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HETEROGENEITY IN EARLY LIFE INVESTMENTS: A LONGITUDINAL ANALYSIS OF CHILDREN'S TIME USE

Slawa Rokicki[1,2]* and Mark E. McGovern[2,3]

[1]*Geary Institute for Public Policy, University College Dublin*

[2]*Department of Health Behavior, Society & Policy, Rutgers School of Public Health*

[3]*CHaRMS - Centre for Health Research at the Management School, Queen's University Belfast*

We examine socioeconomic heterogeneity in children's time use using diary data from two waves of a nationally representative longitudinal cohort study in Ireland. Children from disadvantaged households spend significantly less time reading, doing homework, and engaging in physical exercise and sport than their counterparts, and more time engaging in unstructured play. Though most gaps are relatively small at age 9, they widen considerably by age 13. This pattern is similar for girls and boys. Parental education appears to be a more important factor in family investment decisions about children's time use than household income. Given the important role of extra-curricular activities in promoting cognitive and non-cognitive skill development, the systematic differences in children's time use we document in this paper may contribute to cumulative disadvantage and widening skill gaps through adolescence and into adulthood.

JEL Codes: I30, J10, J22

Keywords: early life conditions, inequality, skill development, socioeconomic status, time use

1. Introduction

How children spend their time has important implications for their cognitive and non-cognitive development. Activities pursued in one context, such as participating in extra-curricular engagements, contribute to the development of competencies in another, such as in school or the labor market. Activities during after-school hours in particular are an important contributor to children's developmental trajectories (Posner and Vandell, 1999). Sports and other prosocial activities promote growth and positive development by creating opportunities for belonging, cooperating with others, and skill building (Fredricks and Eccles, 2006). Activities such as reading and doing homework directly contribute to learning (Hofferth and Sandberg, 2001), as well as provide indirect learning opportunities such as development of attention, self-regulation, and self-esteem (Posner and Vandell, 1999). Unstructured play activities may also contribute to developing initiative and problem solving skills (Hofferth and Sandberg, 2001; Burdette and Whitaker, 2005).

*Correspondence to: S. Rokicki, Geary Institute for Public Policy, University College Dublin, Belfield, Dublin 4, Ireland (slawa.rokicki@ucd.ie).

Moreover, there is broad evidence linking involvement in extra-curricular activities to a wide range of health, social, and labor market outcomes in adulthood (Heckman, 2008). For example, participation in sports is associated with higher educational attainment, labor force participation, and wages (Barron et al., 2000; Lipscomb, 2007; Pfeifer and Cornelißen, 2010; Stevenson, 2010). Time spent on educational activities at young ages, such as reading and computer time, is associated with higher test scores at later ages (Fiorini, 2010; Fiorini and Keane, 2014). Participation in health-promoting activities such as physical exercise in childhood may impact on adult health directly through reducing the risk of overweight and obesity (DeMattia et al., 2007), and indirectly by promoting transmission of these healthy behaviors and routines into later life (Perkins *et al.*, 2004; Telama *et al.*, 2005). Poor health in childhood, including overweight and obesity, has been found to predict poor health in adulthood as well as affect education and labor outcomes (Gortmaker *et al.*, 1993; Black *et al.*, 2007; Smith, 2009; Delaney *et al.*, 2011).

Consequently, differences in children's time use by family background, particularly during non-school hours, are a potential contributor to the emergence and persistence of inequalities in cognitive and non-cognitive skills. This hypothesis is supported by evidence from a wide range of contexts showing inequalities in non-cognitive skills by socioeconomic status (SES) (Heckman, 2008). Moreover, in the US there are diverging trends in children's time spent in skill-promoting activities by parental education (Ramey and Ramey, 2010; Altintas, 2016; Putnam, 2016). Given that half of the inequality in lifetime earnings has been argued to be due to factors determined by age 18 (Heckman, 2008), the policy implications of inequality in children's time use are potentially important.

