups! Separate Children, Insane, Paupers and Criminals', *Boston Daily Advertiser*, 4 February 1897.

[99] 'Annual Report of the Children's Institutions Department for the Year 1897', p. 4.

Marcella Street Home was closed in 1898 because all of the children were placed out with foster families. However, it seems that the trustees' disgust for the Home was not merely limited to the mayor's political allies. In 1899 a member of the common council of Boston and a political opponent of Mayor Quincy made the following argument when one of his colleagues suggested that the Marcella Street Home be renovated to accommodate truant boys that were being held at another institution on Rainsford Island at the time.[100]

> The Marcella Street Home is not fit to be used for a stable for bum contractors of the city of Boston let alone for any human being. The institution at Marcella Street Home is a disease-breathing spot. There is not sufficient light in the rooms for the children to see for an hour a day. I say that whatever bad acts the Trustees for Children have committed—and they have committed many of them—one good act which they have done was to close the Marcella Street Home.[101]

Thus, the rosier depictions of the Home in the early 1890s probably understated some of the problems with the location and its administration, but at the same time Dwyer and the trustees' horrific descriptions of the Home must be counterbalanced with knowledge of their political goals. Dwyer and the commissioners and trustees highlighted real problems and carried out substantial improvements after 1896, but the evidence presented later in the chapter suggests that the institution was not as bad as some of the descriptions would have us believe. Therefore, it seems plausible that the Marcella Street Home provided a better sanitary environment and better food in larger quantities than the children would have received in their own homes. In other words, the institution provided an opportunity for catch-up growth.

5.4.3 A Positive Health Intervention: The Ashford School, 1908-16

Conditions in the Ashford School were also substantially better for the pauper children there than the conditions they experienced before entering the home. The diet

[100] 'Meeting of the Boston Common Council', *Boston Daily Advertiser*, 13 October 1899.
[101] 'Meeting of the Boston Common Council', *Boston Daily Advertiser*, 13 October 1899.

in the Ashford School was somewhat more varied than the Marcella Street Home, but it was still fairly monotonous (see tables 5.6 and 5.7). The children had the same thing for breakfast every day: cocoa (made with milk), bread and margarine. They had a light lunch of sultana bread followed by a major meal at dinner. For dinner and supper there were different menus for older children aged seven to fourteen than the younger children aged three to seven. For the younger children dinner consisted of minced mutton three days per week, rice or bread pudding two days per week, and

Table 5.6: Diet of children aged 3-7 with calorie and protein levels per day in the Ashford School.

		Quantity of Food Served per Day						
Food	Units	Sun	Mon	Tue	Wed	Thur	Fri	Sat
Breakfast:								
Cocoa	pints	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Bread	oz	4	4	4	4	4	4	4
Margarine	oz	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lunch:								
Sultana Bread	oz	2	2	2	2	2	2	2
Dinner:								
Bread	oz	2	2	2	2	2	2	2
Minced Beef	oz	3						
Minced Mutton	oz			3		3		3
Soup	pints		0.75					
Baked Potatoes	oz	2				2		
Boiled Potatoes	oz			4				2
Vegetables	oz	2				2		2
Rice Pudding	oz						8	
Bread Budding	oz				8			
Supper:								
Milk	pints	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Tea	pints							
Bread	oz		4		4	4		4
Margarine	oz		0.5		0.5	0.5		0.5
Sultana Bread	oz	4		4			4	
Total Calories per Day	kcal	1641	1645	1646	1930	1698	1694	1702
Total Protein per Day	grams	59.6	57.2	66.6	51.7	63.9	49.1	65.9

Notes: Recipes for the various dishes above were used to calculate their protein and calorie content. The recipes specified the amount of raw ingredients that went into a certain amount (gallon or pound) of each dish. Calorie and protein amounts were taken from nutritiondata.self.com, which gives calorie and protein estimates for a very wide range of foods. The calories and protein of non-enriched foods were used. I tried to make reasonable assumptions when the recipes were vague for instance about the types of fresh vegetables in the soup, etc.

Sources: LMA, Dietary Tables, Recipes, etc., Dietary of 1909, WLSD/468.

minced beef or soup for one night per week each. These courses were supplemented with bread, baked or boiled potatoes and vegetables. For supper, the younger children received milk and either bread and margarine or sultana bread. The older children had more variety for dinner with mains dishes such as baked mutton, baked beef, meat pie, raisin pudding, and soup. They received bread with the meal if the main was not a pie, and also were given substantial amounts of potatoes and vegetables. For supper, the older children received bread with tea (and milk) and treacle and cheese two to three times per week.[102] The children's diet seems to be lacking, however, in fresh fruit, which is corroborated by the fact that gifts of oranges for the children were always recorded in the board of management signed minutes.[103]

It is more difficult to attempt to calculate the average caloric intake for the children because although simplified recipes are provided for the dishes, they are often vague about the ingredients. For instance, the ingredients for the school's soup were raw meat or shins of beef; split peas, lentils, or haricot beans; fresh vegetables; potatoes; and oatmeal.[104] Determining precise calorie levels for such vague food categories is problematic at best, but I have tried to use reasonable assumptions to come up with a level of calories per day per child. Tables 5.6 and 5.7 also display the number of calories and grams of protein per day that children received in the two age categories. There was considerable variation across the week in each category. Young children were provided with between 1,641 and 1,930 kcal per day with an average of 1,708 kcal per day. The older children received more calories ranging from 1,896 kcal

[102] LMA, Dietary Tables, Recipes, etc., Dietary of 1909, WLSD/468.
[103] LMA, SMBM 1908, WLSD/24/2, p. 42; LMA, SMBM 1910, WLSD/25, p. 63; LMA, SMBM 1911, WLSD/27, p. 36; LMA, SMBM 1913, WLSD/28/1, p. 81; LMA, SMBM 1914, WLSD/28/2, p. 55; LMA, SMBM 1915, WLSD/28/3, pp. 18, 72.
[104] LMA, Dietary Tables, Recipes, etc., Dietary of 1909, WLSD/468.

Table 5.7: Diet of children aged 7-14 with calorie and protein levels per day in the Ashford School.

		Quantity of Food Served per Day						
Food	Units	Sun	Mon	Tue	Wed	Thur	Fri	Sat
Breakfast:								
Cocoa	pints	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Bread	oz	5	5	5	5	5	5	5
Margarine	oz	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lunch:								
Sultana Bread	oz	2	2	2	2	2	2	2
Dinner:								
Bread	oz	3	4			3		
Baked Mutton	oz					4		
Baked Beef	oz	4						
Soup	pints		0.875					
Baked Potatoes	oz	4				4		
Boiled Potatoes	oz			8			8	
Vegetables	oz	4				4		
Meat Pie	oz			10			10	
Raisin Pudding	oz				13			13
Supper:								
Tea	pints	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Bread	oz		5		5	5		5
Margarine	oz					0.5		
Sultana Bread	oz	5		5			5	
Treacle	oz		1					
Cheese	oz				0.75			0.75
Jam or Marmolade	oz				1.5			1.5
Total Calories per Day	kcal	2027	1896	2544	2874	2070	2544	2874
Total Protein per Day	grams	71.2	66.4	82.4	56.8	76.8	82.4	56.8

Notes and Sources: see table 5.7.

per day to 2,874 kcal per day with a mean of 2,404 kcal per day.[105] These ranges were probably wide in part because of the imprecise nature of the calorie calculations, but the children did appear to be given more food on Wednesdays and Saturdays. With regard to grams of protein in the diet, the younger children received 59 grams of protein on average per day, while the older children received 70 gram of protein per day. This level of calories and protein was more than would be required for the children's growth. Boys in modern populations do not need 1,700 kcal/day until they

[105] The maximum values in the category of older children were driven by the high calorie content of the raisin pudding. I checked these calculations and believe them to be correct, but even if they are excluded the average energy available only falls to 2,216 kcal/day.

are seven, so all of the children in the younger group had plenty of calories. For the older boys, boys in modern populations do not need 2,400 kcal/day until age twelve.[106] However, this did not mean that the boys above age twelve were not getting the calories they required. The food servers almost certainly did not give children age seven the same amount of food as the fifteen-year-olds in the school. Thus, it is safe to imagine that the food was allocated in the home such that all of the children had more than enough calories for growth and to lead a healthy life.

The superintendent and board of management were also acutely interested in maintaining the quality of the food that they provided for the children. They were constantly sending back meat without labels and other meat that did not meet their expectations. This was especially a problem at the beginning of the period studied here in 1907-8 and as World War I began to affect the meat supply in 1915.[107] They also had problems throughout the period procuring enough milk. Early in the period, the school owned a dairy herd that provided its milk, but they had constant problems with getting enough milk out of the cows.[108] This problem reached a peak in September 1908 when the superintendent reported that during the last ten weeks 'the weekly supply [of milk] fell from 2,864 pints to 1,740 pints' or a decline of 40 per cent.[109] This prompted the Board of Management to sell the herd and procure the milk through private contractors. As a part of the review of this policy change the medical officer suggested that all milk be boiled and that it be periodically tested for contamination.[110] There is evidence that these recommendations were followed throughout the period studied with the board taking a very strict stance; they found

[106] Schneider, 'Real Wages', p. 4; FAO, 'Human', pp. 26-7; see chapter 1.
[107] LMA, SMBM 1907, WLSD/24/1, pp. 138, 169; LMA, SMBM 1908, WLSD/24/2, p. 31; LMA, SMBM 1914, WLSD/28/2, pp. 64; LMA, SMBM 1915, WLSD/28/3, p. 55, 91.
[108] LMA, SMBM 1907, WLSD/24/1, p. 118; LMA, SMBM 1908, WLSD/24/2, pp. 38, 153, 158.
[109] LMA, SMBM 1908, WLSD/24/2, p. 153.
[110] LMA, SMBM 1908, WLSD/24/2, p. 204.

the milk to be deficient in fat in August 1916 and questioned the contractor about it.[111] The superintendent and board also had problems with the quality of flour, margarine, raisins, and cocoa delivered various times.[112] All of these anecdotes highlight how vigilant the school was in providing the children the best quality of food that they could afford.

Sanitary conditions in the West London School District changed quite dramatically during period studied in this chapter (1908-16). At the beginning of the period, most of the toilet facilities were earth closets.[113] Earth closets were an advancement upon the privies of the past because the excreta was kept in a closed container that was regularly cleaned out rather than letting the excreta soak into the soil and enter the water supply. They were called earth closets because dirt was added periodically to the mixture to help decompose the waste. Earth closets were initially seen as superior to water closets because water closets often emptied into caverns or poorly constructed septic tanks, thus ensuring that the excreta thoroughly soaked into the soil.[114] However, it is not hard to imagine how water closets (primitive flush toilets) connected to a functioning sewage system would be a great improvement for sanitation, especially around small children. Removing the waste immediately from the lavatory eliminated the need for emptying the earth closets, reducing the amount of contamination in the lavatory and allowing the saved labour hours to be used to keep the lavatories cleaner. Major sewage improvements were undertaken at the Ashford School between September 1909 and January 1911. During this period nearly all of the earth closets were converted to water closets and the drains and general

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[111] LMA, SMBM 1909, WLSD/24/3, p. 151; LMA, SMBM 1910, WLSD/25, p. 62; LMA, SMBM 1914, WLSD/28/2, p. 80; LMA, SMBM 1916, WLSD/29/1, p. 70.

[112] LMA, SMBM 1907, WLSD/24/1, p. 68; LMA, SMBM 1909, WLSD/24/3, pp. 155, 160; LMA, SMBM 1910, WLSD/25, pp. 149, 159; LMA, SMBM, WLSD/27, pp. 20-21, 29-30; LMA, SMBM 1913, WLSD/28/1, p. 148; LMA, SMBM 1914, WLSD/28/2, p. 41.

[113] LMA, SMBM 1908, WLSD/24/2, pp. 78-85.

