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ORIGINAL PAPER

Measuring and decomposing income inequalities in child and adolescent mental health in the UK

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Abstract
Children from low-income families experience worse mental health than their wealthier peers. In this study, we quantified income inequalities in child mental health from early childhood to adolescence and identified key contributing factors explaining observed inequalities. Using data from the UK Millennium Cohort Study, we followed 5,667 children aged 3 to 17. We analysed overall mental health problems and their internalising and externalising domains, assessed using the Strengths and Difficulties Questionnaire. We applied a concentration index approach to quantify these inequalities, incorporating both relative and absolute inequality measures. We then decomposed the concentration index to analyse the contribution of various risk factors at different ages. We found inequalities across all mental health domains at every age, with poor mental health concentrated among children from low-income families, and an increasing inequality in internalising problems over time. The decomposition analysis showed that maternal depression and child-parent relationships were key contributors to these inequalities. These findings highlight the importance of addressing income inequalities in child mental health. Reducing inequalities in maternal depression and child-parent relationships may help reduce the mental health gap between children from low- and high-income families.

Keywords Child mental health · Income inequality · Health inequality · Decomposition of concentration index

JEL classification I140

Introduction

Over recent decades, socio-economic inequalities have been identified across various health outcomes, including mortality, diabetes, and self-reported ill health [1, 2]. Understanding the direction and extent of socio-economic inequalities in health, i.e., unfair differences in health (inequities), has important policy implications. The United Nations' 2030 Agenda for Sustainable Development highlights that the central focus of the global policy agenda has shifted toward the eradication of inequality [3]. In the UK, reducing socio-economic inequalities in health has been a consistent focus, drawing growing concerns in recent government policy agenda [4]. With the increasing prevalence of mental health problems [5], tackling health inequalities has remained a longstanding priority in mental health in the UK healthcare services [6]. Notably, studies have found that inequalities in health originate from childhood [7, 8], and almost half of mental disorders start before age 18 [9]. Understanding socio-economic inequalities in child mental health is therefore essential, not only for improvements in child well-being but also for reducing health inequalities over the long term.

The existing literature on socio-economic determinants of child mental health has frequently used family income as the indicator of socio-economic status [10–12]. Regression techniques are typically employed to assess the 'income gradient' in child mental health, examining how mental health outcomes change with each unit change in family income. In general, lower income is associated with poorer child mental health in countries like the UK [13, 14], the US [15],

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and Australia [16]. Studies from the UK have shown that living in lower income families is associated with poorer overall child mental health [17, 18], as well as more internalising problems (e.g. anxiety) and externalising problems (e.g. hyperactivity) [19]. The strength of these associations may vary across child developmental stages, tending to be stronger during adolescence than in childhood [20]. However, while these regression techniques identify associations between income and mental health problems, they do not capture the overall distribution of mental health across income levels or quantify the extent of inequalities in child mental health and how these inequalities change over time.

To address this, researchers have used summary measures of inequality, such as the slope index of inequality (SSI), which is defined as the gradient of health across socio-economic groups [21]. For example, a recent UK study using SSI found that inequalities in child mental health problems during childhood and adolescence were greater among children from the lowest income quintile at 9 months of age, compared to those from higher income quintiles [22]. However, the SSI relies on grouped socio-economic data rather than individual-level data. In contrast, the concentration index (CI), a widely used measure of inequality, utilises individual-level socio-economic data, allowing for a more precise assessment of inequalities throughout the entire income distribution [21]. It measures the degree of variation of one variable (e.g. health) that is related to the variation of another variable (e.g. income) [21] and can be used to monitor the change of inequality over time [23].

Furthermore, the CI can be decomposed into contributing individual factors, which explain socio-economic inequality in health [23]. Both theoretical and empirical evidence indicate that income inequalities in child mental health may be explained by other factors. Two theoretical frameworks, Parental Investment (PI) and Parental Stress (PS) theories, have been used to explain the relationship between income and child development, which has then been extended also to mental health outcomes [19, 24]. The PI theory suggests that richer families are better able to invest more resources that support child development [25, 26], while the PS theory maintains that low income can generate stress for parents, which negatively impacts their health and parenting practices and, in turn, may be associated with negative effects on child outcomes [27]. Existing empirical evidence indicates that the PS theory, where poor maternal mental health is a key indicator, plays an important role in the income gradient in child mental health [19, 28]. However, these studies often only rely on regression techniques without assessing the relative contributions of the different factors that operationalise the PI and PS theories. The decomposition of the concentration index addresses this limitation and elucidates the potential sources of these inequalities [29, 30].

To our knowledge, Islam, Ormsby [31] and Ride [32] are the only two studies that quantify inequalities in the 'child mental health–income gradient' using the CI approach. Drawing on data from Australia and the UK, respectively, they both reported that mental health problems were concentrated among children at the lower end of the income distribution. However, both studies focused on adolescence: Islam, Ormsby [31] pooled adolescents aged 12–17 years, and Ride [32] analysed 11 and 14-year-old children. The Ride [32] study also decomposed the inequalities – while the Islam, Ormsby [31] did not – but mainly focused on the role of maternal depression, and found that postpartum depression was a significant contributor to income inequalities in child mental health.

We are not aware of studies that have examined income inequalities in child mental health from younger ages to adolescence using the CI approach and its decomposition, including other potential determinants, such as parenting practices and maternal physical health. Given the policy importance of understanding mental health inequality and the limited empirical evidence in the field, this study used national representative UK data to quantify income inequalities in child mental health from ages 3 to 17 years using the CI approach, and decomposed these inequalities to identify key contributing factors across age groups. This study contributes to the literature in several respects. First, to our knowledge, this is the first study that applies CI approach to quantify inequalities in child mental health across childhood and adolescence. Second, we decomposed income inequalities using a rich and consistent set of contributing factors across ages. Third, we examined overall mental health, and its internalising and externalising domains, as the extent of inequalities and the role of contributors may vary by domain [19].

Methods

Data

Millennium cohort study

We used the UK Millennium Cohort Study (MCS), a nationally representative study of children born in the UK between 2000 and 2002 [33]. The MCS data was collected through face-to-face interviews by trained interviewers, along with online questionnaires completed by parents, teachers or children themselves [33]. This dataset is well-suited to our analyses for several reasons. First, it follows children prospectively from early childhood, collecting data when they were 9 months, 3, 5, 7, 11, 14, and 17 years old, allowing for consistent measurement of both child mental health

outcomes and family income throughout the study. This is essential for examining income-driven inequalities in child mental health from a longitudinal perspective. Second, the MCS includes information on socio-demographic factors, parental health, and parenting practices, offering a comprehensive basis to explore the factors that contribute to income inequalities in child mental health across different age groups.

Study population

We used all available surveys in MCS [34–42]. There were 18,552 families (18,818 children) that were involved in the first survey when children were 9 months old, 10,625 of whom participated in the most recent 17-year-old survey [43]. To ensure that our results were comparable across different age groups, we restricted our study population to singletons who participated in all available surveys. We further restricted the study population to those whose mental health in their childhood and adolescence was assessed by their biological mother across all the surveys. In addition, to ensure that our study population was representative of the MCS baseline study population, we used MCS sample weights in our analyses to adjust for missing cases due to loss to follow-up [33].