Though there exists a wide range of literature describing heterogeneity in parental time spent with children across family background (see, for example, Gustafsson and Kjulin, 1994; Hallberg and Klevmarken, 2003; Sayer *et al.*, 2004; Guryan *et al.*, 2008; Kalil *et al.*, 2012; Fiorini and Keane, 2014), there is very little research describing heterogeneity in children's own time use. While parental time spent with children is an important input in its own right, it does not capture an important component of children's activities, that is, what children do outside of time spent with parents.

In this paper, we examine socioeconomic differences in children's time use in a longitudinal cohort in Ireland. We aim to answer the following research questions: (1) what is the extent of inequality in children's time use by family socioeconomic background, and (2) how do these socioeconomic differences in time use change over the period from middle childhood to early adolescence? To guide our analysis, we apply a theoretical framework based on a human capital production function, detailed below, that classifies time use into investment activities (those activities which the literature has demonstrated are important for human capital acquisition and are associated with adult outcomes, i.e., reading, physical exercise/sports, and homework), and leisure activities (other activities for which the literature is less clear about their long run beneficial impacts).

We make a number of contributions to the literature. First, we use detailed time diary data from a nationally representative longitudinal panel of school children. Time diary data is more accurate than data derived from stylized survey questions on overall time spent in a particular activity (Hofferth and Sandberg, 2001; Kan

and Pudney, 2008). These data also capture all of a child's activities during a day, instead of focusing on a few particular categories. Thus, we are able to examine not only socioeconomic differences in time spent in specific activities, but also which activities are substituted for in their place as children age. Second, we examine the association between socioeconomic background and time use on both the extensive margin (participation in activities) and the intensive margin (length of time spent participating). Third, we apply concentration curves to quantify the extent of income-related inequality in time use. Fourth, we use the longitudinal nature of our data to analyze trajectories in time use as children age. Finally, we use fixed effects models to account for time-invariant omitted factors common to children and families. To the best of our knowledge, this is the first paper to analyze longitudinal changes in time use among children in this way.

The rest of the paper is as follows: Section 2 provides a theoretical framework for understanding average differences in children's time use and why they are expected to grow as children age. Section 3 discusses the data, descriptive statistics, and our estimation strategy. Section 4 presents our results and Section 5 discusses the findings.

2. Theoretical Background

From an economics perspective, children's time use allocation can be viewed as the realization of parents' and children's decisions about when and where to invest in human capital acquisition (Leibowitz, 1974; Haveman and Wolfe, 1995). Under a production function framework for human capital, investment decisions regarding the allocation of resources to inputs and children's time use will be based on parents aiming to maximize life cycle returns to them and their children (Becker and Tomes, 1986). Given these investments, children then also make choices to maximize their own welfare as they gain agency (Haveman and Wolfe, 1995). This framework can provide an insight into potential explanations for heterogeneous patterns of children's time use across families and across time as children age. In what follows we discuss the main features of the model, while a more formal representation is presented in Section A1 in the Appendix.

2.1. *Previous Evidence on Socioeconomic Differences in Average Time Use*

The first main feature of the framework we consider is that a variety of factors may contribute to differences in children's time use across levels of SES. We expect to see differences in children's time use by household income if some families cannot afford the costs associated with various activities and they are credit-constrained, thereby limiting parental investment decisions. Children from financially disadvantaged families are less likely to have access to material and cultural resources from infancy to adolescence (Bradley and Corwyn, 2002). Evidence suggests that disparities in parental resources by family background have been widening since the second demographic transition in the 1960s (McLanahan, 2004). For example, the direct costs of extra-curricular activity participation are estimated at 10 percent of annual income for a family of two children in the bottom income quintile in the US (Putnam, 2016). Parental time

spent with children has been found to be positively associated with income (Sousa-Poza *et al.*, 2001; Kalenkoski *et al.*, 2009), suggesting that at least some of the differences in children's time use are due to resource constraints.