[114] Wright, *Clean and Decent*, pp. 208-210.

sewage system were improved.[115] The board of managers and medical officer were displeased with the works at first because the pump that moved the sewage through the system was blocked several times in February, March and April of 1910. The medical officer made the following report in April 1910:

> During the past few months the School has not been in satisfactory sanitary condition, and remains so. Some of the children have headaches, and are feverish; some sick and state they fell ill; others have sore throats, and some with pneumonia and pleurisy. All the milk is boiled. The water has been analysed, and found to be fit for drinking. The food appears to be good. By the process of elimination it would appear that the drainage system is still at fault and probably the cause of the condition.[116]

The next month, the medical officer even grumpily reported that 'the ground near the Boys' Playgound has been recently saturated with sewage'.[117] However, after a temporary pump was installed and the system was modified, the insanitary conditions seemed to subside.[118] There was a later report in 1912, which indicated that the boys needed training on how to use the new facilities properly. The boys were all using one toilet, which quickly became blocked, rather than spreading the load across a larger number of toilets in the lavatory.[119] However, by September 1915 after the final adjustments had been put in place, the system was reported to be working 'in a most satisfactory manner'.[120] In addition, aside from the brief period at the beginning of 1910 described above, there were no references to illness being the result of poor sanitation. Likewise, children were very rarely sent to the infirmary because of diarrhoea and there were no reported cases of typhoid during the period studied.

The superintendent and board of managers were also concerned to maintain the quality of the water supply. The water in the school was drawn from a deep well,

[115] LMA, SMBM 1909, WLSD/24/3, p. 126; LMA, SMBM 1911, WLSD/27, p. 43; LMA, SMBM 1908, WLSD/24/2, pp. 78-85.
[116] LMA, SMBM 1910, WLSD/25, p. 62.
[117] LMA, SMBM 1910, WLSD/25, p. 75.
[118] LMA, SMBM 1911, WLSD/27, p. 43.
[119] LMA, SMBM 1912, WLSD/26, pp. 69-71.
[120] LMA, SMBM 1915, WLSD/28/3, p. 158.

and the drinking water was regularly tested for signs of impurity.[121] The water tanks were also regularly cleaned and improved over the years.[122] There were occasional problems with the pump that pulled the water out of the deep well, but these were generally solved quickly, and the managers could also draw water from private utilities if necessary.[123] However, like nearly all buildings in this period, there was lead piping throughout the building, which likely diminished the cognitive ability and general health of all in the institution.[124]

The staff in the school also enforced personal hygiene. Bathing took place once a week for the older children but more frequently for the younger children age six and below.[125] There were several motions over the years to replace the tub baths, in use at the beginning of the period, with spray baths akin to showers. Spray baths were more sanitary because it meant that children did not have to share bath water. However, it is not entirely clear that this transition ever took place because the building works for the new spray baths were delayed again and again.[126] There are some references though to limited spray baths being in use by 1910.[127] The children also washed their hands with soap frequently in primitive sinks, again avoiding contamination through sharing water.[128] Monnington and Lampard mentioned that the children had clean towels three times a week, but this cannot be corroborated for the

[121] Monnington and Lampard, *Poor*, p. 8; LMA, SMBM 1907, WLSD/24/1, pp. 47, 56-7, 141; LMA, SMBM 1910, WLSD/25, p. 63; LMA, SMBM 1911, WLSD/27, p. 2; LMA, SMBM 1913, WLSD/28/1, p. 101; LMA, SMBM 1914, WLSD/28/2, pp. 14, 32.
[122] LMA, SMBM 1907, WLSD/24/1, pp. 56-7; LMA, SMBM 1910, WLSD/25, pp. 18, 21-2; LMA, SMBM 1914, WLSD/28/2, p. 114; LMA, SMBM 1915, WLSD/28/3, pp. 40, 97, 193; LMA, SMBM 1916, WLSD/29/1, p. 51.
[123] LMA, SMBM 1909, WLSD/24/3, pp. 24, 42, 49.
[124] LMA, SMBM 1908, WLSD/24/2, p. 169; LMA, SMBM 1910, WLSD/25, p. 192.
[125] LMA, SMBM 1912, WLSD/26, p. 216.
[126] LMA, SMBM 1907, WLSD/24/1, pp. 6, 19, 85, 100, 115; LMA, SMBM 1909, WLSD/24/3, pp. 110-11; LMA, SMBM 1913, WLSD/28/1, pp. 166-67; LMA, SMBM 1914, WLSD/28/2, pp. 7-8, 73, 136.
[127] LMA, SMBM 1910, WLSD/25, p. 84; LMA, SMBM 1914, WLSD/28/2, pp. 7-8.
[128] LMA, SMBM 1907, WLSD/24/1, p. 100; LMA, SMBM 1909, WLSD/24/3, p. 97; LMA, SMBM 1910, WLSD/25, p. 81; Monnington and Lampard, *Poor*, pp. 10-11.

later period in the minutes.[129] The older children were also provided with a toothbrush and brushing powder to brush their teeth regularly.[130] In conclusion, even though the personal hygiene of the children was not as good as might be expected by modern standards, it seems highly unlikely that children of the working poor would have had such good conditions in their homes.

The staff attempted to prevent the spread of illness within the school and introduction of new illnesses from outside by quickly quarantining sick children and enforcing strict rules about visitation and admission. Children with different illnesses were kept in separate wards in the infirmary, and they were not allowed to re-enter the general student population until they were fully recovered. In January 1909, the superintendent even prevented the children from taking afternoon walks around the school's extensive grounds because there was an outbreak of Measles in the area.[131] Later in 1914, the medical officer advised that children confirmed to have fevers such as scarlet fever and diphtheria should be removed from the school and sent to the Metropolitan Asylums Board's Hospital.[132] The school also owned a large steam disinfector, which was used to disinfect clothing and bedding.[133]

In addition, there was a set of policies that prevented disease from entering the school. Each child entering the school was held in the lodge for a couple of weeks to ensure that they were not carrying any diseases.[134] In February 1907, the children housed at the Lodge were kept in quarantine for an additional fortnight because several children were returned from a convalescent home where there had been a

[129] Monnington and Lampard, *Poor*, p. 10.
[130] LMA, SMBM 1911, WLSD/27, p. 212; Monnington and Lampard, *Poor*, p. 10.
[131] LMA, SMBM 1909, WLSD/24/3, p. 12.
[132] LMA, SMBM 1914, WLSD/28/2, p. 211.
[133] LMA, SMBM 1907, WLSD/24/1, p. 32.
[134] LMA, SMBM 1916, WLSD/29/1, p. 63.

scarlet fever outbreak.[135] Likewise, when epidemic diseases were ravaging the school or London, the school temporarily stopped admitting children to protect the existing student population; for instance, admissions were suspended in June 1911 after four children became ill with diphtheria.[136] The medical officer and superintendent also limited visitation rights during periods of epidemic hazard in London, though the board was generally reluctant to keep parents and relatives from visiting their children.[137] However, between July 1914 and September 1915, children under 16 were not allowed to visit the home at all because of fears of scarlet fever in London, though the board eventually removed the ban believing the medical officer's recommendation that it be adopted permanently overly cautious.[138] These procedures generally kept the incidence of infectious diseases in the school to a minimum; most of the child deaths described in the minutes were from heart disease or other chronic illnesses rather than infectious diseases.

The children's health and growth was also affected by the environmental conditions in the home. Keeping the school warm in the winter was a particular problem at the beginning of the period studied here.[139] In January 1908, the superintendent reported that 'the Children's Rooms were very cold that morning, and at 10 o'clock he could not get a temperature of 50 deg. in many of the rooms'.[140] A new heating system was implemented in 1907 and 1908 and refined periodically thereafter, which though not entirely effective, was a great improvement on prior conditions where the school buildings had not been heated; in February 1908, the

[135] LMA, SMBM 1907, WLSD/24/1, p. 27.
[136] LMA, SMBM 1911, WLSD/27, p. 87.
[137] LMA, SMBM 1907, WLSD/24/1, p. 151; LMA, SMBM 1913, WLSD/28/1, p. 221.
[138] LMA, SMBM 1914, WLSD/28/2, pp. 134, 170, 182, 211, 221; LMA, SMBM 1915, WLSD/28/3, pp. 5, 40, 71, 97, 147, 162.
[139] LMA, SMBM 1907, WLSD/24/1, p. 15; LMA, SMBM 1908, WLSD/24/2, p. 2; LMA, SMBM 1909, WLSD/24/3, p. 26; LMA, SMBM 1910, WLSD/25, pp. 5-6; LMA, SMBM 1911, WLSD/27, p. 3; LMA, SMBM 1916, WLSD/29/1, p. 103.
[140] LMA, SMBM 1908, WLSD/24/2, p. 2.

medical officer reported that the previous year there were 51 children being treated for chilblains in February compared to one case that year.[141]

Table 5.8: Children's work in the Ashford School in May 1907.

Department	Number of Chlidren Working	Approximate Total Hours of Work per Day
Boys		
Tailor	28	6
Shoemaker	20	4.5
Carpenter	9	4.5
Baker	10	8.5
Painter	5	--
Farm	23	4.5
Garden	12	4
Total Boys Working	107	
Girls		
Laundry	9	8
Staff Kitchen	6	8
Dormitories and Repairing	5	8
Infants and Babies	4	8
Staff's Apartments	4	8
Matron's Stores	1	8
Lodge	2	8
Total Girls Working	31	

Sources: LMA, SMBM 1907, WLSD/24/1, p. 58.

Physical activity and work also affected the children's nutritional status because they would need more calories if they were working harder. The Ashford School's first mission was to educate the children resident there. Thus, most of the children in the home were in school lessons for a large part of the day. However, a number of older boys and girls were given full or partial exemptions from the classes having either passed out of them or reached an age where more practical skills were deemed necessary. The number of boys and girls at work, then, was somewhat independent from the actual labour required day to day in the school.[142] Table 5.8

[141] Chilblains is 'an inflammatory swelling produced by exposure to cold' *OED Online*; LMA, SMBM 1908, WLSD/24/2, p. 26.

[142] LMA, SMBM, 1908. WLSD/24/2, p. 33; LMA, SMBM 1910, WLSD/25, p. 20.

presents the number of boys and girls working in various tasks in May 1907 and the amount of time they worked per day. Girls tended to work much longer hours than boys, but a larger percentage of the boys worked: 107 of the 352 boys over the age of six in May 1907 worked (30.4 per cent) whereas only 31 of the 268 girls over the age of six worked (11.6 per cent). However, there were 42 other girls only given a partial exemption from school who attended lessons in 'Housewifery' fives times per week.[143] There was some concern that the working hours for girls and for boys working in the Bakery were too long, but the girls' hours were never reduced. The hours worked by boys in the bakery, however, were reduced to six hours in April 1910.[144] It is difficult to precisely identify how this work would have affected the children. The girls were likely working harder because they worked longer hours and had to carry heavy laundry around and clean, but the boys were also engaged in hard activity such as working on the farm and more of them worked. In addition, the boys often played football, increasing their energy expenditure. On balance, then, it does not appear that either the boys or girls worked significantly harder than the other. In any case, this work effort would have only mattered if the children were not receiving enough food to cover their energy costs, but given the very generous diet, this would seem to be unlikely.