Variables

Child mental health

Child mental health was measured by Strengths and Difficulties Questionnaire (SDQ), a validated screening tool for assessing child emotional and behavioural problems [44–46]. We used mother-reported SDQ collected at ages 3, 5, 7, 11, 14 and 17 years old. The SDQ includes 25 items covering five subscales: conduct problems, emotional problems, hyperactivity, peer problems, and pro-social behaviour, with 5 items in each subscale (full SDQ tools are reported in Tables A1 and A2). The Total Difficulties Score (TDS) was generated by adding the first four subscales together, with a score ranging from 0 to 40, where a higher score indicates worse overall mental health problems. Internalising problems and externalising problems were generated by adding up the emotional problems and peer problems, and conduct problems and hyperactivity, respectively, with each score ranging from 0 to 20.

Income

Family income in MCS was reported as the total take-home income of both parents or caregivers, or a single parent if only one parent was present, after tax and other deductions. It was formulated into an equivalised annual family income using the modified Organisation for Economic Co-operation and Development equivalence scale [47], making family income comparable across different family structures and compositions. Consistent with previous research on income inequality in health, family income in our study was measured by permanent income [29, 32, 48]. Permanent income in each survey was generated by first adjusting equivalised family income for inflation, using 2018 – the year of the seventh survey (age 17 years) – as the base year, and then averaging the income across all available survey waves up to the current survey. For example, permanent income at the second survey is the average of equivalised income from the first and second surveys, while at the fourth survey, it is the average of income from the first through the fourth surveys.

Other explanatory variables

Child age, sex, ethnicity, gestational age (term: 37–41 weeks; preterm: <37 weeks), and whether the child was the mother's first-born child were chosen as key health endowments. This selection was based on the framework of the health production function [49] and the extended child health production function [50], which suggests that children's health is influenced by their initial endowments as well as inputs received later in life. Other explanatory variables believed to be associated with child mental health and varying across income distributions were also included, which are detailed below. Similar variables have been included in previous studies examining the relationship between income and child mental health [14, 19].

Pregnancy-related characteristics were taken from the first wave when children aged 9 months. These variables included maternal age at childbirth (<20, 20–24, 25–29, 30–34, ≥35 years), maternal smoking during pregnancy (never smoked, stopped smoking during pregnancy, smoked throughout pregnancy), alcohol consumption during pregnancy (never, light, moderate/heavy), and breastfeeding duration (never breastfed, <2 months, 2.0-5.9 months, ≥6 months). Data on child and family factors were collected across all available surveys. Child characteristics included child weight (normal, overweight, obese) based on International Obesity Task Force body mass index thresholds, and whether the child had a limiting longstanding physical illness. Family socio-economic characteristics included whether the child lived in lone parent family, change in family structure (no change, new partner, became single), mother's highest educational level (National Vocational Qualification Level 1&2; Level 3; Level 4&5; none of these).

PS and PI variables were informed by the Parental Stress and Parental Investment theories. For PS variables, maternal

depression (yes/no) was generated by combing two data sources: Kessler Psychological Distress Scale, where a total score of 8 or higher indicates symptoms of psychological distress [51], and information on whether the respondent was currently being treated for depression. A mother was considered as experiencing depression if she either scored 8 or higher on the Kessler scale or reported currently receiving treatment for depression. The lagged variable was used in this study to mitigate reverse causality concerns, i.e. when poor child mental health may be a risk factor for maternal mental health. Maternal self-reported general health (good/poor) was collected at each survey wave. The Pianta Child-Parent Relationship Scale (CPRS), which was collected at age 3, assessed the relationship between parents and the child from the parent' view [52]. A higher score indicates a better relationship between the mother and the child.

PI variables included childcare at 9 months and 3 years old (parental care, formal care, grandparent care, other informal care), and housing tenure at each survey, categorised as owner-occupied/mortgaged, private rent (including part-rent/part-mortgage or private rental), social rent (renting from a local authority or Housing Association), and other arrangements. Data collected about parenting activities with the child, such as reading to children, teaching songs and playing sports with children, varied across MCS surveys. To assess the longitudinal relationship between parental activities and child mental health, a parental involvement score was created that captured the frequency of the joint parent-child activities at each survey, where a higher score indicates greater parental involvement.

Estimation strategy

Income inequality measurements

The concentration curve is used to graphically depict socioeconomic inequalities in health, and the concentration index is defined with reference to the concentration curve to quantify inequalities [23]. In this study, the concentration curve plots the cumulative percentage of a child mental health variable against the cumulative percentage of the population, ranked by family income from the poorest to the richest.

The CI, derived from the concentration curve, serves as an important measure for quantifying income inequality in health. The standard CI can be defined as:

$$CI\left(h\right)=\frac{1}{n}\sum{}_{i=1}^{n}[\frac{h_i}{\overline{h}}(2r_i-1)] \tag{1}$$

where h_i is the health variable of individual i, $\overline{h}$ is the mean health, $r_i = {}^{i}\!/_{n}$ is the fractional rank of an individual in the income distribution of n individuals [23]. The standard CI is a measure of relative inequality, which means that the inequality remains unchanged when the health variable has the same *proportional* changes for the whole population. Multiplying the standard CI by the mean health $\overline{h}$ generates the generalised CI (GCI), which is a measure of absolute inequality [21]. In other words, the inequality measured by the GCI remains unchanged when the health variable has the same *amount* of changes for all individuals.

To accommodate bounded health variables in our study that have specific limits or constraints on both the upper and lower bounds, we used the modified concentration index (MCI) to measure relative inequality [53]:

$$MCI\left(h\right)=\frac{1}{n}\sum{}_{i=1}^{n}[\frac{h_i}{\overline{h}-h_{min}}(2r_i-1)] \tag{2}$$

and the Erreygers index (EI) for absolute inequality [53, 54]:

$$EI\left(h\right)=\frac{4}{h_{max}-h_{min}}GCI\left(h\right) \tag{3}$$

where h_{max} and h_{min} are the upper and lower limits of the health variable, respectively.

In our analyses, income inequalities in child mental health were measured when children were aged 3, 5, 7, 11, 14, and 17 years. The concentration curves were first presented. Both relative and absolute income inequalities in child mental health were then reported using the MCI and EI, respectively.

When calculating the concentration indices for a bounded health variable as in our study, its bounded nature introduces the issue of the relation between inequality in good health and ill health [53]. The Total Difficulties Score, internalising and externalising symptom scores are the indicators of ill health because, by construction, they all focus on the negative aspect of mental health. Each measure, however, has a corresponding 'mirror' variable that focuses on the positive aspect of mental health. A desirable property of the CI for bounded variables is the 'mirror' property, where the index's magnitude remains the same while the direction should be opposite when calculating the CI of the good-health variable and its associated ill-health variable, since they mirror each other [54]. However, MCI does not satisfy the mirror property while the EI does [53]. For consistency with previous empirical research [31, 32], we focused on the ill-health analyses in this study.

Decomposition of the income inequalities

The concentration indices can be decomposed into the inequality contributing factors [55]. As EI satisfies mirror property while MCI does not, the decomposition analysis in this study focused on EI. The decomposition of the EI following Erreygers [54] is expressed as follows:

$$EI\,(h) = \frac{4}{h_{max} - h_{min}}[\sum{}_{k=1}^{K}\beta{}_{k}GCI_{k} + GCI_{\epsilon}] \quad (4)$$

where GCI_{k} is the GCI of the explanatory variable x_{k} and GCI_{ϵ} is that of the error term ε. The absolute contribution of each explanatory variable x_{k} is the product of the coefficient of the explanatory variable on the health outcome, $\beta{}_{k}$, and the income inequality in that variable, GCI_{k}, while adjusting for the lower limit h_{min} and upper limit h_{max} of the health variable. The relative contribution of the explanatory variable x_{k} can be estimated by:

$$\frac{4}{h_{max} - h_{min}}\left[\frac{\beta{}_{k}GCI_{k}}{EI\,(h)}\right] \quad (5)$$

The contribution of an explanatory variable is larger if the coefficient $\beta{}_{k}$ is larger in magnitude or the variable is more unequally distributed across the income distribution (i.e., GCI_{k} is larger in magnitude). The residual component captured by the GCI of the error term, GCI_{ϵ} in Eq. (4), reflects the income inequality that is unexplained in the model [23]. The relative contribution of the error term can then be estimated by:

$$1 - \frac{4}{h_{max} - h_{min}}\sum{}_{k=1}^{K}\left[\frac{\beta{}_{k}GCI_{k}}{EI\,(h)}\right] \quad (6)$$

In this study, the EI of all three mental health outcomes were decomposed separately. The association between the mental health and explanatory variables, as indicated by $\beta{}_{k}$ in Eq. (4), was estimated using linear regressions. The concentration indices were calculated using the '*conindex*' command in STATA/SE 16.0 [56, 57].