Costs associated with activities may not necessarily be monetary and may also depend on geographic location, employment flexibility, and the opportunity cost. For example, high-income mothers are more likely to have flexible work schedules and spouses who are more involved in child rearing (Heckman, 2008; Kalil *et al.*, 2012), while low-income parents are more likely to have inflexible and atypical (late, rotating, or weekend) work schedules; in the US this disparity has been increasing since the 1970s (Hamermesh, 2002). Evidence shows that for mothers without a college degree, maternal employment significantly reduces total time spent with children, while for highly educated mothers there is no correlation, suggesting that less-educated women have increased barriers to balancing work and family life (Hsin and Felfe, 2014). Other research has found that while number of hours worked generally exerts a negative effect on parental time with children, the negative impact of hours worked in the evening (between 6pm and 10pm) is twice as large as daytime work hours (Rapoport and Le Bourdais, 2008). Other potential costs include mother's marital status, as single mothers may have less available time to organize and manage their children's activities (Hofferth and Sandberg, 2001; Burton and Phipps, 2007; Fox *et al.*, 2013). A study using the American Time Use Survey found that among teenagers aged 15-17, those in households with single mothers spend more time in unsupervised activities (Wight *et al.*, 2009).

Neighborhood characteristics may also influence parental decisions about children's time investments (Kling et al., 2007; Doyle *et al.*, 2012). For example, in a study of SES disparities in physical activity and screen time, Tandon *et al.* (2012) found that household rules around outdoor play are more restrictive in lower SES households, while children's average screen time is higher. Their findings suggest that low SES parents have greater concerns about their neighborhood's safety and have less access to alternative activities, which makes indoor screen-based options more appealing.

Finally, if initial endowments vary by SES as the literature supports (Currie, 2011), and the productivity of investments depends on these initial endowments, then we would also expect SES differences in children's time use to emerge because investment activities are more productive for higher SES families. Factors such as birth weight are strongly patterned by SES (Boardman *et al.*, 2002; Hsin, 2012; McGovern, 2013). Although it can be difficult to separate out initial ability from parental responses as children age, it has been well established that gaps in cognitive ability appear very early in life (Heckman and Masterov, 2007). As a result, families may form differing beliefs about later life returns to investments informed by initial endowments (Kalil *et al.*, 2012). This can manifest itself in the form of theories of parenting and may differ across SES. Parents with higher levels of education may tend to "concertedly cultivate" their children's development due to beliefs that this will maximize their children's future opportunities (Lareau, 2003). For example, they may organize and monitor children's after-school and weekend activities, use cognitively stimulating parenting practices more frequently, and leverage their social capital to advocate for their children in school (Lareau, 2003; Kalil *et al.*, 2012; Harding *et al.*, 2015). Conversely, parents with lower levels of

education may tend to follow the parenting model of "accomplishment of natural growth," which encourages children to be independent and learn to make their own decisions in an effort to build their resilience and resourcefulness (Lareau, 2003). Kalil *et al.* (2012) show that compared to less educated mothers, more educated mothers invest more time in basic care and play with children under 6 years of age, and more time in management of activities (such as scheduling and monitoring extracurricular activities) for children aged 6 to 13. A wide range of evidence from the US and Europe finds that highly educated parents spend more time engaging with their children and monitoring their activities than do less educated parents (Sayer *et al.*, 2004; Bianchi *et al.*, 2006; Guryan *et al.*, 2008; Gimenez-Nadal and Molina, 2013). The fact that this trend is similar across countries despite substantial cross-national variation in levels of social assistance and services for families suggests that better educated parents may have different parental values and behaviors than less educated parents (Sayer *et al.*, 2004). Finally, in the UK, Delaney and Doyle (2012) present evidence that time preferences differ across SES, as measured by traits such as hyperactivity, impulsivity, and persistence, and that they are transmitted through parents' non-cognitive skills such as self-esteem and attachment, as well as through parental time investments such as time spent reading to and teaching the child.

2.2. *Previous Evidence on Widening Differences in Time Use*

The second main feature of the framework we consider is that gaps in children's time use can be expected to widen over time for certain activities. From an economics perspective, increasing SES gaps in time use as children age may be explained by the presence of self-productivity, whereby skills gained at earlier ages promote skill acquisition in the future, and cross-complementarities, whereby prior time investments raise the returns to later investments. Due to these features, older children who received time inputs from parents when they were younger benefit more from investments in later periods. In addition, children who have greater skills at younger ages will be better able to develop new skills at older ages.