The punishment regime in the school could have also influenced the children's health if they were forced to carry out hard labour or if corporal punishment was overused. However, neither of these seem to have been the case. An extensive list of punishments is described in the board of management minutes in February 1912. Punishments varied by sex, but the only punishment that could possibly qualify as hard labour was one of hour of scrubbing, which was used as punishment for boys

[143] LMA, SMBM 1907, WLSD/24/1, pp. 58, 62.
[144] LMA, SMBM 1907, WLSD/24/1, pp. 83, 111, 171; LMA, SMBM 1910, WLSD/25, p. 20, 69.

only.[145] Corporal punishment was strictly forbidden for girls. It did take place from time to time, but whenever the board of management became aware that girls were struck or caned, they immediately forced the resignation of the staff member involved: the headmistress, Miss Mark, was dismissed for admitting to caning the girls in December 1910 and an assistant chargemaster was fired in February 1912 for striking a girl while supervising bathing.[146] Corporal punishment was allowed for the boys, but it was strictly regulated with at least two members of staff required to be on hand at the time of punishment. The committee was equally strict with this rule, forcing the resignation of the bandmaster after he struck a boy in anger in May 1915 and reprimanding the temporary chargemaster in September 1916.[147] Unfortunately, even though the official punishment book survives, it does not include specific information about punishments for this period, so it is difficult to know how often corporal punishment was employed.[148]

A final consideration is that the period studied here includes the first years of World War I, so a little must be said about how the institution faired during the war. The war was certainly disruptive, but the effects of the war on the children's health are smaller than might be expected. The war influenced the school in two main ways. First, the school's contractors were not able to obtain the same quality and brands of meat as they were before the war. The superintendent reported in May 1915 that 'owing to the unprecedented shortage of British beef they [the contractors] would be compelled to supply Frozen or Colonial, if they could procure it, for Officers' Meat, and cannot be sure of procuring the particular brand of legs of Mutton'.[149] Thus, it

[145] LMA, SMBM 1912, WLSD/26, p. 43.
[146] LMA, SMBM 1910, WLSD/25, pp. 156, 173; LMA, SMBM 1912, WLSD/26, pp. 43, 221.
[147] LMA, SMBM 1912, WLSD/26, p. 43; LMA, SMBM 1915, WLSD/28/3, p. 96; LMA, SMBM 1916, WLSD/29/1, p. 73.
[148] LMA, Punishment Book, WLSD/438.
[149] LMA, SMBM 1915, WLSD/28/3, p. 91.

seems that the superintendent was forced to feed the children poorer quality meat, but there is no indication that the quantity of meat served declined during the war. In addition, as mentioned above, the superintendent had no qualms in rejecting spoiled meat, so although the fat content of the meat was probably lower, the meat was probably still safe to eat. Second, the war took a toll on the school's labour force. Twelve officials were already 'absent with the forces' in December of 1915.[150] This loss of manpower was detrimental to the children's general behaviour with the superintendent and matron filing more and more negative reports over the course of the war. The board even broke with its strict policy of firing those inflicting elicit punishments in September 1916 by only reprimanding the temporary chargemaster for caning a boy rather than dismissing him. Likewise, in October 1916 the visiting committee reported that the water tanks could only be cleaned twice per year rather than quarterly because there was not sufficient manpower to clean the tanks so often.[151] The decline in discipline and other problems related to the shortage of manpower could have influenced the children's health, but they seem rather small when compared to changes in diet, etc.

In conclusion, the children in the Marcella Street Home and the Ashford School satisfy both of the preconditions for catch-up growth. They were stunted in terms of height-for-age and weight-for-age upon entry to the institutions. And the conditions in the institutions were likely to be a significant improvement on the conditions they experienced in their homes before entering the institutions.

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[150] LMA, SMBM 1915, WLSD/28/3, p. 208.
[151] LMA, SMBM 1916, WLSD/29/1, pp. 73, 78, 89.

5.5 Catch-up Growth in the Marcella Street Home and Ashford School

5.5.1 A Descriptive Look at Catch-up Growth in the Institutions

Having satisfied the preconditions for catch-up growth, we can now turn to measuring the children's longitudinal growth while in each school to see whether they were catching up to or falling behind modern standards while in each school. The measure of catch-up growth employed in this paper is the change in WHO Z-score while the child was in the institution, the Z-score at discharge minus the Z-score at admission.[152] If the change in Z-score was negative, then the child fell behind modern standards during his/her time in the school. If the change in Z-score was zero, then the child would have continued growing at the same rate as predicted by modern standards, though likely at lower level. Finally, if the change in Z-score was positive, then the child would have grown faster than modern growth standards, catching up relative to the mean. This method assumes that the intervention that sparks catch-up growth is not age dependent but is instead dependent on the age at which the child enters the institution, which is random.

Figures 5.15-5.17 display the kernel density plots of the change in Z-score for height, weight and BMI. For Z-score change in height, girls seem to have had an advantage in both schools relative to boys. The right side of the girls' distribution extended farther and a greater number of girls experienced Z-score growth rather than Z-score decline. Table 5.9 reports the means and standard deviations of the distributions along with the results of a one-sample t-test comparing each distribution to zero. The mean change in height Z-score was significantly positive for both boys and girls in the Ashford School, but was only significant in girls in the Marcella Street Home. Height Z-score change for Boys in the Marcella Street Home was not

[152] It is not necessary to include a time element in this variable because the children's Z-scores for height, weight and BMI are age dependent.

statistically different than zero partially because there were a number of children sentenced for truancy that were probably not from the same underprivileged background: this is explained in detail later. The change in weight Z-score distributions were less clear cut than the change in height Z-score distributions. In the Marcella Street Home, girls (under 10) appeared to have had an advantage in weight gain whereas the opposite was true in the Ashford School. These findings are corroborated by the means of each of the distributions, and all of the means were statistically different than zero. Finally, for change in BMI Z-score, the results were again mixed. Girls seemed to have an advantage in the Marcella Street Home whereas boys seemed to have a slight advantage in the Ashford School. Again, the means of the distributions corroborate this evidence, but only girls in the Marcella Street Home and boys in the Ashford School had change in BMI Z-scores that were significantly different than zero. However, we cannot be certain of these results without controlling for a number of potentially confounding factors in a multiple regression framework.

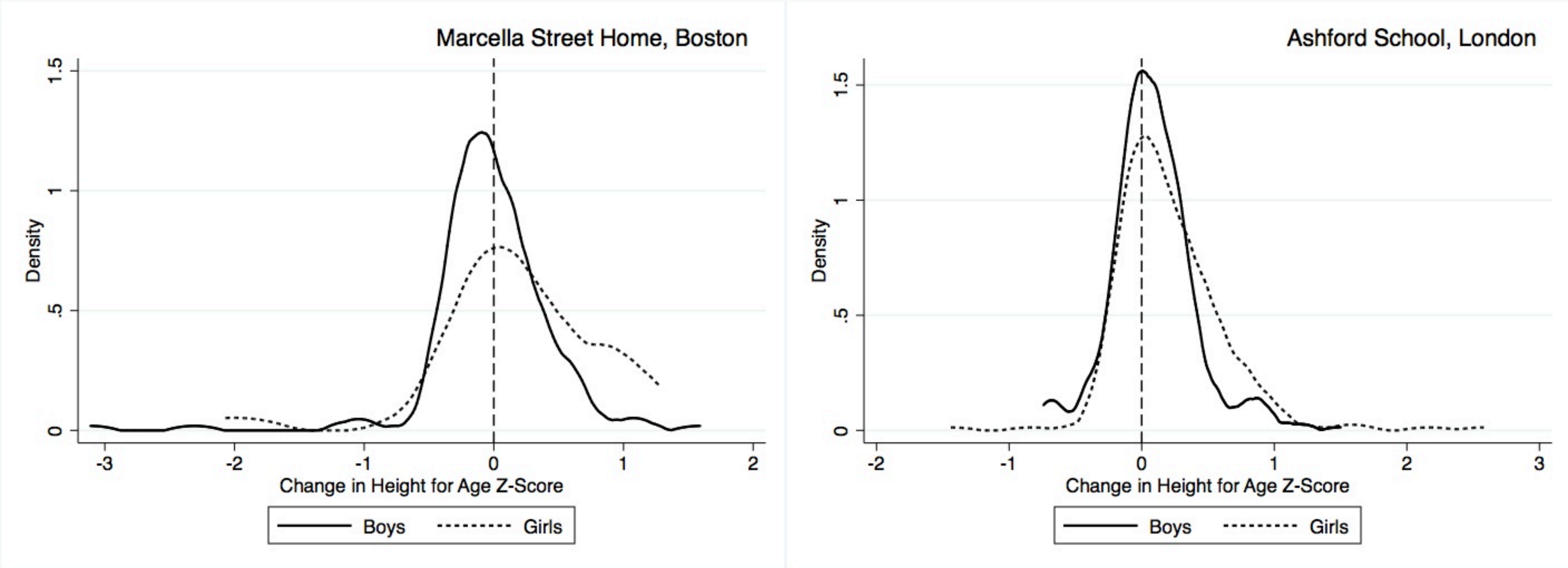
Table 5.9: Descriptive statistics of change in height-for-age, weight-for-age, and BMI-for-age Z-scores for boys and girls in the institutions

	Marcella Street Home, Boston		Ashford School, London	
	Boys	Girls	Boys	Girls
Change in height-for-age Z-Score				
mean	-0.017	0.193	0.087	0.213
standard deviation	0.469	0.644	0.315	0.408
one sample t-test (ref = 0)	-0.48	2.22	5.10	8.28
Change in weight-for-age Z-Score				
mean	0.201	0.450	0.255	0.153
standard deviation	0.584	0.618	0.425	0.389
one sample t-test (ref = 0)	2.38	4.30	7.96	4.59
Change in BMI-for-age Z-Score				
mean	0.058	0.333	0.141	0.058
standard deviation	0.707	0.736	0.654	0.604
one sample t-test (ref = 0)	1.11	3.59	4.25	1.62

Notes: One sample t-tests tested whether each measure of catch-up growth was significantly different than zero. Sample sizes varied across the distributions, but in general t-values above 2 were significant at the 95 per cent level.

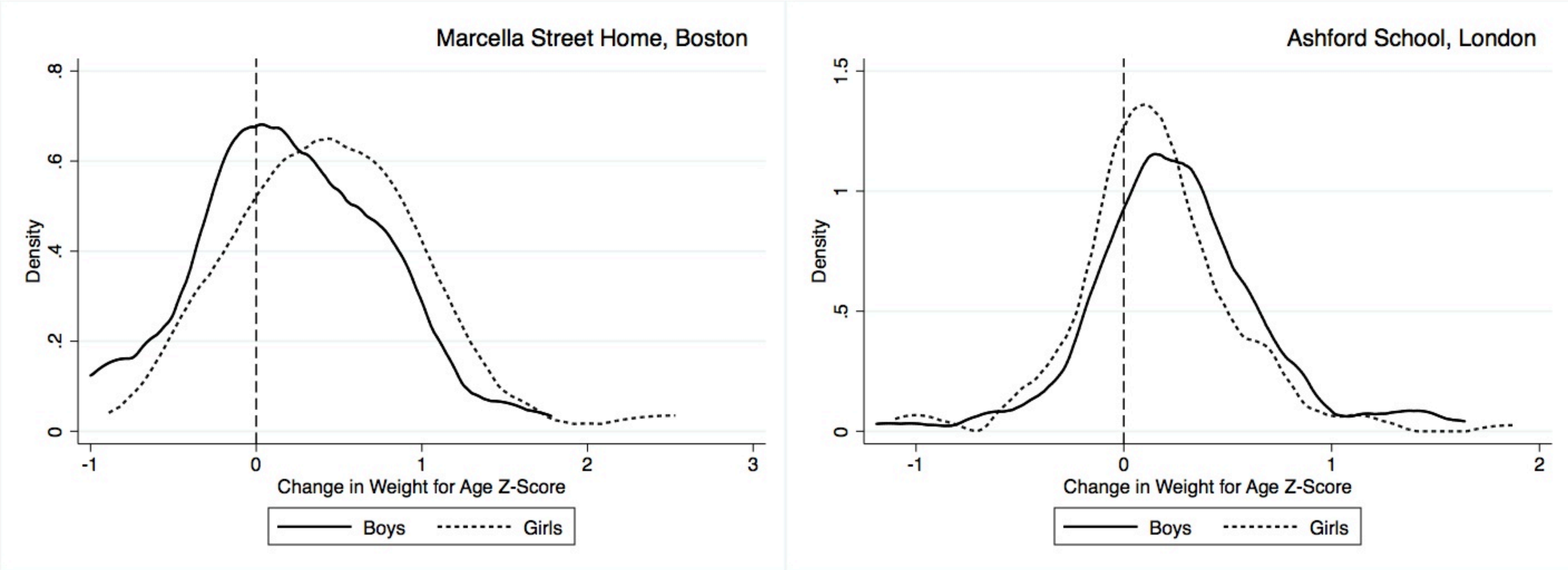
Sources: see figure 5.15.