Sensitivity analysis

In addition to the continuous child mental health variables, we also generated a binary TDS variable using validated cut-offs, where a TDS above 16, for age 3, and 17 for other ages is categorised as 'abnormal' mental health [58], meaning that the child has a probable mental health problems. We repeated the concentration index and its decomposition analysis for the TDS binary variable in the sensitivity analysis.

We conducted multiple imputation in the main analysis to fill in the missing data due to item non-response, where the child participated in the survey but missed one or more questions. We generated 30 imputed datasets where the predictors included all variables used in the subsequent analysis, and the datasets were combined using Rubin's rules [59]. We repeated our analyses using only complete cases.

Results

Descriptive results

For 5,667 singleton children that were included in the analyses at ages 3, 5, 7, 11, 14, and 17 years, almost half of the children were male and 8% were from minority ethnic group (Table 1). The mean Total Difficulties Score and externalising problems were the highest at age 3, and internalising problems reached the peak at 17 years. The mean permanent income reduced gradually with age. Descriptive results for all the other variables included in our model are presented in Table A3.

Children who were obese, had a limiting longstanding physical illness, lived in a lone-parent family, and those

Table 1 Descriptive statistics of study population

Variables	3 years	5 years	7 years	11 years	14 years	17 years
Child mental health outcomes - mean (SD)						
Total Difficulties Score	8.9 (4.9)	6.7 (4.7)	6.9 (5.1)	7.2 (5.7)	7.5 (5.8)	7.0 (5.8)
Internalising symptoms scores	2.6 (2.3)	2.3 (2.4)	2.5 (2.6)	3.1 (3.1)	3.6 (3.4)	3.7 (3.5)
Externalising symptoms scores	6.3 (3.6)	4.4 (3.3)	4.4 (3.4)	4.1 (3.4)	4.0 (3.4)	3.4 (3.2)
Permanent income (£) - mean (SD)	30,317 (16444)	29,671 (15382)	29,425 (14696)	29,259 (13149)	28,905 (12140)	28,435 (11634)
Health endowments						
Age, years - mean (SD)	3 (0.2)	5 (0.2)	7 (0.2)	11 (0.3)	14 (0.3)	17 (0.3)
Male[a] - *n* (%)	2737 (48.9)					
Minority ethnic group[a] - *n* (%)	701 (8.0)					
Preterm (<37 weeks gestation)[a] - *n* (%)	396 (7.1)					
Firstborn[a] - *n* (%)	2893 (51.8)					

Notes: $N=5667$; SD standard deviation; [a] baseline variable which remains the same across all surveys

whose mothers smoked or consumed alcohol heavily during pregnancy, had never breastfed, or showed symptoms of depression or poor general health, had poorer mental health than their counterparts (Table A4).

Cumulative distribution of child mental health from poor to rich

Figure 1 shows the concentration curves for overall mental health problems from 3 to 17 years old. The 45-degree line is the 'line of equality', which indicates that every child has the same value of mental health irrespective of income level. All the concentration curves were above the equality line, indicating that there were inequalities where child mental health problems were concentrated on the poor. The concentration curves for internalising and externalising problems were similar with those for overall mental health problems (Fig. A1).

Quantifying income inequalities in child mental health

Figure 2 shows that the MCIs and EIs for TDS, internalising and externalising problems were all negative, and statistically significant at the 1% level (index table see Table A5). Combined with the shape of concentration curves, these findings indicate the presence of both relative (MCI) and absolute (EI) income inequality in child mental health, with problems concentrated on the poorer children. MCIs showed a gradual increase in inequalities in overall mental health problems, internalising and externalising problems over time, and inequalities in internalising problems were higher than those in externalising problems for most age groups. EIs showed increasing inequalities in internalising problems with age, while inequalities in externalising problems was relatively constant. From ages 3 to 14, inequalities in internalising problems were smaller than externalising

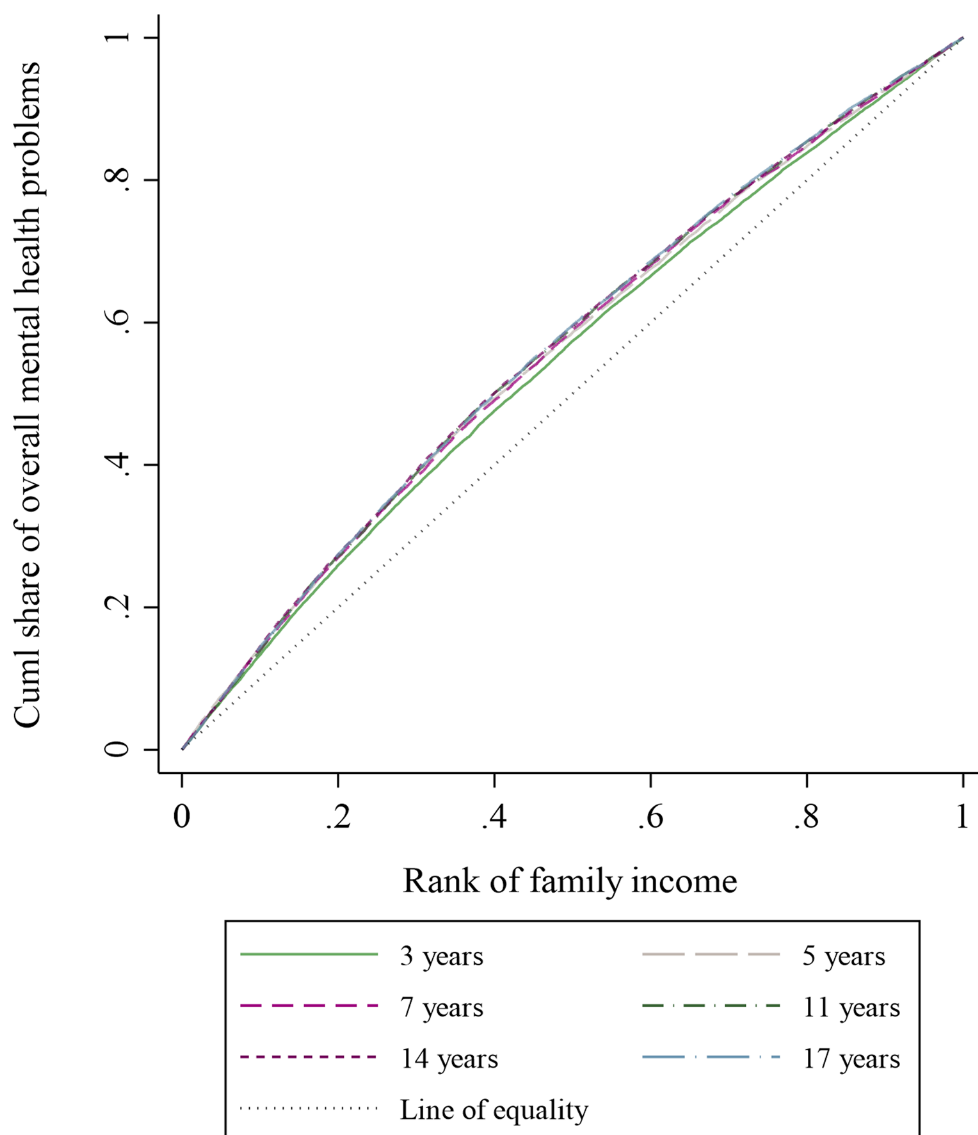


Fig. 1 Concentration curves for child overall mental health problems from 3 to 17 years old