These insights from the economics literature can be combined with evidence from other disciplines. For example, one feature which is absent from a framework in which parents are the main decision-makers is the agency of the child and their capacity to decide about the activities on which to spend their time (Haveman and Wolfe, 1995). Children have increasing input into decisions about their time use as they age. One way to consider the implications of this is in terms of the self-productivity of skills. Children are likely to choose activities for which they feel they have an aptitude, or in other words, activities for which the entry costs are not too high. Additionally, social networks and peer groups can facilitate engagement in activities such as sport and we can view a lack of a peer group in terms of increasing the cost of engaging in the activity. These may also widen over time as children transition from family-based activities to school- or peer-based activities which rely on cooperation and support within peer groups. Finally, we can consider the literature on cumulative disadvantage. In sociology it is recognized that initial disparities can widen over time as different types of disadvantages combine to amplify initial inequalities in skill outcomes (DiPrete and Eirich, 2006). In terms of the

model we describe above, this can be viewed as a virtuous cycle of parental and child investments whereby initial investments raise the return to later inputs.

2.3. *Research Hypotheses*

We apply this framework to consider two predictions about the association between socioeconomic background and children's time use, which we can test using our data.

> Hypothesis 1: There are socioeconomic differences in children's average time use.

Based on the theoretical framework and existing evidence outlined in section 2.1, we hypothesize that there are differences in the types of activities in which children engage and the length of time spent in these activities across socioeconomic background.

> Hypothesis 2: Socioeconomic differences in children's time use widen as children age.

Based on the theoretical framework and existing evidence outlined in section 2.2, we hypothesize that SES differences in time spent in investment activities (such as reading, physical exercise/sports, and homework) will grow wider as children age. As we describe above, self-productivity and cross-complementarities imply widening gaps in these activities as children age because they are path-dependent, relying on the development of skills in previous periods. To account for any relative increased time spent in these investment activities, children would need to decrease relative time spent in other domains, in particular, leisure activities. Therefore, in groups for whom relative time spent in investment activities increases over time, we expect a relative decrease in at least one leisure activity, and vice versa.

For both hypotheses, a variety of factors may contribute to explain observed differences in time use, including resources, initial endowments, and alternative beliefs about the return on investments. In this paper, we use mother's education and household income as measures of SES in order to examine possible mechanisms – in particular to establish the extent to which time use differences are due to resource constraints as opposed to differing beliefs about investments.

3. Data and Methods

3.1. *Data*

We use data from the Growing Up in Ireland (GUI) survey, a nationally representative longitudinal study of two cohorts (one of infants and one of children). We use the children's cohort, which first recruited and interviewed 8,568 9-year-olds and their families in 2007/2008. A two-stage design was adopted that initially sampled primary schools and, subsequently, children within those schools.

The second round of interviews occurred 4 years later, when 7,535 participants were successfully contacted at age 13.

Both waves of the GUI child cohort included a Time Use Diary (TUD), which recorded details on the activities of participants over a 24-hour period, dividing the day and night into 15-minute intervals. In the first wave, parents were asked to complete the diary with their children (if possible); at the second wave, the 13-year-old children were asked to complete the diary with the help of their parents (if necessary).

There were 22 pre-coded activities in wave 1 and up to five activities could be recorded concurrently. In wave 2, there were 21 pre-coded activities (and 4 spaces for specifying 'other' activities), and up to 3 activities could be recorded concurrently. Respondents were not asked to prioritize concurrent activities. However, only 1 percent of time slots had concurrent activities recorded (3 percent of the after-school time slots from 2pm to 9pm); therefore, we only use data on the first activity recorded. The lists of possible activities were not the same across the two waves, therefore in order to compare time use at ages 9 and 13 we consolidate the activities into 12 categories: sleeping, personal care (which includes eating, traveling, and personal care), school, homework, sport/exercise, playing/unstructured time, hobbies, media (which includes watching TV and videos, using the computer/internet, using phones, using social media, and listening to music), reading for pleasure, housework, family time (which includes shopping trips and outings), and other. A summary of these categories is shown in Table A1 in the Appendix. For simplicity, we refer to physical exercise/sports as sports throughout the paper, and playing/unstructured time as playing.