Figure 5.15: Kernel density plot of change in height-for-age Z-score for boys and girls in the Marcella Street Home, Boston and the Ashford School, London.



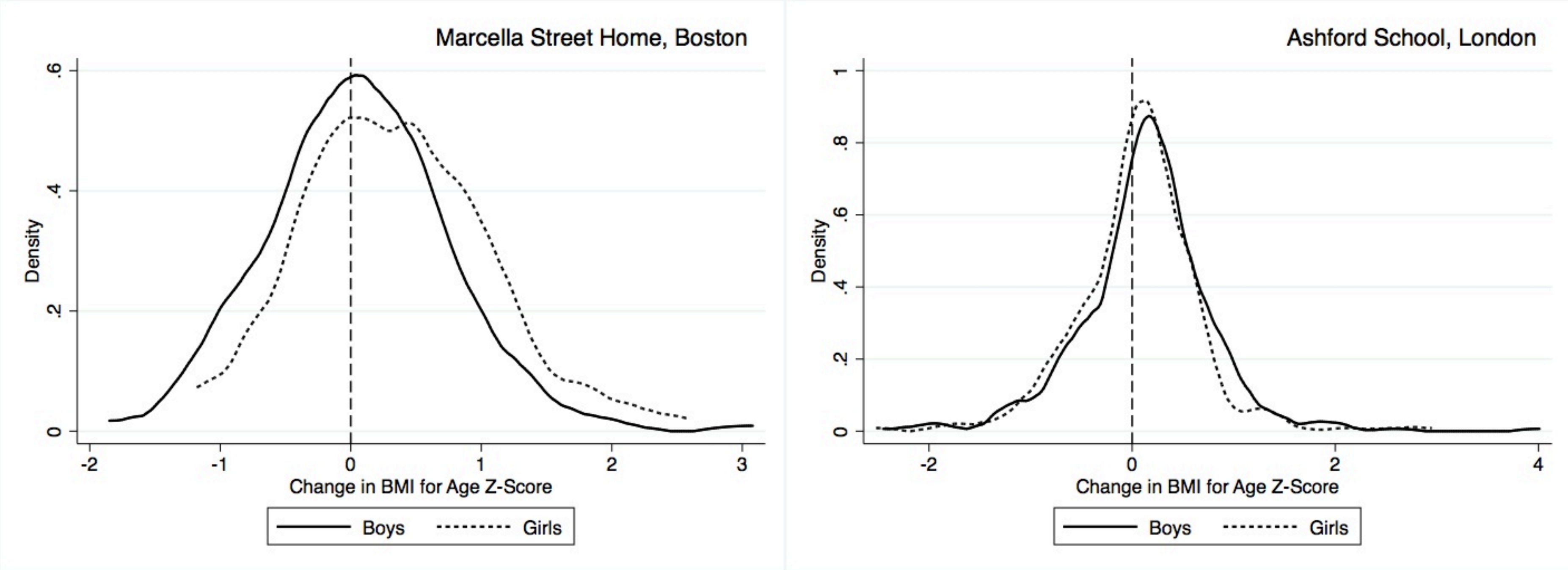
Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; LMA, West London School District, Medical Officer's Report Book, WLSD/435.

Figure 5.16: Kernel density plot of change in weight-for-age Z-score for boys and girls in the Marcella Street Home, Boston and the Ashford School, London.



Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; LMA, West London School District, Medical Officer's Report Book, WLSD/435.

Figure 5.17: Kernel density plot of change in BMI-for-age Z-score for boys and girls in the Marcella Street Home, Boston and the Ashford School, London.



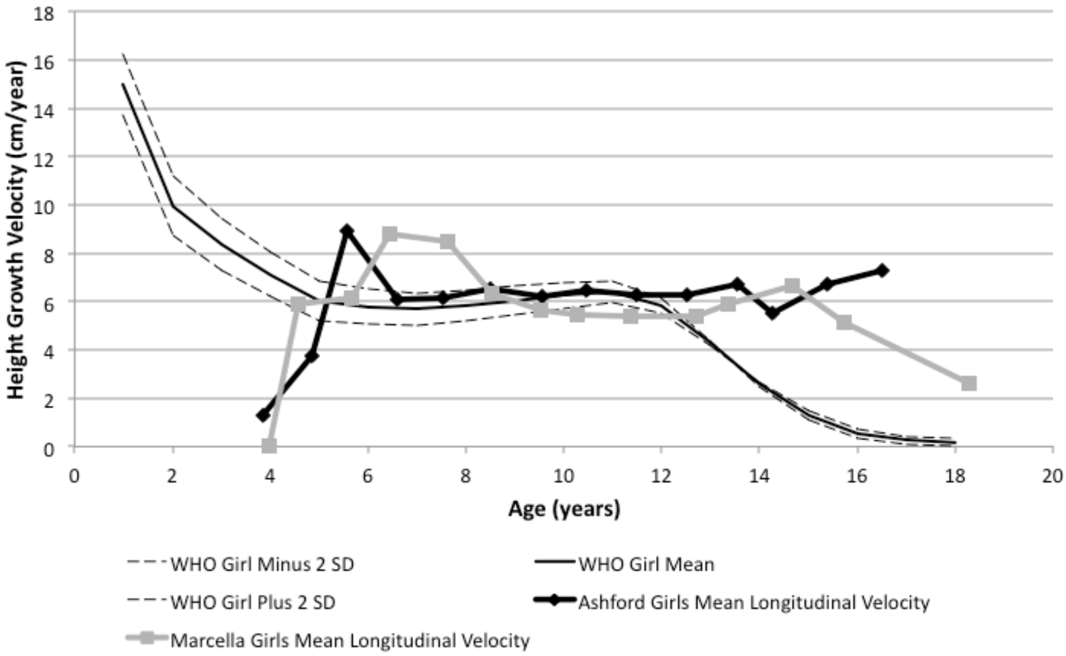
Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; LMA, West London School District, Medical Officer's Report Book, WLSD/435.

5.5.2 Modelling Catch-up Growth in a Multiple Regression Framework

Although it is clear that children were experiencing catch-up growth in terms of height and weight in both schools, these calculations are much more complicated than may first appear because, as discussed above, children in the past rarely grew at the growth curve represented by modern standards. The children in the Marcella Street Home and Ashford School had a later pubertal growth spurt than the children used to represent modern standards. Thus, as shown in Figure 5.18, girls in both the Marcella Street Home and Ashford School were growing much faster after the age of 13 than modern standards would suggest. This higher velocity would give the girls the appearance of experiencing rapid catch-up growth when really they were just reaching the pubertal growth spurt at a later age. This effect is especially problematic since there were few boys in the schools past the age of 16 or 17, so many boys had not completed their pubertal growth spurt by the time they left the school (Figure 5.19). Thus, it is necessary to measure catch-up growth in a multiple regression framework where we can control for the differences between the historical and modern growth curves. These problems were not as strong for weight-for-age Z-scores, which tended to gradually increase over time and could not be calculated for children over the age of ten. However, as mentioned above, historical BMI growth curves were slightly different than modern BMI growth curves, so it is again necessary to control for differences between the two curves.

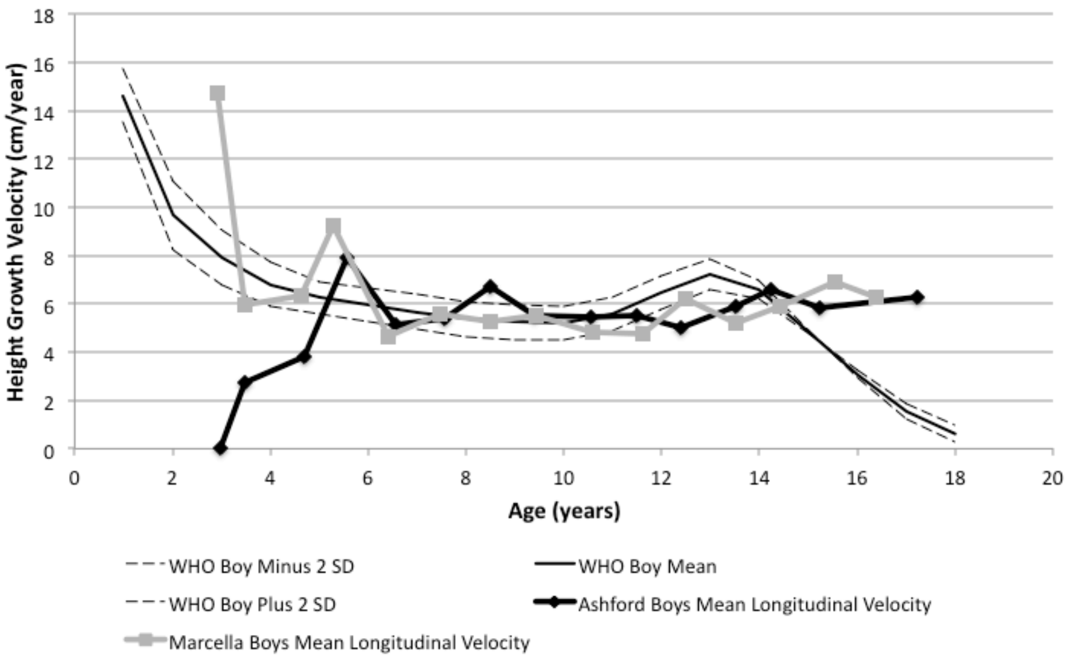
Thus, in order to measure differences in catch-up growth between different groups within each institution, the change in Z-score is held as the dependent variable in the OLS regression analysis and a number of independent variables are introduced to measure between group differences. First, the amount of time that each child spent

Figure 5.18: Longitudinal growth velocity of girls in the Marcella Street Home, Boston and the Ashford School, London compared with modern growth velocity curves



Sources: CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1898, 8503.001; LMA, West London School District, Medical Officer's Report Book, WLSD/435; WHO growth reference data drawn from http://www.who.int/growthref/en/.

Figure 5.19: Longitudinal growth velocity of boys in the Marcella Street Home, Boston and the Ashford School, London compared with modern growth velocity curves



Sources: see figure 5.18.

in the institution is included to control for any differences between children who may have stayed in the institution longer than others.[153] In addition, the height and BMI Z-scores at admission are included to control for regression to the mean and the relationship between weight and growth.[154] Regression to the mean is a well-known phenomenon whereby extreme initial measurements of random variables are likely to move closer to the average of the distribution of the variable. In this case, children who were very tall or very short for their age when measured at admission would be more likely to be at a point closer to the average when next measured. I think the case for regression to mean here is somewhat weak because growth is not a random process but is instead programmed based on genetic factors and environmental conditions during foetal and early life development.[155] However, many of the scientific studies of catch-up growth include the height at initial measurement to control for regression to the mean, so I have included in the regressions since it seems to be scientific best practice.[156]

Including BMI in the height change regression and height in the BMI change regression controls for the relationship between height and weight. For instance, children often put on some fat before their pubertal growth spurt in order to help provide energy for growth. Thus, one would expect children with higher BMIs upon admission to the schools to grow in height faster than children with lower BMIs. Another important variable is whether each child had siblings present in the school. Hatton and Martin have found that children with more siblings were shorter than their counterparts with fewer siblings because larger families had to spread limited

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[153] Correlations between the height-for-age Z-score at admission and the length of time spent in the institutions were very low and insignificant. The natural log of the time in the institution was also included in the regressions, but the results were unaffected.

[154] Height-for-age Z-scores and BMI-for-age Z-scores were not highly correlated, so there are no potential problems with multicolinearity in the regressions.

[155] Godfrey *et al.*, 'Epigenetic Mechanisms'; Gluckman and Hanson, 'Consequences', pp. 6-8.