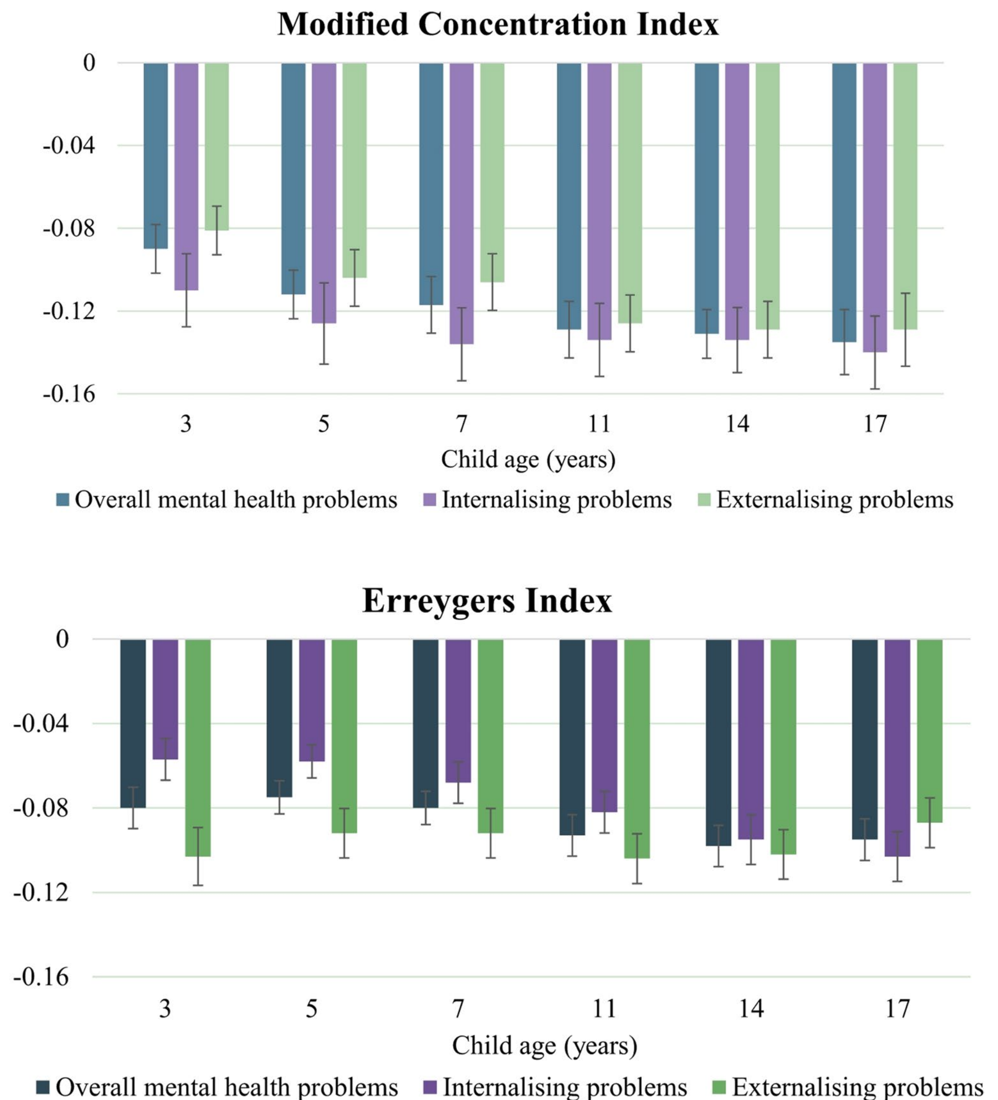


Fig. 2 Concentration indices on child mental health problems

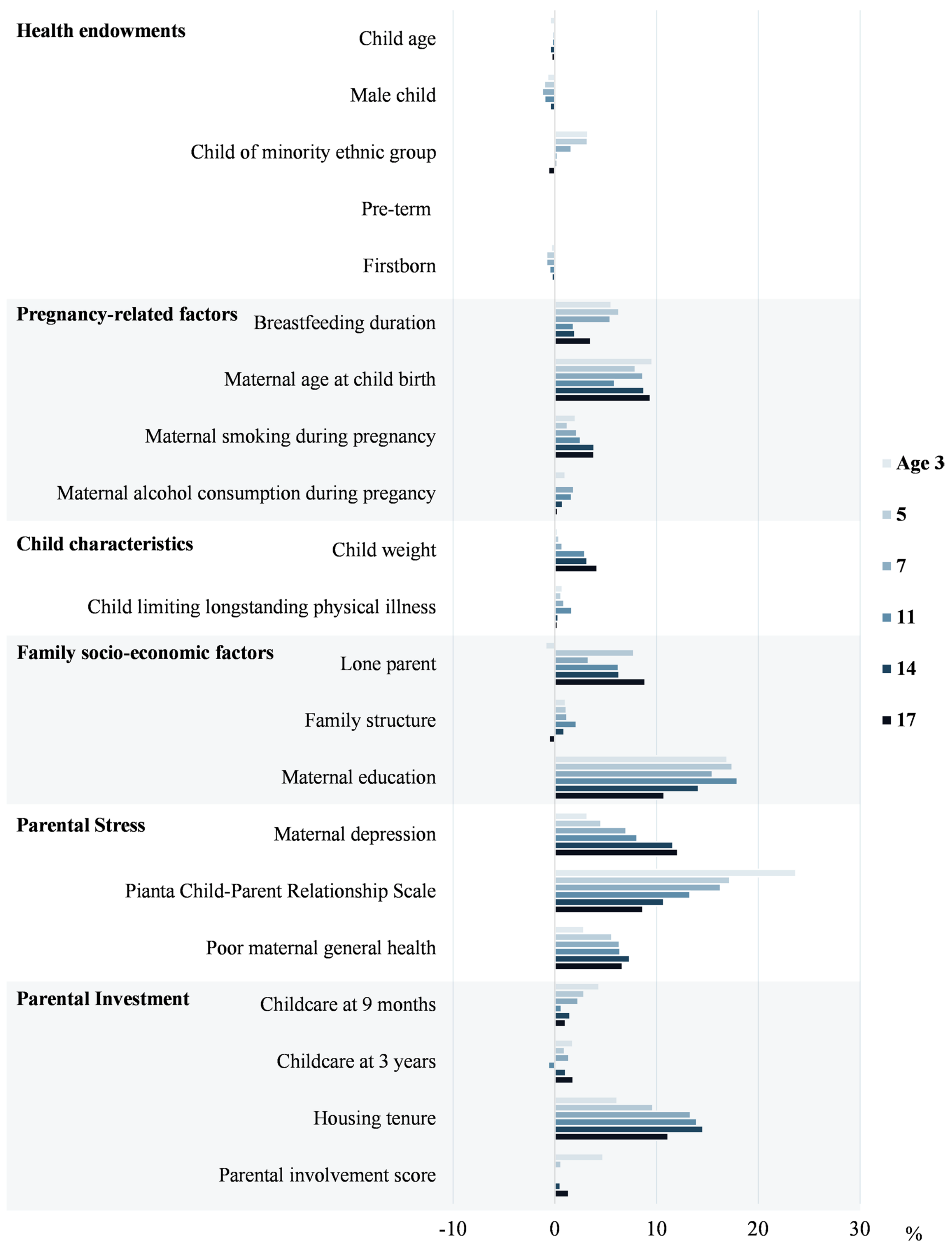
problems, but the gap narrowed over time and reversed at age 17.