Not all respondents completed the TUD: in wave 1, 6,228 (72.6 percent) returned usable diaries and in wave 2 the corresponding number was 5,023 (67 percent of whom had also completed the TUD in wave 1). Households were more likely to reply to the TUD survey if the primary caregiver (usually the mother) was older, not employed, more educated, and owned their home. To adjust for this, survey weights were provided to ensure that the sub-sample of TUD respondents remained nationally representative (Quail and Williams, 2013; Quail and Williams, 2015). As with the main family-based survey interviews, TUD data were collected throughout the year from August 2007 to July 2008 for wave 1, and from August 2011 to April 2012 for wave 2. Respondents were instructed as to what day of the week they were to complete the diary so as to distribute respondent days across the week. Respondents indicated if they completed the diary at the end of the diary day, the day after the diary day, or another day. They also indicated whether the diary day was during the school term or out of term, and what "type" of day it was (ordinary/school day, holiday, etc.). Information on when and how the TUD was completed is provided in Table A2 in the Appendix. We adjust for these diary variables in our analyses. In order to compare participants' activities on similar days, we limit our data to only those participants who completed a questionnaire on a weekday, during the term time, and on an ordinary/school day, although we also consider the full sample as a robustness check. Throughout the paper, we define a child's mother as a female parent or step-parent living in the household, regardless of marital or biological status. We drop children whose mothers are not found in the household from the sample (1 percent of all observations). Appendix Figure A1 shows the construction of the analysis dataset. Table 1 demonstrates that the

TABLE 1
SAMPLE CHARACTERISTICS AND COMPARISON TO POPULATION

	Wave 1		Wave 2	
	Full survey sample[a]	Analysis sample[b]	Full survey sample[a]	Analysis sample[b]
	N = 8,568	N = 3,923	N = 7,525	N = 3,257
Mother's education (%)				
Less than secondary	30	31	20	20
Secondary	36	37	38	40
More than secondary	32	32	40	40
Not in household	1	0	2	0
Father's education (%)				
Less than secondary	26	25	17	16
Secondary	22	24	23	24
More than secondary	28	29	31	31
Not in household	17	16	18	18
Missing/No response	7	5	12	10
Mother's employment (%)				
Employed	53	54	57	57
Not employed	46	46	41	43
Not in household	1	0	2	0
Father's employment (%)				
Employed	73	75	66	67
Not employed	10	9	16	15
Not in household	17	16	18	18
Mother's age <=39 (%)	50	48	24	25
Mother married (%)	82	84	81	82
Urban location (%)	45	42	45	43
Household income (€) [mean (SD)]	18,994 (12,437)	19,182 (12,362)	15,974 (9,098)	16,179 (8,772)
Household size [mean (SD)]	4.7 (1.2)	4.7 (1.2)	4.7 (1.2)	4.6 (1.2)

Notes: "Married" indicates married or living together. Household income is equivalized according to household size.
[a]Weighted with wave-specific GUI sample weights.
[b]Weighted with wave-specific GUI time use sample weights.

weighted characteristics of the respondents in the analysis sample matches those of the full survey sample at each wave. We apply the TUD survey weights in all of our descriptive analyses.

In the Irish education system children undertake 6 years of primary school. Currently all children must then complete at least 3 years of junior cycle secondary education (after which there is a national state exam, the junior certificate), followed by either 2 or 3 additional years of senior cycle secondary education (depending on whether they undertake a "transition year" which is optional in some schools), at the end of which there is a second state examination (the leaving certificate or related vocational qualifications) which forms the basis for university admission. In wave 1 of the GUI survey, cohort members were attending primary school, while in wave 2, cohort members had transitioned to the junior cycle of secondary school.