[156] Walker *et al.*, 'Early Childhood', p. 3019.

resources across more individuals, so it is important to attempt to control for this effect.[157] Unfortunately, this is rather difficult because the only information about each child's family size is the number of children from a particular family that entered the institution together. There is no guarantee, however, that the children entered with all of their siblings, and there were too many children entering the schools alone for them to have been only children. The only way to verify each child's family size would be to link the school registers with census data, which would be very time consuming. Because of these problems, family size was entered into the regression as a dummy variable where children with siblings in the school with them were assigned a one and all others were assigned a zero. Finally, a dummy variable representing sex was included in the regressions to see if boys and girls experienced significantly different catch-up growth.

There were also several variables specific to the Marcella Street Home that could be included in the regression analysis because the Marcella Street Home register was more detailed than the Ashford School Medical Officer's Report Book. The medical officer reported whether each child's father and mother were alive, so dummy variables were entered into the regressions to control for the effect of having a dead father or mother. These variables were kept separate rather than combining them into a parent death dummy variable because the effect of having a dead father or a dead mother could have been different. Without a father, the family would lose a major source of income in the household, but without a mother, the children might not have someone to take care of them and to bargain for them when household resources were allocated.[158] Testing these effects separately could provide an interesting way of measuring whether the income loss from a dead father was worse for children's health

[157] Hatton and Martin, 'Effects'; Hatton and Martin, 'Fertility'.
[158] Horrell and Oxley, 'Bargaining'.

than the care and bargaining loss from a dead mother. It is also necessary to include a dummy variable in the Marcella Street Home regressions for children who entered the school to serve sentences of truancy. Truant children were normally sent to a separate reformatory in Boston, but from October 1895 to June 1896, 123 boys and 6 girls were admitted to the Marcella Street Home to serve sentences for truancy.[159] These boys and girls came from a different background than their counterparts and were also significantly older than the average child entering the school: the mean age of truant boys and girls at admission was 11.81 and 12.07 respectively whereas the mean age of other boys and girls in the school at admission was 7.99 and 7.55 respectively. It was therefore necessary to include a dummy variable to capture the potential differences between truant inmates and regular inmates in the regressions. Finally, for some of the children in the home, the medical officer reported when they became sick with contagious diseases. These diseases included whooping cough (pertussis), chicken pox, mumps, measles, and scarlet fever. Thus, we can measure whether children who suffered from one or more of these diseases had slower growth over their time in the home than the other children who did not suffer from these diseases.

The final set of variables included in the regressions for both schools attempted to capture the differences in the growth curves between modern and historical populations. As mentioned above, by calculating the Z-score compared to modern standards for each child, I am implicitly assuming that the children followed a modern growth curve, but this was clearly not the case. Both boys and girls grew at a slower rate for a longer period of time and had later pubertal growth spurts than modern populations. In order to control for these effects, the sex dummy variable was interacted with age dummy variables, one for each one-year increment. These

[159] CBA, Marcella Street Home Register of Sentenced Inmates, 1877-1909, ref. 8503.001.

interactions, therefore, control for any systematic Z-score change that occurs for all children of a certain age and sex. Therefore, the coefficients on the interacted age dummies for girls from age twelve onward are all positive because girls in the past reached their pubertal growth spurt at a later age than modern girls and grew at a faster rate than would be predicted solely by modern standards. There were also some adjustments for boys, though these were not as dramatic. The age for the interaction was measured in two ways: by the age of each child upon discharge from the institution and by the middle age of each child between entry and discharge from the institution. These two ways of measuring the effect of the age of a child on Z-score change capture potentially different aspects of growth. The discharge age attributes any systematic catch-up growth (Z-score change) to the final age assuming that the child was likely growing at a faster rate at the end of the period rather than at the beginning. The middle age assigns the growth to the midpoint of the child's stay assuming that this is a better measure.

Simple OLS regressions were run for each school independently for each measure of growth, change in height, weight, and BMI Z-score. It was not possible to estimate fixed effects regressions for the data because the children were not measured at regular intervals, making the panel structure unbalanced. In addition, I am more interested in the differences in catch-up growth between different populations and children, the time invariant change, than the specific factors that could have affected individual children's growth while they were in the institution. All of the regressions exclude a very small number of 'outlier' children who either had negative height growth or grew at ridiculously high rates. These data points were verified in the original sources and most likely represent measurement or arithmetic error in the original sources. A number of children in both schools also entered and left the institution more than once. Because the purpose of measuring the velocity of catch-up growth is to make inferences about the nutritional and environmental conditions that children were facing before they entered the home, it was important to exclude children's additional entries into the school. Finally, the medical officers recording heights in the institutions often rounded to the nearest half inch, so children who were in the schools for only a short period of time were more likely to be reported as not having grown at all or having grown at an unrealistically high rate. These rounding errors would have skewed the results, so children who only stayed in the institutions for less than 30 days were excluded from the height change regressions.

5.5.3 Catch-up Growth Regression Results

Beginning with the change in height Z-score regressions (Tables 5.10 and 5.11), there are a number of interesting factors that help to explain children's longitudinal growth during the late nineteenth and early twentieth century. In both the Marcella Street Home and the Ashford School, there was regression to the mean in children's growth. Children who entered the institution short for their age experienced more catch-up growth than their taller counterparts. In addition, children who entered with higher BMI-for-age Z-scores experienced greater growth than those children who entered with little excess fat that could be converted to energy for growth. These are both expected results. However, the effect of the length of time each child spent in the institutions was different in the Marcella Street Home than in the Ashford School. In the Ashford School, the longer children remained in the school the more they caught up relative to modern growth standards whereas in the Marcella Street Home there was no significant relationship between the length of time a child spent in the school and their catch-up growth. Whether a child had siblings in the school with him/her or not was also not statistically significant on either side of the Atlantic, though as mentioned above there were some problems with this measure. Thus, there were no measureable growth benefits for children who had siblings to help them and protect them in the school, and family size does not seem to have played a strong role in catch-up growth. These results should not be overemphasized, however, since the number of children entering the institution together was at best a weak proxy for family size.

For the variables specific to the Marcella Street Home, children's orphan status did not significantly affect the children's catch-up growth. In addition, children who suffered from an acute infectious disease in the home did not experience significantly slower catch-up growth than the other children in the Home. This result suggests that these short, acute diseases were probably less of a problem for long-run growth than chronic diseases such as diarrhoea, though the effect of these chronic diseases cannot be explicitly tested here. Finally, children sentenced for truancy experienced slower catch-up growth than the other children in the Home. This result confirms that the truant children were drawn from a more diverse class background and were slightly better off than the rest of the children in the Home.

Finally, the most interesting result is that in both schools girls experienced faster catch-up growth than boys controlling for all the other variables mentioned above and for age-specific differences between modern and historical growth curves. The sex dummy coefficient did become insignificant in the Ashford School regressions when controlling for the middle age of each child interactions, but the coefficients remained negative and of a similar magnitude. This result and its implications will be discussed more thoroughly in the next section of the chapter.

Table 5.10: Change in height Z-score for age regressions for the Marcella Street Home, Boston, MA.

Dependent: Change in Height Z-Score	1	2	3	4	5
Model	OLS	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust	Robust
N	228	228	228	228	228
Constant	-0.091	0.037	0.156	0.077	0.181
	(-0.71)	(0.26)	(1.23)	(0.62)	(1.65)
Length of Stay (years)	0.001	-0.051	-0.042	-0.025	-0.035
	(0.03)	(-1.06)	(-0.57)	(-0.52)	(-0.45)
Height for Age Z-Score at Admission	-0.191***	-0.189***		-0.166***	
	(-5.22)	(-4.97)		(-4.48)	
BMI for Age Z-Score at Admission	0.130**	0.175***		0.172***	
	(2.56)	(3.14)		(3.02)	
Sibling present in School	-0.067	-0.016	-0.016	-0.031	0.008
	(-0.82)	(-0.20)	(-0.16)	(-0.43)	(0.11)
Child's Father Dead	0.146	0.130	0.117	0.093	0.105
	(1.64)	(1.41)	(1.19)	(1.07)	(1.16)
Child's Mother Dead	0.082	-0.012	-0.073	-0.013	-0.090
	(0.98)	(-0.14)	(-0.95)	(-0.17)	(-1.23)
Disease Dummy	-0.255	-0.128	-0.071	-0.080	0.025
	(-1.14)	(-0.76)	(-0.29)	(-0.43)	(0.10)
Sentenced for Truancy	-0.251***	-0.269***	-0.212***	-0.269***	-0.199***
	(-3.79)	(-3.65)	(-3.33)	(-3.74)	(-3.17)
Sex Dummy (1 = male)	-0.113	-0.645***	-0.315***	-0.665***	-0.780***
	(-1.26)	(-9.33)	(-7.30)	(-3.72)	(-4.68)
Age and Sex Interactions:					
Discharge Age		X	X		
Middle Age in Institution				X	X
R-square	0.30	0.49	0.26	0.47	0.27
F-statistic	6.73				

Notes: see table 5.11.

Sources: see sources for figure 58.

Table 5.11: Change in height Z-score for age regressions for the Ashford School, West London School District, London, UK.

Dependent: Change in Height Z-Score	1	2	3	4	5
Model	OLS	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust	Robust
N	594	594	594	594	594
Length of Stay (years)	0.069***	0.067***	0.074***	0.068***	0.074***
	(4.63)	(4.39)	(5.12)	(4.62)	(5.05)
Height for Age Z-Score at Admission	-0.058***	-0.037**		-0.038**	
	(-3.31)	(-2.52)		(-2.48)	
BMI for Age Z-Score at Admission	0.029	0.041**		0.042**	
	(1.65)	(2.05)		(2.08)	
Sibling present in School	0.015	0.015	0.024	0.010	0.019
	(0.52)	(0.55)	(0.89)	(0.38)	(0.69)
Sex Dummy (1 = male)	-0.107***	-0.795***	-0.708***	-0.567	-0.472
	(-3.57)	(-10.82)	(-8.52)	(-1.46)	(-1.18)
Age and Sex Interactions:					
Discharge Age		X	X		
Middle Age in Institution				X	X
Parish/Poor Law Union Dummies	X	X	X	X	X
R-square	0.12	0.29	0.27	0.29	0.27
F-statistic	7.05**				

Notes: Unstandardized coefficients with t-statistics in parentheses. * denotes significance at the 10 per cent level; ** denotes significance at the 5 per cent level; *** denotes significance at the 10 per cent level. Excluding outliers, entries after the first, and lengths of stay less than one month.

Sources: LMA, West London School District, Medical Officer's Report Book, WLSD/435.

Table 5.12: Change in height Z-score-for-age regressions for children under the age of 8 for the Ashford School, West London School District, London, UK.

Dependent: Change in Height Z-Score	1	2	3
Children's Age	< 8	< 8	< 8
Model	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust
N	107	107	107
Constant	0.228**	0.091	-0.209
	(2.22)	(0.79)	(-0.86)
Ln Length of Stay (years)	0.139***	0.125***	0.109**
	(3.37)	(2.85)	(2.55)
Height for Age Z-Score at Admission	-0.014	-0.009	-0.005
	(-0.44)	(-0.27)	(-0.14)
BMI for Age Z-Score at Admission	-0.021	0.021	0.007
	(-0.54)	(0.52)	(0.19)
Sibling present in School	0.084	0.031	0.042
	(1.58)	(0.59)	(0.77)
Sex Dummy (1 = male)	-0.105*	-0.965***	-0.113*
	(-1.67)	(-7.40)	(-1.86)
Parish/Poor Law Union Dummies	X	X	X
Age Dummy and Sex Interactions		X	
Age Dummies			X
R-square	0.16	0.40	0.35
F-statistic	2.45		

Notes: Unstandardized coefficients with t-statistics in parentheses. * denotes significance at the 10 per cent level; ** denotes significance at the 5 per cent level; *** denotes significance at the 10 per cent level. Excluding outliers, entries after the first, and lengths of stay less than one month.

Sources: LMA, West London School District, Medical Officer's Report Book, WLSD/435.