Decomposition of the inequalities

The EI was decomposed into its contributing factors to quantify their contributions to income inequalities in child mental health. Figure 3 visualises the relative contribution of each factor on inequalities in overall mental health problems across all age groups, while Table 2 provides more detailed decomposition results that can explain the relative contributions observed in Fig. 3. In Table 2, the entries in each column are derived from Eq. (4) in the *Methods* section. Columns 'β' report the association between each contributor x_k and the child mental health outcome h. Columns 'GCI' report the generalised concentration index for each contributor, indicating the extent of the absolute inequality in the contributor across the income distribution. The relative contribution of each factor can then be calculated using this information, as illustrated in Eq. (5), and is reported in columns '%' in Table 2.

At age 3 years, the largest contribution to income inequalities was from the parent-child relationship (Pianta CPRS), a variable operationalising the Parental Stress theory (Fig. 3). A better parent-child relationship was associated with less mental health problems, as indicated by $\beta = -2.67$ ($p < 0.01$), and children whose mothers reported a good relationship were more concentrated at the upper end of the income distribution, as indicated by $GCI = 0.071$ ($p < 0.01$) (Table 2). Parent-child relationship at age 3 accounted for 7% of the EI for child overall mental health problems ($p < 0.01$). While its relative contribution decreased over time, it continued to explain 8.7% of the inequality at age 17 (Fig. 3; Table 2).

While the relative contribution of parent-child relationship decreased, that of maternal depression increased with child age, from 3.2% at age 3 to 12.1% at age 17 (Fig. 3;



Notes: The high statistical significance of the relative contribution estimates results in narrow confidence intervals that are barely visible in the figure and are therefore omitted. For statistical significance, please refer to Table 2.

Fig. 3 Relative contributions of factors in explaining income inequalities in child overall mental health problems (TDS) from age 3 to 17 years

Table 2). This was because maternal depression was more frequent in lower-income families and the association between maternal depression and children having mental health problems became larger when children grew older (Table 2). The β, GCI, and relative contribution estimates for maternal depression were statistically significant at 1% level.

Maternal poor general health, another indicator of the Parental Stress theory, also contributed to inequalities in all age groups. Its positive association with overall mental health problems, combined with higher prevalence of poor maternal health in lower-income families, resulted in relative contributions ranging from 2.9% to 6.6% across different age groups (Table 2). The βs, GCIs, and relative contributions were statistically significant at the 1% level.

Notes: The high statistical significance of the relative contribution estimates results in narrow confidence intervals that are barely visible in the figure and are therefore omitted. For statistical significance, please refer to Table 2.

Regarding the variables that operationalised the Parental Investment theory, housing tenure consistently represented the largest contribution to inequality, ranging from 6.1% to 14.0% among all age groups (Fig. 3). This was largely driven by social rent – renting from a local authority or Housing Association – which had a larger relative contribution than other factors (Table 2). Specifically, compared to children living in own/mortgaged housing, those in social rent housing experienced worse mental health problems ($p<0.01$ in all age groups except for age 3), and were more highly represented at the lower end of the income distribution (GCI = -0.1, $p<0.01$ among all age groups, Table 2).

Lone-parent family structure and maternal education were also associated with greater income inequalities in all age groups (Fig. 3), as illustrated in Appendix A2.3. The patterns observed in these variables, along with maternal depression, child-parent relationship, poor maternal general health, and housing tenure, were consistent across TDS, internalising and externalising problems (Appendix A2.3).

The decomposition analysis showed differences in how PS and PI variables contributed to income inequalities in internalising and externalising problems (Fig. 4). The relative contribution of parent-child relationship at age 3 years was consistently larger for externalising problems than internalising problems across all age groups. At age 3, it accounted for 27.5% and 16.8% of the inequalities in externalising problems and internalising problems, respectively, with the gap narrowing over time. By age 17, the contributions were 10.6% and 7.0%, respectively. Childcare at 9 months was associated with increased inequalities for internalising problems but a decreased inequalities for externalising problems in all age groups, except for age 3. This difference was mainly driven by formal care. Specifically, children who received formal care were concentrated at the upper end of the income distribution (i.e., GCI > 0, $p<0.01$ in all cases), and they had fewer internalising problems (β < 0) but more externalising problems (β > 0) compared with those receiving parental care (Tables A6 and A7). However, the estimated βs for externalising problems failed to reach statistical significance, while those for internalising problems were statistically significant at 1% level at age 3, 5, and 7.

Notes: The high statistical significance of the relative contribution estimates results in narrow confidence intervals that are barely visible in the figure and are therefore omitted. For statistical significance, please refer to Tables A6 and A7.

Sensitivity analysis

Consistent with the main analysis, both MCIs and EIs were negative for ‘abnormal’ mental health measured by the TDS binary variable, indicating the presence of inequalities where mental health problems were concentrated among children at the lower end of the income distribution (Figs. A4–A6). Inequalities in child ‘abnormal’ mental health were larger than those in internalising and externalising problems, except for inequalities measured by EI at age 5 and 7. The largest inequality for children with mental health problems as ‘abnormal’ emerged at age 5 for MCI and at age 3 for EI. The decomposition results were consistent with the main analysis (Fig. A7; Table A8).

Among the 5,667 children in the study population, those with missing data due to item non-response were more likely to have mental health problems, live in lower-income families, and be from minority ethnic groups (Table A9). Analyses using complete cases aligned with the main findings (Appendix A2.5), though the magnitude of the concentration indices for complete cases were smaller than those using imputed data, except for the MCI at age 7 for child mental health problems (Table A10).

Discussion

This study examined income inequality in child mental health problems in childhood and adolescence and decomposed the inequality into its contributing factors. It provided consistent evidence that poorer mental health outcomes were concentrated among children from lower-income families across all outcomes examined, i.e. overall mental health problems, internalising and externalising problems, at all age groups from 3 to 17 years, using both relative and

absolute inequality measures. The inequality observed in this study aligns with the results from the only two studies that examined income inequalities in child mental health using the concentration index approach, Ride [32] for 11 and 14-year-olds using data from the UK, and Islam, Ormsby [31] for Australian children between the ages of 12 to 17 years, both of which used the EI to measure inequality. Moreover, the persistent inequality observed in our study through age 17 years is consistent with the findings of Chua, Schlüter [22], who also used data from the MCS to age 17 but quantified inequality using a different measure, i.e. the slope index of inequality.

We observed an increase in income inequality in internalising problems over time, as evidenced by both MCIs and EIs, while inequality in externalising problems remained relatively constant. These results align with a previous study by Fletcher and Wolfe [60], who examined the same mental health outcomes but applied different methods. Specifically, the study by Fletcher and Wolfe [60] found that in the US, the negative association between family income and externalising problems was relatively constant from age 6 to 12 years, while the association for internalising problems increased when children grew older. Our findings and previous research alike all suggest that internalising problems may be more responsive to family income than externalising problems when children grow older.