We consider two measures of SES in our analysis: mother's education (highest level of education attained by the mother) and family income. Maternal education has been strongly linked to parental investment behaviors and children's development in the economics literature (Haveman and Wolfe, 1995; Guryan *et al.*, 2008; Gimenez-Nadal and Molina, 2013; Prickett and Augustine, 2016). In the Irish context, maternal education is commonly used as a measure of household SES (e.g., Nolan and Layte, 2014; Madden, 2017). Finally, maternal education stays relatively constant across waves, providing a stable measure of underlying SES. Unlike income, education is not subject to random or temporary shocks, meaning that a gain in education is more likely to indicate a real increase in status. Mother's education is categorized into 3 groups: less than secondary (mothers who do not have the leaving certificate), secondary (mothers who have completed the leaving certificate), and more than secondary (mothers who have some third level qualification). The proportion in each category is shown in Table 1.

Our second measure of SES is household equivalized income, which provides information on whether the financial circumstances of families changed across waves. In our data, changing income is especially interesting to examine because the two waves of GUI coincided with the recession, with the first wave occurring just before any effects of the recession were felt and the second wave occurring at the height of the recession's impact (McGovern and Rokicki, 2018). Table 1 shows evidence of the recession, with a decrease in father's employment and household income from wave 1 to wave 2. For our measure, we use annual disposable household income, which is recorded as total gross household income, including social benefits and less statutory deductions of income tax and social insurance contributions, obtained via a series of questions to the primary caretaker. This income is then equivalized to take household size and structure into account. The equivalence scales assign a weight of 1 to the first adult in the household, 0.66 to each subsequent adult (aged 14 and above living in the household) and 0.33 to each child (aged less than 14). Household equivalized income is then calculated as disposable household income divided by the sum of the weights. This calculated measure is provided by GUI in the data. Prices at the time of interview in wave 1 were not much changed by wave 2, so unsurprisingly, results involving income are virtually identical whether we adjust for inflation or not. In what follows we present results using the unadjusted income data. Income quintiles are defined relative to the sample, which is representative of the Irish population of families with 9-year olds in 2007/8.

3.2. *Descriptive Statistics*

Before applying more formal analysis, we begin by describing the basic patterns underlying how children spend their time. Figure 1 shows the proportion of children that engage in activities from 2pm to 10pm at waves 1 and 2. We present data for boys and girls combined as the sex-stratified patterns are similar.

At ages 9 and 13 the school day ends at about 2:30pm and 4pm, respectively, for the majority of students. The immediate after-school period is often spent doing homework. The increase in the proportion of all children engaging in personal care at 6pm is most likely due to the consumption of an evening meal. From about 6pm onwards, time is spent using media, doing sport, playing, engaging with family, and doing personal care related activities. Compared to 9-year-olds, 13-year-olds go to sleep later in the evening and are less likely to engage in sport and reading. In contrast, 13-year-olds are more likely to engage in homework, media, and family activities.