One potential worry about this gendered result is that it is solely dependent on the differences between historical and modern growth curves. In order to allay some of these fears, I re-ran the Ashford School regressions only including children under the age of eight, the age when the pubertal growth spurt would not have begun for either girls or boys. This sub-sample thus provides a cleaner look at the gendered differences in catch-up growth than the larger sample, but the sample size of children is also much smaller, only 107 individuals, which suggests restraint when making any conclusions. There are two interesting results to this robustness check presented in table 5.12. First, the sex dummy is consistently negative and significant across all three specifications: one where only a sex dummy was included, another where sex dummy and age dummy interactions were allowed, and a final one where both age and sex dummies were included in the regression but not interacted. Thus, the result that girls experienced greater catch-up growth than boys is not merely a statistical artefact of different growth curves. Another interesting result is that the BMI-for-age Z-score at admission ceased to be significant in the regressions. This suggests that the positive, significant relationship between BMI Z-score at entry and catch-up growth found in the regressions for the full sample must be related to the pubertal growth spurt. These largely similar results for the gendered aspect of catch-up growth in the sub-sample and full sample from the Ashford School provide more confidence in the finding that girls grew faster relative to modern standards than boys in these schools.

The change in weight-for-age Z-score and BMI-for-age Z-score regressions were less enlightening with few significant and consistent results across the regressions (Tables 5.13-5.16). I have included the regression tables here for the sake of completeness, but there are very few concrete lessons to draw from these results.[160] In both cases regression to the mean was still significant and negative in the regressions. Children who entered the institution with lower BMI-for-age Z-scores were more likely to catch-up in terms of weight-for-age or BMI-for-age than their fatter counterparts. Aside from weight-for-age in the Marcella Street Home, children who entered the institutions with taller height-for-age Z-scores experienced greater

[160] When writing up this chapter as a journal article, I will exclude weight and BMI entirely because they are clouded by fast weight gain before entering the institutions and BMI especially is not an intuitive measure of growth in children.

Table 5.13: Change in weight-for-age Z-score regressions for children under 10 in the Marcella Street Home, Boston, MA.

Dependent: Change in Weight Z-Score	1	2	3	4	5
Model	OLS	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust	Robust
N	73	73	81	73	81
Constant	-0.062	1.242*	0.231	-0.143	2.417***
	(-0.36)	(1.99)	(0.28)	(-0.39)	(9.51)
Length of Stay (years)	0.038	-0.009	0.128*	0.044	0.118*
	(0.55)	(-0.14)	(1.93)	(0.71)	(1.68)
Height for Age Z-Score at Admission	-0.156***	-0.173***		-0.176***	
	(-3.86)	(-4.12)		(-3.92)	
BMI for Age Z-Score at Admission	-0.272***	-0.300***		-0.287***	
	(-4.29)	(-5.20)		(-4.57)	
Sibling present in School	0.218	0.093	0.051	0.125	0.195
	(1.61)	(0.61)	(0.21)	(1.00)	(1.06)
Child's Father Dead	-0.329	-0.642*	-0.259	-0.657**	-0.432
	(-1.11)	(-1.80)	(-0.41)	(-2.50)	(-1.00)
Child's Mother Dead	-0.000	0.154	-0.360	0.151	-0.370
	(-0.00)	(0.72)	(-1.23)	(0.67)	(-1.10)
Disease Dummy	-0.149	-0.191	0.083	-0.134	-0.110
	(-0.96)	(-1.28)	(0.31)	(-0.82)	(-0.46)
Sentenced for Truancy	0.110	0.185	0.108	0.138	0.055
	(0.57)	(0.70)	(0.33)	(0.56)	(0.19)
Sex Dummy (1 = male)	-0.060	0.544	-0.510	-0.008	-0.410
	(-0.58)	(1.39)	(-0.76)	(-0.04)	(-1.43)
Age and Sex Interactions:					
Discharge Age		X	X		
Middle Age in Institution				X	X
R-square	0.40	0.57	0.30	0.53	0.39
F-statistic	4.52				

Notes: see table 5.14.

Sources: see sources for figure 5.8.

Table 5.14: Change in weight-for-age Z-score regressions for children under 10 in the Ashford School, West London School District, London, UK.

Dependent: Change in Weight Z-Score	1	2	3	4	5
Model	OLS	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust	Robust
N	310	310	310	310	310
Length of Stay (years)	-0.075**	-0.076**	-0.120***	-0.076**	-0.097***
	(-2.49)	(-2.40)	(-3.47)	(-2.51)	(-2.91)
Height for Age Z-Score at Admission	0.115***	0.115***		0.099***	
	(3.20)	(3.13)		(2.61)	
BMI for Age Z-Score at Admission	-0.235***	-0.225***		-0.209***	
	(-5.62)	(-4.85)		(-4.40)	
Sibling present in School	0.041	0.039	0.039	0.040	0.046
	(0.91)	(0.88)	(0.81)	(0.89)	(0.93)
Sex Dummy (1 = male)	0.047	0.545***	0.562***	0.312	0.365
	(1.09)	(8.52)	(7.94)	(0.77)	(0.93)
Age and Sex Interactions:					
Discharge Age		X	X		
Middle Age in Institution				X	X
Parish/Poor Law Union Dummies	X	X	X	X	X
R-square	0.19	0.23	0.14	0.25	0.17
F-statistic	7.65**				

Notes: Unstandardized coefficients with t-statistics in parentheses. * denotes significance at the 10 per cent level; ** denotes significance at the 5 per cent level; *** denotes significance at the 10 per cent level. Excluding outliers and entries after the first but including lengths of stay less than one month.

Sources: LMA, West London School District, Medical Officer's Report Book, WLSD/435.

Table 5.15: Change in BMI Z-score for age regressions for the Marcella Street Home, Boston, MA.

Dependent: Change in BMI Z-Score	1	2	3	4	5
Model	OLS	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust	Robust
N	246	246	246	246	246
Constant	0.412***	-0.716**	-0.133	1.945**	0.801
	(3.01)	(-2.33)	(-0.44)	(2.36)	(1.00)
Length of Stay (years)	-0.097**	-0.039	-0.050	-0.064*	-0.028
	(-2.49)	(-0.97)	(-0.76)	(-1.74)	(-0.44)
Height for Age Z-Score at Admission	0.080**	0.097**		0.104***	
	(2.25)	(2.24)		(2.78)	
BMI for Age Z-Score at Admission	-0.317***	-0.413***		-0.377***	
	(-6.07)	(-7.39)		(-6.11)	
Sibling present in School	0.172*	0.033	0.056	0.084	0.063
	(1.74)	(0.31)	(0.47)	(0.80)	(0.57)
Child's Father Dead	0.013	0.040	0.050	0.021	0.014
	(0.12)	(0.37)	(0.39)	(0.18)	(0.11)
Child's Mother Dead	-0.052	-0.039	-0.030	0.006	0.038
	(-0.46)	(-0.33)	(-0.21)	(0.04)	(0.25)
Disease Dummy	0.214	0.045	-0.039	0.018	-0.131
	(0.92)	(0.21)	(-0.13)	(0.09)	(-0.45)
Sentenced for Truancy	-0.155	-0.022	-0.176	-0.037	-0.171
	(-1.52)	(-0.18)	(-1.47)	(-0.33)	(-1.56)
Sex Dummy (1 = male)	-0.180*	1.178***	0.609***	-0.678***	-0.358
	(-1.81)	(4.83)	(2.70)	(-2.84)	(-1.57)
Age and Sex Interactions:					
Discharge Age		X	X		
Middle Age in Institution				X	X
R-square	0.23	0.38	0.17	0.34	0.15
F-statistic	6.54				

Notes: see table 5.16.

Sources: see sources for figure 5.8.

Table 5.16: Change in BMI Z-score for age regressions for the Ashford School, West London School District, London, UK.

Dependent: Change in BMI Z-Score	1	2	3	4	5
Model	OLS	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust	Robust
N	672	672	672	672	672
Length of Stay (years)	-0.201***	-0.163***	-0.220***	-0.184***	-0.213***
	(-9.46)	(-7.34)	(-10.41)	(-8.98)	(-9.65)
Height for Age Z-Score at Admission	0.032*	0.026		0.027	
	(1.69)	(1.24)		(1.41)	
BMI for Age Z-Score at Admission	-0.229***	-0.302***		-0.299***	
	(-6.58)	(-6.82)		(-6.58)	
Sibling present in School	0.051	0.076*	0.048	0.069	0.041
	(1.15)	(1.83)	(1.06)	(1.54)	(0.85)
Sex Dummy (1 = male)	0.020	0.140	-0.384	-1.012*	-1.150**
	(0.48)	(0.33)	(-1.36)	(-1.68)	(-2.06)
Age and Sex Interactions:					
Discharge Age		X	X		
Middle Age in Institution				X	X
Parish/Poor Law Union Dummies	X	X	X	X	X
R-square	0.26	0.34	0.22	0.32	.21
F-statistic	20.96***				

Notes: Unstandardized coefficients with t-statistics in parentheses. * denotes significance at the 10 per cent level; ** denotes significance at the 5 per cent level; *** denotes significance at the 10 per cent level. Excluding outliers and entries after the first but including lengths of stay less than one month.

Sources: LMA, West London School District, Medical Officer’s Report Book, WLSD/435.

weight and BMI growth than their shorter counterparts. In the Ashford School, there was a negative and significant relationship between the length of stay in the school and the change in weight and BMI-for-age Z-score. This result is puzzling because it suggests that children in the institution longer were falling behind modern standards for weight and BMI. The magnitude of the coefficients and their significance is also consistent when including different age dummy and sex dummy interactions, so it cannot be explained by the age structure of the population in the school. Finally, unlike height catch-up, there were no consistent findings of gender bias in weight-for-age or BMI-for-age Z-score growth. The most plausible explanation for these weak results is that because children were likely in the workhouse or court system for a couple of weeks before entering the schools and weight gain takes place much faster than growth in height, the children may have already put on significant weight before entering institutions, skewing the figures reported by the medical officers. BMI-for-age is also a very problematic indicator for children, as mentioned above, so it is not entirely surprising that the results for BMI are inconclusive.

5.6 Explaining Gender Differences in Catch-up Growth

As mentioned above, the main finding from the catch-up growth regressions were that girls experienced faster catch-up growth in terms of height in both the Marcella Street Home and the Ashford School controlling for difference between modern and historical growth curves, but there was not a similar effect for weight or BMI growth. There are three possible explanations for the faster catch-up growth in girls than in boys in these institutions: girls could have been treated better than boys in the institutions; girls could have a greater natural propensity for catch-up growth than boys; and finally, girls could have been deprived relative to boys suggesting that girls may have been discriminated against in the allocation of household resources before entering the institutions. I will deal with each of these possibilities in turn.

There is not strong evidence that girls were better treated in the Ashford School and Marcella Street Home than boys. It is true that the boys' dormitories tended to be more crowded and messier than the girls' dormitories, but this does not necessarily translate into worse conditions. Levels of work appeared to have been similar if not entirely comparable. The only potential place where girls may have been given an advantage over boys is in their diet. In the dietaries reported by both schools, there was no distinction between the amount of food given to girls and boys.[161] Because the average boy requires more energy than a girl of the same age, if girls and boys were given the same amount of food, this would be an advantage for girls relative to boys.[162] However, the dietary for the Marcella Street Home did not break down the portion size by the age of children, and it seems unlikely that children of all ages were given the same portions of food.[163] Likewise, even though the Ashford School dietary did break down the dietary into two age categories, the age categories were still quite wide.[164] Thus, any difference in food portion size can probably be explained away by the fact that girls were probably given less food in the first place and consumed less of what they were given than boys. We can then tentatively reject the better treatment of girls as an explanation for their greater catch-up growth.