The use of the concentration index approach in this study provides valuable insights into the relationship between family income and child mental health beyond those identified in previous studies using only regression techniques. The concentration index approach not only quantifies the extent of income-driven inequalities in child mental health and how these inequalities change over time, as illustrated above, but also provides a common metric that enables direct comparison across different types of mental health outcomes, usually also operationalised in different ways, such as abnormal mental health expressed as a binary variable, and overall mental health problems, internalising and externalising problems expressed as continuous variables [54, 61]. In regression analyses, studies examining the relationship between family income and binary child mental health outcomes may apply a logit model, with results interpreted as changes in the probability of a child experiencing abnormal mental health as the income increases or decreases [19], whereas studies using continuous outcomes may capture changes in mental health scores (often expressed in standard deviation units) as the income increases or decreases by 1%, when the income is expressed in its logarithm form as it is often the case [19, 20]. In contrast, the concentration index offers a consistent summary measure that can be conventionally compared across various health outcomes, independently on how they are measured. Using this approach, we found that inequalities in abnormal mental health (binary measure) was larger than those in overall mental health problems across all age groups (Table A5).

In our study, the results were not always consistent across the relative (MCIs) and absolute (EIs) inequality measures. Inequalities in internalising problems were higher than externalising problems in most of the age groups when using inequalities relative measures, while the opposite was found for absolute inequality measure. These differences may arise because relative measures capture proportional differences, reflecting the disparities in relation to the group's average mental health at a given age, while absolute measures capture the absolute difference in health levels, therefore accounting for both the level of health and inequality [23, 62]. The observed higher average externalising symptoms score compared to internalising symptoms score in most age groups (Table 1) may contribute to these differences, as EIs reflect levels more directly than MCIs.

The choice of inequality measure may have different implications for policy. Internalising problems appear more important from a relative viewpoint, while externalising problems may be more significant from an absolute perspective. However, there is still limited evidence on people's viewpoints and policymakers' preferences regarding relative versus absolute inequality [61, 63]. Reporting both relative and absolute measures of health inequality is therefore beneficial to present a more comprehensive picture.

In the decomposition analysis, this study examined the contributions of parental stress and parental investment variables. The variables reflecting Parental Stress, especially maternal depression and parent-child relationship, acted as more significant contributors than variables reflecting Parental Investment in child mental health problems over time. This is because they consistently contributed to income inequalities in all child mental health outcomes across all age groups, while the PI variables did not exhibit such consistency. This finding is consistent with previous studies conducted using MCS surveys of children aged 3 to 17 years [19] and with Australian data when children were aged 4 to 13 years (Khanam & Nghiem, 2016), but the methods utilised in these studies differed from the methods used in our study. Yang, Carson [19] and Khanam and Nghiem [28], using cross-sectional and longitudinal regression methods, examined the extent to which the association between income and child mental health was attenuated by PS and PI and found that the observed income effect diminished more substantially after controlling for PS than PI variables. The decomposition of the concentration index in this study allows for a direct comparison of the contributions made by different types of determinants. This provides additional evidence regarding the relative significance of PS and PI factors when assessing the relationship between

Table 2 Decomposition of Erreygers index for child overall mental health problems

	3 years			5 years			7 years			11 years			14 years			17 years		
	β	GCI	%	β	GCI	%	β	GCI	%	β	GCI	%	β	GCI	%	β	GCI	%
Health endowments																		
Child age	-0.627	-0.006**	**-0.471****	-0.913**	<0.001	**-0.043****	-0.520	-0.003	**-0.195****	-0.847**	-0.003	**-0.273****	-0.665**	-0.007	**-0.475****	-0.502*	-0.006	**-0.317****
Male child	0.722**	0.008	**-0.722****	0.863**	0.009	**-1.036****	1.097**	0.009	**-1.234****	1.035**	0.009	**-1.002****	0.577**	0.008	**-0.471****	-0.078	0.008	**0.065****
Child of minority ethnic group	1.302**	-0.020**	**3.256****	1.094**	-0.022**	**3.209****	0.587*	-0.022**	**1.613****	0.097	-0.022**	**0.230****	0.09	-0.023**	**0.211****	-0.257	-0.023**	**-0.622****
Pre-term	0.327	-0.001	**0.041****	0.358	-0.002	**0.095****	0.321	-0.002	**0.080****	0.241	-0.003	**0.078****	0.425	-0.003	**0.130****	0.299	-0.004	**0.126****
Firstborn	0.145	0.019**	**-0.344****	0.381**	0.016**	**-0.813****	0.436**	0.015**	**-0.818****	0.319*	0.015**	**-0.514****	0.169	0.017**	**-0.293****	0.105	0.012*	**-0.133****
Pregnancy-related factors																		
Breastfeeding duration (ref. never breastfed)																		
<2 months	-0.163	-0.010*	**-0.204****	-0.147	-0.010**	**-0.196****	-0.029	-0.010**	**-0.036****	0.411	-0.011**	**0.487****	0.426	-0.011**	**0.478****	0.126	-0.012**	**0.159****
2-5.9 months	-0.495**	0.029**	**1.793****	-0.622**	0.029**	**2.404****	-0.586**	0.029**	**2.125****	-0.27	0.029**	**0.842****	-0.149	0.029**	**0.440****	-0.374	0.029**	**1.143****
≥6 months	-0.703**	0.045**	**3.956****	-0.683**	0.045**	**4.095****	-0.584**	0.046**	**3.358****	-0.098	0.049**	**0.516****	-0.200	0.051**	**1.042****	-0.415	0.051**	**2.227****
Maternal age at child birth (ref. 25–29 years)																		
<20 years	0.799*	-0.026**	**2.596****	0.325	-0.026**	**1.127****	0.008	-0.025**	**0.025****	0.123	-0.026**	**0.343****	0.157	-0.025**	**0.400****	0.635	-0.025**	**1.670****
20–24 years	0.830**	-0.051**	**5.291****	0.538**	-0.052**	**3.733****	0.450	-0.051**	**2.867****	0.560	-0.053**	**3.193****	0.671*	-0.054**	**3.697****	0.867*	-0.053**	**4.834****
30–34 years	-0.149	0.058**	**1.081****	-0.184	0.060**	**1.470****	-0.506**	0.058**	**3.667****	-0.177	0.059**	**1.123****	-0.429*	0.059**	**2.582****	-0.321	0.058**	**1.963****
≥35 years	-0.129	0.037**	**0.597****	-0.321	0.037**	**1.583****	-0.441*	0.038**	**2.096****	-0.269	0.042**	**1.216****	-0.487	0.042**	**2.086****	-0.211	0.042**	**0.931****
Maternal smoking during pregnancy (ref. never)																		
Stopped smoking	-0.020	-0.007*	**-0.017****	-0.077	-0.008**	**-0.082****	0.136	-0.007*	**0.119****	0.263	-0.008**	**0.226****	0.250	-0.008**	**0.204****	0.081	-0.008**	**0.068****
Smoked throughout pregnancy	0.247	-0.066**	**2.038****	0.148	-0.067**	**1.324****	0.243	-0.067**	**2.039****	0.311	-0.069**	**2.304****	0.514	-0.070**	**3.670****	0.514	-0.070**	**3.787****
Maternal alcohol consumption during pregnancy (ref. never)																		
Light	-0.163	0.052**	**1.062****	-0.007	0.053**	**0.049****	-0.264	0.054**	**1.779****	-0.280	0.054**	**1.624****	-0.142	0.054**	**0.785****	-0.051	0.055**	**0.296****
Moderate/heavy	0.288	0.001	**-0.036****	-0.111	0.002	**0.030****	-0.293	0.002	**0.073****	-0.113	0.002	**0.024****	0.031	0.002	**-0.006****	0.034	0.002	**-0.007****
Child characteristics																		
Child weight (ref. normal)																		
Overweight	-0.085	0.000	**0.005****	-0.101	-0.007*	**-0.094****	0.193	-0.011**	**0.265****	0.586**	-0.019**	**1.197****	0.553**	-0.017**	**0.960****	0.575**	-0.017**	**1.029****
Obese	0.349	-0.006**	**0.262****	0.950**	-0.004	**0.507****	0.518	-0.007**	**0.453****	1.262**	-0.013**	**1.764****	1.552**	-0.014**	**2.218****	1.489**	-0.020**	**3.136****
Child limiting longstanding physical illness	1.473**	-0.004**	**0.736****	1.155**	-0.004*	**0.616****	1.436**	-0.005**	**0.897****	2.581**	-0.006**	**1.665****	0.662	-0.005**	**0.338****	1.184*	-0.002	**0.249****
Family socio-economic factors																		
Lone parent	-0.115	-0.064**	**-0.916****	0.820**	-0.071**	**7.759****	0.383	-0.069**	**3.305****	0.766**	-0.076**	**6.262****	0.794**	-0.078**	**6.323****	0.970**	-0.087**	**8.884****
Change in family structure (ref. no change)																		
New partner	0.241	-0.017**	**0.512****	1.038*	-0.012**	**1.660****	0.932*	-0.015**	**1.747****	0.604	-0.015**	**0.973****	0.791	-0.012**	**0.968****	-1.872*	-0.001	**-0.197****
Became single	0.252	-0.017**	**0.537****	-0.262	-0.015**	**-0.525****	-0.404	-0.011**	**-0.555****	0.668	-0.016**	**1.150****	-0.061	-0.009**	**-0.056****	-0.389	-0.009**	**-0.369****
Maternal education (ref. NVQ Level 1&2)																		