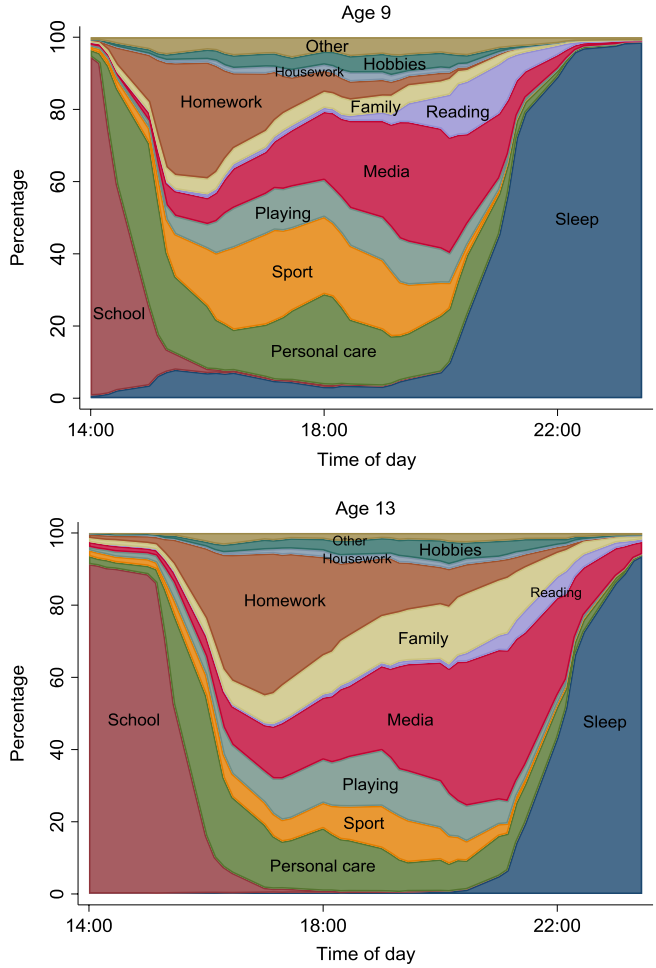

Figure 1. Percentage of Children Participating in After-School Activities at Ages 9 (Top) and 13 (Bottom) [Colour figure can be viewed at wileyonlinelibrary.com]

Next we establish whether there are any differences by family background in the raw data on activity participation. Figure 2 shows the difference in the proportion of girls (top) and boys (bottom) engaging in after-school activities by maternal education at ages 9 and 13. The y-axis is the proportion of girls/boys engaging in an activity whose mothers had completed more than secondary education minus the proportion of girls/boys engaging in an activity whose mothers had completed less than secondary education. Therefore, a positive value indicates that an activity is relatively more common at the specified time for children with more highly educated mothers. While few differences exist for girls at age 9, gaps are present by age 13; girls in households with low maternal education are much more likely to participate in media and in play—unstructured activities such as "hanging out with friends"—and less likely to participate in reading between 4pm and 10pm. For sports, the pattern reverses from age 9 to 13: more girls from low SES backgrounds participate in sport at age 9 for most of the after-school period, while at age 13 the opposite is true. Boys exhibit a broadly similar pattern.

We examine differences in minutes spent by maternal education and household income quintile for all activities in Appendix Tables A3 and A4.

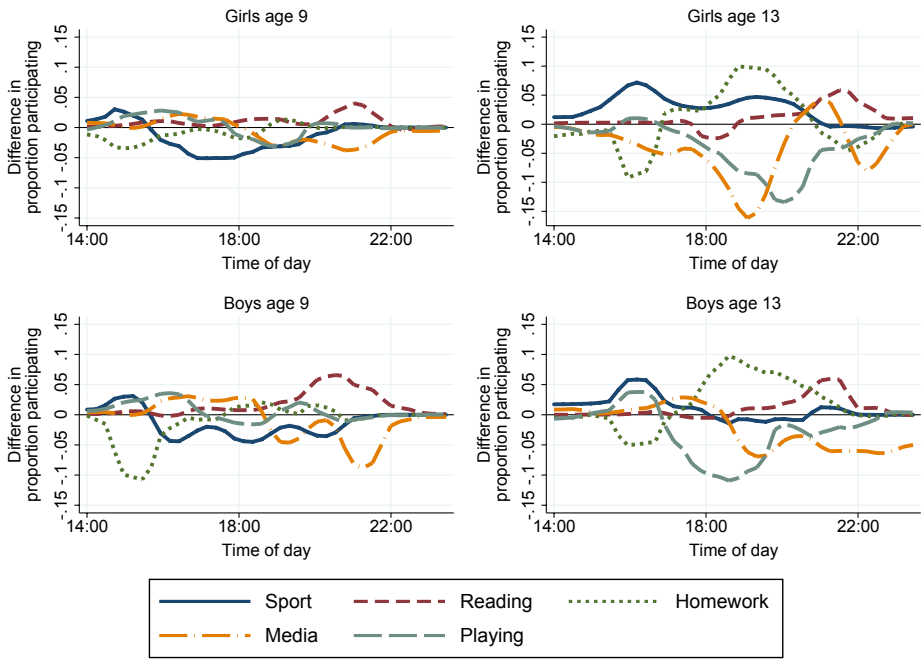

Figure 2. Differences in Children's Participation at Ages 9 and 13 in After-School Activities for Children in Households with High Maternal Education Compared to Households with Low Maternal Education

Notes: Differences are calculated as the proportion of children with mothers with more than secondary education participating in the activity minus proportion of children with mothers with less than secondary education participating. Positive values indicate the activity is relatively more common for children with highly educated mothers, while negative values indicate the activity is more common for children with less educated mothers.