The second explanation, that girls have a greater natural propensity for catch-up growth, is more difficult to handle for two reasons. First, there are very few, if any, truly experimental studies of catch-up growth because purposely starving children to

[161] 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 184-196; LMA, Dietary Tables, Recipes, etc., Dietary of 1909, WLSD/468.
[162] Schneider, 'Real Wages', p. 3; FAO, 'Human', pp. 26-27; chapter 1.
[163] 'Annual Report of the Institutions Commissioner for the Year 1896-7', pp. 184-196.
[164] LMA, Dietary Tables, Recipes, etc., Dietary of 1909, WLSD/468.

measure their catch-up growth is unethical.[165] Thus, scientists and development economists have had to measure catch-up growth by conducting interventions on children who were deprived. The second difficulty with testing whether girls have a greater natural propensity for catch-up growth is that most of the catch-up growth studies do not include gender explicitly in their analysis. Many of the classic papers measuring catch-up growth do not distinguish between boys and girls in their analysis at all.[166] However, there are a few papers worth mentioning. Adair found that Filipino girls experienced catch-up growth at higher rates, defined as moving from a height below -2 standard deviations of modern standards at age 2 to above that level at age 8.5. However, Adair found that boys and post-menarchal girls were more likely to experience catch-up growth between the ages 8.5 and 12 than girls who had not yet reached menarche.[167] In addition to Adair's study, Prentice *et al*. and Coly *et al.* found that girls experienced greater catch-up growth in adolescence than boys in both the Gambia and Senegal.[168] However, none of the authors makes the claim that the patterns observed reflect the greater natural propensity of one sex for catch-up growth because it would be difficult to separate this natural propensity from societal factors that could explain the difference. Thus, we cannot rule out that the greater observed growth among girls in these societies is due to the fact that girls were worse off to begin with.

It is also important to note that there has been a debate about whether girls or boys are more resilient to nutritional deprivation. Some scientific literature from the 1960s found that boys tended to respond more dramatically to nutritional insults than girls and that boys also responded more sharply when conditions improved again.

[165] Boersma and Wit, 'Catch-up', p. 648.
[166] Walker *et al.*, 'Early'; Perez-Escamilla and Pollitt, 'Growth'; etc.
[167] Adair, 'Filipino Children', pp. 1143-1144.
[168] Prentice *et al.*, 'Critical Windows', pp. 914-915; Coly *et al.*, 'Preschool Stunting'; Singh *et al.*, 'School Meals', pp. 12-13.

However, these factors were not undisputed in the earlier literature.[169] If boys did respond more to poor economic conditions than girls, then we would expect boys to catch-up faster than girls. Thus, it is possible that the differences in catch-up growth measured in this chapter actually understate the deprivation girls were experiencing before entering the schools. However, it should also be noted that more recent studies including the development literature discussed above have found that girls were in some ways more sensitive than boys. Baten and Murray found that women's adult heights respond more readily to economic conditions than men's heights, and Harris found that girls suffered relative to boys during the Nazi occupation of Norway.[170]

Overall, then, it seems that there is no consensus in the scientific and development literature about whether males or females are more sensitive to nutritional and environmental shocks. This is probably in part due to the fact that socioeconomic factors may shift the direction of the bias depending on the situation. However, I believe it is possible to tentatively reject the hypothesis that the measured difference in boys' and girls' catch-up growth in the Ashford School and Marcella Street Home is caused by girls' greater natural propensity for catch-up growth.

Thus, we can cautiously accept the third explanation that girls were deprived relative to boys before entering the schools. Finding a reason for this relative deprivation, on the other hand, is more difficult, and unfortunately is somewhat untestable with the data studied here. However, following other historians it seems plausible to infer that these differences health reflect discrimination against girls in the allocation of household resources.[171] It is the most parsimonious explanation for these differences. These gender differences in health are compatible with bargaining

[169] Acheson and Fowler, 'Sex', pp. 32-33; Tanner, *Growth at Adolescence*, p. 127-128.
[170] Komlos, 'On the Significance', p. 211; Baten and Murray, 'Heights'; Harris, 'Anthropometric History', pp. 66-67.
[171] Horrell *et al.*, 'Measuring Misery'; Meredith and Oxley, 'Blood and Bone'.

models of household allocation where children who brought resources to the family received a larger share of the resources. Boys in late nineteenth-century Boston and early twentieth-century London had more labour market opportunities, possibly explaining their relative health compared to girls. However, it is also possible that ideology played a role; households may have valued their girls less than their boys for non-economic reasons. Unfortunately, I cannot distinguish between these two mechanisms of allocation.

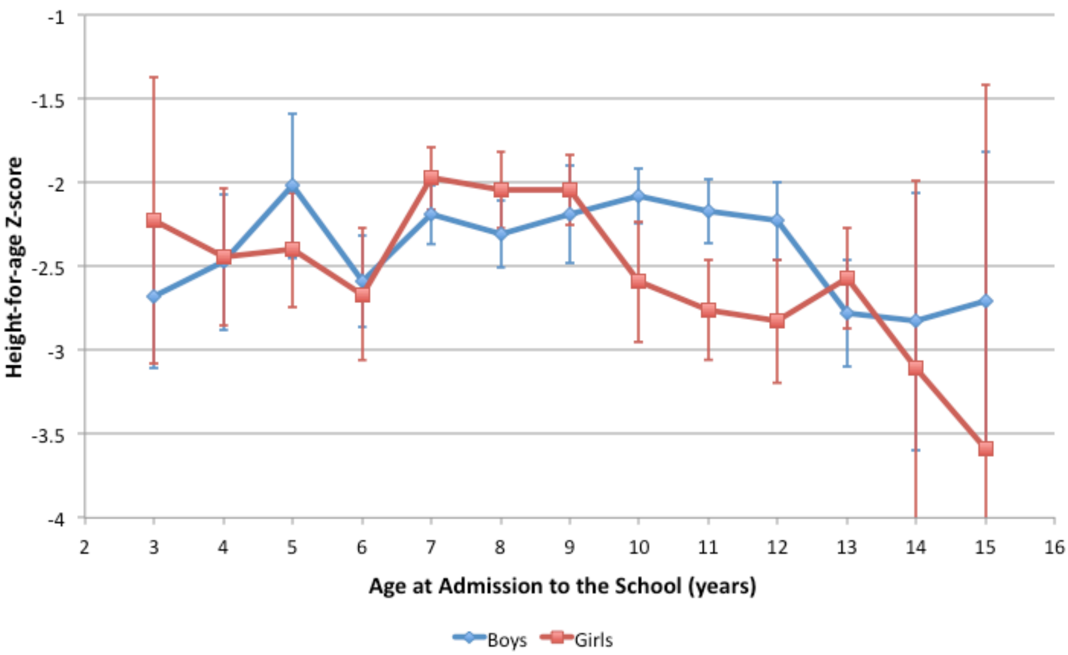
This finding of relative female deprivation is inconsistent in many ways with the current literature. It challenges the household budget literature, which found no gender discrimination in resource allocation among upper working class families in Britain and the US, and it also is at odds with Harris's findings of female height advantage in early twentieth century Britain and his findings that girls did not have substantially higher mortality rates than boys across the second half of the nineteenth and twentieth centuries.[172] It is, however, consistent with Horrell *et al.*'s finding of low BMIs and thus poor health for London women in the late nineteenth century.[173] The question, then, is why the results produced by this study are different.

There are perhaps three reasons why this study has found relative female deprivation and others have not. Part of the difference may have to do with the representativeness of the datasets employed in this chapter. As has been argued above, the children in the two schools were likely from the poorer echelons of the working class. However, the households in the US Department of Labor study were predominantly the households of higher status workers.[174] Thus, it is possible that families closer to poverty were forced to make harder decisions when allocating

[172] Horrell and Oxley, 'Crust'; Logan, 'Family Allocation'; Harris, 'Gender', (1998); Harris, 'Gender', (2008).
[173] Horrell *et al.*, 'Measuring Misery'.
[174] Haines, 'Poverty', in Hershberg (ed.), *Philadelphia*, pp. 245-9; Horrell and Oxley, 'Crust', p. 499.

household resources to their children. If the female deprivation measured in this study is linked to poverty, it is not difficult to believe that fifty years before these children entered their schools, when wages were substantially lower in both Britain and the US, a much wider section of girls in the population could have been in poorer health relative to their brothers. Thus, perhaps it was the increase in real wages and food availability in Britain through imports that allowed families to allocate resources more equitably among household members.[175]

Figure 5.20: Average height-for-age Z-score at admission for one-year age groupings for children in the Ashford School.



Notes: 95% confidence intervals are included around the means. Wide confidence intervals at ages 14 and 15 are in part driven by low sample sizes, especially for girls. Children are only included when first entering the school and several outliers (almost certainly measurement errors) have been excluded.

Source: LMA, West London School District, Medical Officer's Report Book, WLSD/435.

Second, this study also warns that female deprivation can be hidden by cross-sectional comparisons of children's heights at certain ages. As mentioned above, Harris's cross-sectional evidence of relatively well-off schoolchildren suggested that girls in Britain before the First World War had a height percentile advantage between

[175] Floud *et al.*, *Changing Body*, pp. 158-160.

the ages of five and nine with boys taking the advantage after the age of twelve.[176] This pattern, however, is more a function of growth curves than anything else. Remember that the distribution of height-for-age Z-scores at admission to the Marcella Street Home and the Ashford School for boys and girls were nearly identical (see figure 5.10 above). Yet despite these similarities when all ages are combined, the pattern is different when boys and girls' height-for-age Z-scores at admission are plotted against their age (figure 5.20). The data confirm Harris's finding that girls tended to be taller relative to modern standards between the ages of 7 and 9 and boys tended to be taller than girls relative to modern standards between the ages of 10 and 12. However, these differences do not tell us anything about the relative well-being of boys and girls because they mostly reflect the earlier pubertal growth spurt in modern populations. If the children were perfectly following the modern growth curve, then we would expect the lines in figure 5.20 to be perfectly flat though at a lower Z-score. This would suggest that children were following their canalized growth trajectory across different ages. However, the lines in figure 5.20 are decidedly not flat because of the differences between historical and modern growth curves. The girls' height-for-age Z-scores decline from ages 9 to 12 because modern populations of girls, the reference, experience their pubertal growth spurt at those ages, whereas the historical population of girls continue growing at a lower, pre-adolescent growth spurt rate and fall behind their modern counterparts. We can observe the same phenomenon for boys. The modern population begins its pubertal growth spurt at age 12 while the historical population has a much later growth spurt, which causes the boys' height-for-age Z-score to fall.

[176] Harris, 'Gender', (1998), p. 427.

These insights highlight several problems with studying children's historical growth patterns in a cross-sectional framework. First, as mentioned above, the height-for-age Z-score or percentile differences between boys and girls at specific ages are strongly influenced by the timing of the pubertal growth spurt in historical and modern populations. This also highlights the fact that boys and girls need to be studied separately in cross-section because pooling the boys and girls would produced skewed results even if there were equal number of girls and boys in the sample. Second, it is very difficult to accurately disentangle catch-up growth from the different timing of the pubertal growth spurt by looking at cross-sectional data alone. This does not discount all studies that have inferred catch-up growth from cross-sectional data. For instance, Steckel's finding that American slave boys were at the 0.2 percentile of modern standards at age 4.5 and at the 27th percentile by the time they were adults certainly implies some catch-up growth.[177] However, it is important to consider whether we are measuring catch-up growth or merely observing a slower velocity of growth for a longer period of time. As mentioned in the previous chapter, in order for type B catch-up growth to occur, the population must surpass their earlier level of growth. Thus, an extension of the growing years into the twenties is not in and of itself evidence of catch-up growth. Finally, time series of children's height-for-age Z-scores or percentiles at a specific age, such as those presented by Harris,[178] are interesting for tracking changes in children's growth over time, but an increase in height-for-age Z-scores especially during the pubertal growth spurt ages cannot in and of itself be taken to show improving child nutrition. This is because increases in the height-for-age Z-score could indicate improvements in child health, or they could merely reflect the fact that the historical and modern pubertal growth spurts were

[177] Steckel, 'A Peculiar Population', p. 724.
[178] Harris, 'Anthropometric History', pp. 69-70; Harris, 'Gender', (1998), p. 429.

becoming more closely aligned. Looking at the case of girls in the Ashford School in figure 5.20, it is clear that as the pubertal growth spurt began earlier across the twentieth century, girls at ages 10-12 would experience larger increases in their height-for-age Z-scores than girls at other ages because they would not fall behind as much during the pubertal growth spurt. Therefore, it would be difficult to know whether the timing of the increase in height-for-age Z-scores at these ages was related to changes in the socio-economic circumstances of these children or merely changes in the pattern of growth as the height-for-age curves (in figure 5.20) simultaneously increased at all ages and shifted from a curve with a hole around the pubertal growth spurt toward the flat, canalized growth trajectory of modern populations.[179]

Finally, the fact that the female deprivation found in this study is not necessarily found in terms of excess female mortality may not be all that surprising. Mortality provides a rather limited view of the health of a population since most bouts with illness did not result in death, and it is well known that morbidity and mortality were not perfectly correlated.[180] Thus, the level of deprivation shown here possibly caused by discrimination against girls in the allocation of household resources may not have manifested itself in mortality rates, which were at least in part driven by the susceptibility of the different sexes to infectious diseases. Instead, poorer female nutrition could have been associated with higher female morbidity. Height indicators would therefore be more sensitive to these nutritional and chronic disease factors than mortality statistics. These assumptions follow quite clearly from the work of Hoyt Bleakley showing that the eradication of chronic diseases such as hookworm and

[179] It should be noted that an earlier pubertal growth spurt could be in itself an indicator of good child health.