Table 2 (continued)

	3 years			5 years			7 years			11 years			14 years			17 years		
	β	GCI	%	β	GCI	%	β	GCI	%	β	GCI	%	β	GCI	%	β	GCI	%
NVQ level 3	-0.383*	-0.011**	**-0.527****	-0.219	-0.012**	**-0.351****	-0.424*	-0.015**	**-0.795****	-0.429	-0.019**	**-0.877****	-0.495*	-0.022**	**-1.112****	-0.026	-0.022**	**-0.060****
NVQ level 4&5	-0.920**	0.133**	**15.295***	-0.684**	0.136**	**12.396****	-0.714**	0.134**	**11.964****	-1.028**	0.134**	**14.819****	-0.990**	0.132**	**13.334***	-0.591**	0.132**	**8.217****
None of these	0.376	-0.046**	**2.165****	0.880**	-0.046**	**5.400****	0.785*	-0.044**	**4.320****	0.956*	-0.039**	**4.008****	0.505	-0.037**	**1.905****	0.663	-0.037**	**2.583****
Parental Stress variables																		
Maternal depression	0.543**	-0.047**	**3.188****	0.946**	-0.036**	**4.539****	1.336**	-0.042**	**7.014****	1.882**	-0.040**	**8.095****	2.230**	-0.051**	**11.607****	2.207**	-0.052**	**12.078****
Pianta Child-Parent Relationship Scale	-2.670**	0.071**	**23.693****	-1.767**	0.073**	**17.203****	-1.761**	0.074**	**16.289****	-1.649**	0.075**	**13.298****	-1.417**	0.074**	**10.698****	-1.127**	0.073**	**8.663****
Poor maternal general health	0.586**	-0.039**	**2.856****	1.169**	-0.036**	**5.611****	1.493**	-0.034**	**6.347****	1.657**	-0.036**	**6.413****	1.413**	-0.051**	**7.351****	1.540**	-0.041**	**6.646****
Parental Investment variables																		
Childcare at 9 months (ref. parental care)																		
Formal care	-0.367*	0.088**	**4.036****	-0.216	0.087**	**2.509****	-0.209	0.086**	**2.246****	-0.065	0.086**	**0.600****	-0.134	0.086**	**1.178****	-0.082	0.085**	**0.735****
Grandparent care	-0.215	0.012**	**0.322****	-0.256	0.012**	**0.410****	-0.069	0.011**	**0.096****	-0.094	0.010*	**0.101****	-0.365	0.009*	**0.336****	-0.337	0.009*	**0.319****
Other informal care	-0.188	<0.001	**0.000**	-0.759*	<0.001	**-0.044****	-0.378	-0.001	**-0.047****	-0.488	-0.001	**-0.052****	-0.211	-0.001	**-0.022****	-0.129	<0.001	**-0.004****
Childcare at 3 years old (ref. parental care)																		
Formal care	-0.281	0.060**	**2.106****	-0.151	0.061**	**1.231****	-0.168	0.062**	**1.306****	0.111	0.062**	**-0.740****	-0.162	0.062**	**1.024****	-0.264	0.063**	**1.749****
Grandparent care	0.437*	0.006	**-0.328****	0.261	0.006	**-0.208****	0.034	0.006	**-0.025****	0.269	0.005	**-0.144****	0.278	0.005	**-0.142****	-0.162	0.005	**0.085****
Other informal care	-0.051	-0.002*	**-0.013****	-0.152	-0.003*	**-0.061****	0.264	-0.003*	**0.099****	0.769	-0.003*	**0.248****	0.600	-0.003*	**0.184****	-0.074	-0.003*	**-0.023****
Housing tenure (ref. own/mortgaged)																		
Private rent	0.022	-0.021**	**0.059****	-0.059	-0.023**	**-0.182****	0.303	-0.027**	**1.022****	0.553	-0.032**	**1.903****	0.910**	-0.035**	**3.251****	0.329	-0.033**	**1.143****
Social rent	0.456	-0.101**	**5.754****	0.725**	-0.100**	**9.671****	0.981**	-0.098**	**12.015****	1.148**	-0.099**	**12.216****	1.102**	-0.100**	**11.242****	0.918*	-0.097**	**9.370****
Other	0.275	-0.009**	**0.309****	0.129	-0.008**	**0.137****	0.344	-0.007**	**0.301****	-0.300	-0.005**	**-0.161****	0.139	-0.005**	**0.071****	0.841	-0.007**	**0.620****
Parental involvement score	-0.925**	0.041**	**4.739****	-0.927**	0.005	**0.618****	-0.316	-0.001	**-0.040****	-0.097	0.003	**0.031****	-0.373*	0.014**	**0.533****	-0.867**	0.015**	**1.369****
Residual			**15.294**			**14.249**			**14.211**			**16.816**			**13.332**			**17.587**
Total EI	**-0.080****			**-0.075****			**-0.080****			**-0.093****			**-0.098****			**-0.095****		

Notes: β coefficient, GCI Generalised Concentration Index; % relative contribution of Erreygers Index; ** $p<0.01$ * $p<0.05$

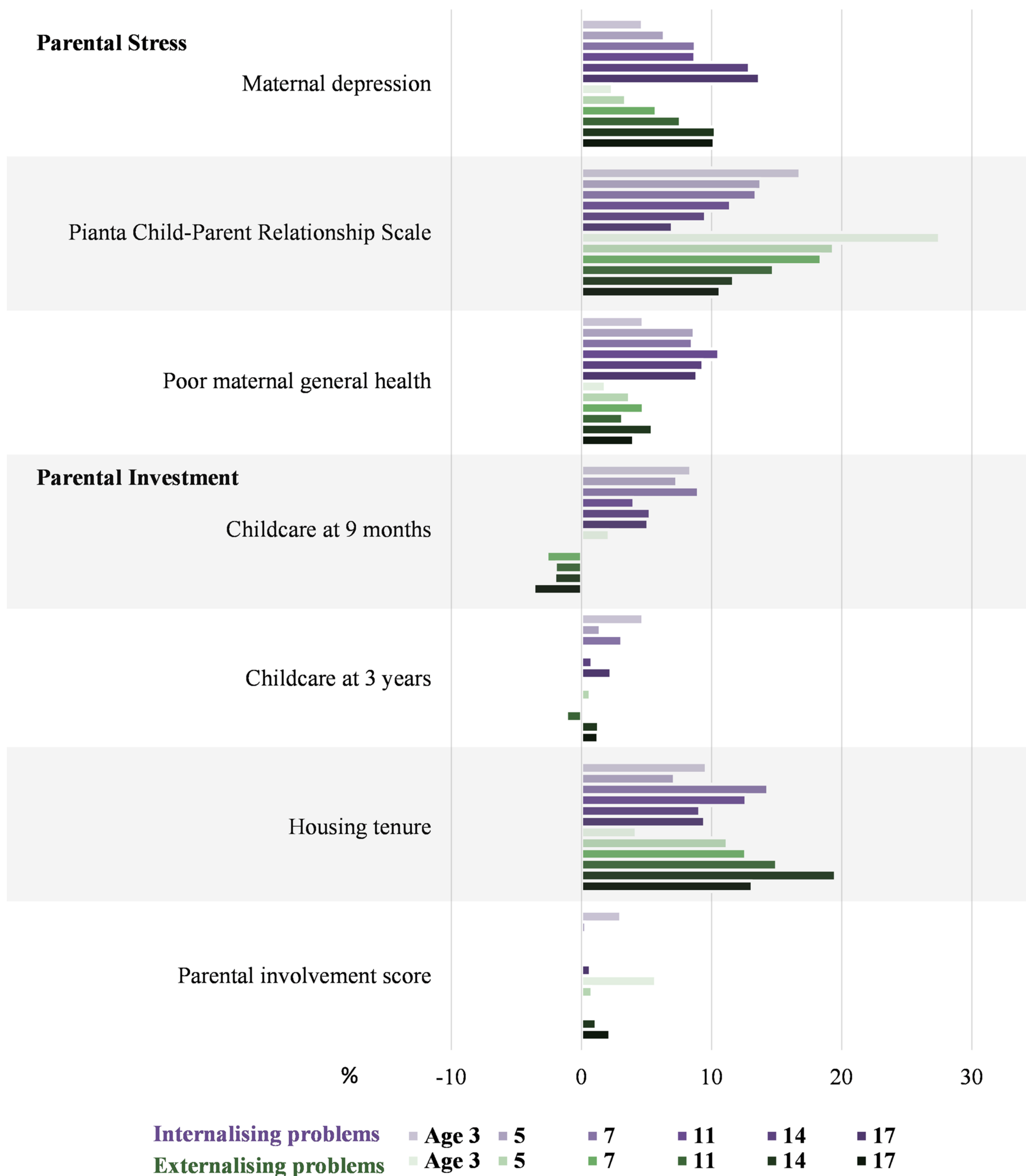


Fig. 4 Relative contributions of PS and PI variables in explaining the income inequalities in internalising and externalising problems

family income and child mental health, going beyond the approaches conducted in Yang, Carson [19] and Khanam and Nghiem [28].

The extent of the relative contribution of PS and PI factors can be explained by the distribution of each factor on income rank, and its association with child mental health problems. We observed a strong association between good parent-child relationships and better child mental health problems across all outcomes, which is consistent with previous research on children's emotional and behavioural development [64, 65]. In addition to this, our study also showed that children whose mothers reported a worse relationship with them were concentrated among the poor. Economic hardship leads to stress on parents, which may in turn harm the parent-child relationship [66]. Therefore, poorer parent-child relationships increased income inequalities in child mental health. The relationship between increasing income inequality in child mental health and maternal depression can be explained by the strong correlation between maternal depression and child mental health problems, and the inequality in maternal depression, as evidenced by prior studies [13, 67].

In contrast to the PS variables, the majority of PI variables played a minor role in contributing to income inequalities in child mental health during childhood and adolescence. A notable exception was housing tenure, especially the social rent category, which exacerbated income inequalities in all three mental health outcomes across most age groups. The significance of social rent contribution was mainly driven by the substantial income inequalities in this housing tenure category. This finding is consistent with the data presented by the Office for National Statistics, which shows that families in social-rented housing generally have lower disposable family income than families who own property in the UK [68].

In comparing the factors contributing to income inequality between internalising and externalising problems, we found that the contributions were similar for most of the PS and PI variables. The only notable difference was the contribution of the parent-child relationship variable, which was larger for externalising than internalising problems, particularly at younger ages, from 3 to 7 years old, which is the period when externalising problems were more prevalent in our sample. The stronger association between the parent-child relationship measure and externalising problems (Table A7) was the main driver of this result, as conflictual and less close parent-child relationships [52] and behavioural problems feed into each other.

The income inequalities in child mental health observed in this study call for public policy interventions to reduce such disparities. Maternal depression emerges as a potential key target for such interventions, as we found that it consistently associated with poor child mental health, and the effect becomes larger when children grow older. In addition, this research revealed that low-income families were disproportionately affected by maternal depression, which has knock-on effects on children's mental health. Targeted interventions to improve maternal mental health, particularly focusing on low-income families, may help narrow the mental health gap between children from affluent and disadvantaged backgrounds.

Another potentially beneficial intervention could focus on improving of the parent-child relationship when children are very young. A good such an example is the Early Head Start Program in the US, which offers support to low-income families with children in their early years, providing weekly home visit services to enhance parental capabilities to support their children's development [69]. This may empower parents to build good relationships with their children from the early years, which in turn may improve their children's mental health. A similar program in the UK, the Sure Start programme, has been found to yield health benefits for children from low-income families, reducing hospitalisations among 11-year-olds from families that used the service [70]. Nevertheless, over the past decade, the program has faced substantial funding reductions [70], which has reduced the support available to children in economically disadvantaged areas.

Our study has some limitations. While the decomposition of the concentration index offers insights into the sources of income inequalities in child mental health, it should be interpreted descriptively rather than causally. However, the contributions of factors, including maternal depression and housing tenure, to income inequalities in child mental health align with Parental Stress and Parental Investment theories which maintain that parental stress and investment may explain the relationship between family income and child development. Nonetheless, our findings warrant further investigation into the causal mechanisms between family income, parental stress and investment, and child mental health. Furthermore, although we controlled for a rich set of variables in explaining the inequalities, a portion of the inequality was unexplained (Table 2). There might be due to omitted variables as, for example, for parsimony reasons, we did not consider neighbourhood level [32]. However, some of the variables we included, such as housing tenure, can also be considered as proxy for neighbourhood characteristics. Child mental health outcome may vary across regions. However, due to data access restrictions, regional variation could not be examined in this study and may be explored in future research. Finally, missing data may introduce selection bias by excluding children in lower-income families and experienced more mental health problems (Table A9), potentially underestimating inequalities. However, the use

of multiple imputation and sample weights that controlled for longitudinal attrition may have mitigated – at least partially – this bias.

Despite these limitations, this study offers a novel perspective on the income inequalities in childhood and adolescent mental health in the UK, by quantifying and decomposing such inequalities and providing new evidence that mental health problems are more concentrated among the poor. This calls for public policy interventions to address these inequalities. Targeting disparities in maternal depression and the parent-child relationship may help reduce the mental health gap between children from low- and high-income families.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10198-026-01918-3.

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Data Availability The UK Millennium Cohort Study data are available from the UK Data Servicedatabase (https://beta.ukdataservice.ac.uk/datacatalogue/series/series?id=2000031).

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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