[180] Harris *et al.*, ‘Long-term Changes’; Floud *et al.*, *Changing Body*, pp. 180-185.

Malaria vivax was very important in increasing investment in human capital and reducing fertility in the American South.[181]

5.7 Conclusion

The evidence presented in this chapter suggests that the girls entering the Marcella Street Home and the Ashford School were in poorer health than their male companions because they grew faster relative to modern standards while in the schools than the boys did. Although it is not possible to determine a precise mechanism for this outcome based on the evidence presented in the chapter, it seems plausible that the girls' ill health could have been caused by gender discrimination in the allocation of household resources. The impoverished families represented in the dataset were forced to make difficult decisions about which household members should receive the most resources, and unfortunately, it appears that girls (and likely their mothers as well) bore the brunt of the suffering from poverty. This finding of poor female health is contradictory to parts of the previous literature, which found only small differences in the mortality and heights of boys and girls. These contradictory results likely result from three sources. First, the samples used to study household allocation of family resources mainly referred to the upper echelons of the working class, not the poor children in the samples employed in this paper. Second, cross-sectional studies comparing boys and girls growth relative to modern growth references can be misleading because of the differences in the timing of the pubertal growth spurt in modern and historical populations. Finally, mortality is a relatively narrow indicator of child health, ignoring chronic diseases that could take a

[181] Bleakley, 'Economic Effects'; Bleakley, 'Disease and Development'.

tremendous toll on children's growth. Thus, poorer female health might be present if better morbidity statistics were available.

As Osmani and Sen have argued, poor female health could have enormous influence on the health of the population as a whole.[182] The poor health of adult women would create an inadequate nutritional environment *in utero* for all of the children they bore, setting the children on a lower growth path and compromising their health in later life. This initial disadvantage was exacerbated for girls by further discrimination in the allocation of household resources so that by the time the girls reached child-bearing age, they were significantly below their full height potential and consequently had a higher risk of mortality. Thus, the poor health of girls and adult women would be transferred into poor health for subsequent generations. Improvement in health proxied by adult heights, morbidity, mortality, etc., then, would lag behind increases in real wages and nutrition. Thus, the relative deprivation of girls likely slowed the progress of improvements in health outcomes across the second half of the nineteenth and early twentieth century.

The degree to which poor female health slowed the secular increase in heights and the decline in mortality is in large part dependant on the share of the population in which females were discriminated against in the allocation of household resources. Placing the evidence presented here with other studies on gender differences in health suggests that by the early twentieth century, female deprivation in childhood may have been limited to the poorest groups in the working classes. However, if we assume that gender discrimination in the allocation of household resources became less prominent with higher real wages and more plentiful food sources, it is not difficult to imagine that relative female deprivation in childhood could have been

[182] Osmani and Sen, 'Hidden Penalties'.

common in the working classes in America and Britain in the mid nineteenth century. Perhaps this partially explains why the most rapid period of height growth for males was during the interwar years.[183] Real wages and nutrition had increased dramatically enough that gender discrimination in the allocation of at least food resources had broken down, leading to rapid increases in height for both men and women. Clearly, relative female deprivation had a role to play in this transition.

[183] Hatton and Bray, 'Long Run Trends'.

CONCLUSION

This dissertation has attempted to integrate the household and children more fluidly into measures of well-being in the past. In part one, I developed a Monte Carlo simulation to test some of the assumptions of Allen's welfare ratio methodology. These included his assumptions that family size was constant over time, that there were no female-headed households and that women and children did not participate in the labour force. After all of the adjustments, it appears that Allen's welfare ratios underestimate the welfare ratios of a demographically representative group of families, especially if women and children's labour force participation is included. However, the predicted distributions also highlight the struggles of agricultural labourers, who are given separate consideration. Even the average agricultural labourers' family with women and children working would have had to rely of self-provisioning, gleaning, poor relief or the extension of the working year to make ends meet at the poorest point in their family life cycle. Part two adjusted Floud *et al.*'s estimates of calorie availability in the English economy from 1700 to 1909 for the costs of digestion, pregnancy and lactation. Taken together, these three additional costs reduced the amount calories available by around 15 per cent in 1700 but only by 5 per cent in 1909 because of the changing composition of the English diet. Part three presented a new adaptive framework for studying changes in children's growth patterns over time and a new methodology, longitudinal growth studies, for measuring gender disparities in health in the past. An adaptive framework for understanding growth provides a more parsimonious explanation for the vast catch-up growth achieved by slave children in the antebellum American South. The slave children were only able to achieve this catch-up growth because they were programmed for a tall height trajectory by relatively good conditions *in utero*. Finally, impoverished girls experienced greater catch-up growth than boys in two schools in late-nineteenth century Boston, USA and early-twentieth century London, suggesting that girls were deprived relative to boys before entering these institutions. Thus, although the dissertation covered a number of distinct topics, they were all connected by a desire to place the household and children at the centre of living standards.

So what broader lessons can be drawn from the dissertation as a whole? First, I hope that the dissertation has shown that incorporating the household and household considerations into measures of living standards provides a more complete picture of well-being in the past. Part one showed that although family size, measured by the median number of children being supported at any given time, was low in early modern England, large families, lone-mothers with children and even the average family were vulnerable when they were supporting the maximum number of children and had the lowest welfare ratio. Women and children's labour force participation increased the family welfare ratio by 31 to 48 per cent and made it easier for the family to make ends meet. Thus, these household considerations are central to understanding the purchasing power and welfare of an average family in early modern England. Part three provided another method of inferring whether there was discrimination in the allocation of household resources. By measuring boys and girls' longitudinal growth relative to modern standards, I was able to detect differences in catch-up growth by gender after the children experienced a positive health intervention. Thus, it seems that there was some pro-male discrimination in the allocation of household resources at least among the poor.

Second, although the dissertation has focussed mostly on Britain with several jaunts to the Americas, there are lessons for cross-country comparisons of real wages, energy availability, and gender inequality. Family sizes and the availability of female and child employment varied across countries based on the fertility and mortality characteristics of the society and the occupational structure of the economy. Likewise, workers in other countries may have had more opportunities to self-provision the household even if the English poor law was likely the most generous form of welfare support in the early modern world. Thus, if one's primary purpose for constructing real wages is to measure living standards rather than economic performance, these additional complications must be taken seriously.[1] Digestion, pregnancy and lactation costs may have also varied across countries affecting international comparisons of diets and calorie availability. For instance, rice has a much lower digestion cost than wheat, so if the amount of calories available per capita in China and Europe was roughly equal in the early modern period, this would mean that the Chinese were actually getting more calories from their diet though perhaps fewer micronutrients as well. Likewise, the high prevalence of infanticide in China would have affected pregnancy and lactation costs in different ways. Higher fertility would have increased

[1] Thanks to Jan Luiten van Zanden for making this point.

pregnancy costs relative to England but high infant mortality rates and infanticide would have reduced lactation costs. Finally, the evidence presented in chapter five along with the extensive literature on gender discrimination in Britain and the US suggests that although gender discrimination and differences in health did exist, they were much smaller than what has been observed in the developing world today. Therefore, it seems that families in at least the UK and the US had a preference for equality but were forced to make difficult decisions about allocating resources when they were closer to the margin. Hopefully, these lessons can be of some service to those studying the Great Divergence in the future.

The ideas in this dissertation also point toward a number of areas where more research is needed. As is clear from chapter two, women and children's labour force participation is crucial to family income, yet historians have very little quantified information on women and children's labour participation rates before the nineteenth century for England. This paucity of data is in part due to the limited source material in early modern England, but perhaps a careful study of population listings, probate inventories, tax records, court records and account books will help clarify this important problem.[2] Understanding how women and children's wages changed over time would also be helpful.[3] In addition, chapters two and three highlight the role of self-provisioning in increasing families' income, but again historians know very little about how many families could self-provision, how many calories they could produce per day and how these factors changed over time. This is especially consequential since Floud *et al.* were not able to robustly incorporate self-provisioning into their estimates of calorie availability.[4] Thus, self-provisioning could have increased the

[2] Jacob Field and Amy Erickson are hoping to work on this in the future. Field and Erickson, 'Prospects and Preliminary Work'; see also Humphries and Sarasúa, 'Off the Record'.
[3] Humphries and Weisdorf are working on this at the moment.
[4] Floud *et al.*, *Changing Body*, p. 157.

amount of calories available to people in historical Britain, and if one assumes that self-provisioning became less common over time and in urban areas (until the end of the nineteenth century when allotments became more prevalent), then the decline in food available from self-provisioning could have contributed to the decline in heights across the Industrial Revolution.[5]

The various findings about children's growth in part three suggest that focusing on female and maternal health, mismatches between the prenatal and postnatal environment, children's responses to disease, different gendered growth patterns and longitudinal growth measures could be fruitful. I currently have three projects in mind that would test these ideas. First, I have collected the heights of men born before, during and after a malaria epidemic in the Argentine city of Santiago del Estero. Thus, I will be able to measure whether boys exposed to malaria *in utero* or in early childhood were more stunted than boys who were never exposed to the disease. Second, I hope to test the influence chronic diarrhoea on the health of men, proxied by adult stature, who were born in Boston and were later imprisoned in the Boston House of Correction. Theory and empirical evidence suggest that acute, highly fatal diseases should have a lesser effect on nutritional status than chronic, less fatal diseases such as diarrhoea. Acute diseases would only reduce energy available for growth for a matter of months, whereas chronic diarrhoea would prevent a child from absorbing all of the nutrients in his/her food for years at a time. Thus, improvements in sanitation and hygiene that led to a decrease in infant and child deaths from diarrhoea and other water-born, faecal-oral transmitted diseases (proxying diarrhoea) should have led to increasing heights among men born in Boston over the second half of the nineteenth century.

[5] Gazeley and Horrell, 'Nutrition', pp. 6-8.

Finally, I hope to expand my work on British children by collecting new evidence on children's growth for the period 1850-1950. The core of the evidence will be the longitudinal growth of boys aged 10-15 on two training ships: the Liverpool-based *Indefatigable* (1865-1990) and London-based *Exmouth* (1876-1945). These longitudinal measurements will provide an incredibly clear picture of how the growth pattern of British boys changed over time. By tracking the children's cross-sectional heights and weights relative to modern standards over time and comparing these with their longitudinal growth velocity, it should be possible to precisely determine key economic, environmental, and social policy factors that may have influenced the children's growth. It may also be possible to track the beginning of the obesity epidemic in the UK since the training ship children were drawn from the poorer echelons of the working class, which have become particularly prone to obesity.[6] The training ship evidence will also be supplemented with other cross-sectional records with children's anthropometric measures so that I can understand what was happening in a broader age range and the differences between boys and girls.

In conclusion, hopefully this dissertation and the papers that come out of it will spark additional interest in seamlessly incorporating the household and children into measures of historical living standards. There is much work left to be done.

[6] Offer, *Challenge of Affluence*, pp. 138-169.

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