3.3. *Describing SES Differences using Concentration Indices*

We use concentration indices to assess the degree of income-related inequality in the distribution of children's time use. The concentration index (C) is calculated as twice the area between the concentration curve and the 45 degree line of equality, where the concentration curve describes the relationship between the cumulative share of equivalized household income and the cumulative share of time spent in a particular activity. This is a common approach in the literature on assessing the extent of inequality in an outcome of interest and has been used previously in a number of different contexts, including obesity (Walsh and Cullinan, 2015), vaccination (Doherty *et al.*, 2014), health in older populations (McGovern, 2014), economic insecurity (Rohde et al., 2014), and child height-for-age (Wagstaff *et al.*, 2003).

Eq. 1 defines the concentration index as,

$$C = 1 - 2\int_0^1 L_h(p)\,dp \tag{1}$$

where $L_h(p)$ is the concentration curve at p percent of the population. The concentration index is bounded between [−1, +1], with zero indicating perfect equality. A positive value indicates that lower income households receive less than their expected share of the minutes in each activity, while a negative value indicates they receive more than their expected share.

We focus on the three investment activities (reading, sport and homework) and compare these to the four leisure activities (media, playing, hobbies, and family). Appendix Figures A2–A8 show the concentration curves for each activity for girls and boys at ages 9 and 13. Table 2 presents the concentration indices for these, stratified by age and sex. The largest concentration index is that for boys' sports time at age 13 at 0.15. As an intuitive interpretation, concentration indices indicate the proportion of the outcome that would need to be redistributed from the richest half of households to the poorest half of households in order to achieve an equal distribution (concentration index of 0) (Koolman and Doorslaer, 2004). For example, if 15 percent of sports time was transferred from the richest half of households to the poorest half of households, the concentration index for boys would then be 0. A concentration index of this magnitude for boys' sport is comparable to that for children's obesity in Ireland (Walsh and Cullinan, 2015), but is smaller than that for birth weight (Madden, 2014).

Overall, we find a high degree of income-related inequality for sports and reading at age 13 for both girls and boys. We find small to negligible inequality for all other activities across age and sex, with the exception of hobbies for boys at age 9. These results differ from those in Figure 2, which found large time use differences for media and playing time by maternal education, indicating that maternal education may be a more important factor determining children's time use than income.

3.4. *Visualizing changes in time use as children age*

As we have described in the introduction, a novel feature of the data is that we are able to track children's time use longitudinally as they age. For example,

TABLE 2
CONCENTRATION INDICES FOR GIRLS AND BOYS AT AGES 9 AND 13

	Sport	Reading	Homework	Media	Playing	Hobbies	Family
Panel A: Girls							
Age 9	0.03	0.0004	−0.03	−0.01	0.002	0.03	0.07
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.03)	(0.04)
Age 13	0.11	0.07	0.01	−0.002	−0.06	0.06	−0.01
	(0.03)	(0.04)	(0.01)	(0.01)	(0.02)	(0.03)	(0.02)
Panel B: Boys							
Age 9	0.01	0.04	−0.01	0.01	−0.04	0.13	−0.10
	(0.01)	0.02	(0.01)	(0.01)	(0.02)	(0.03)	(0.04)
Age 13	0.15	0.09	0.01	−0.03	−0.05	−0.02	−0.001
	(0.02)	(0.04)	(0.01)	(0.01)	(0.02)	(0.04)	(0.02)

Notes: Standard errors are shown in parentheses.

we can establish for every child whether they are participating in the same activity at each point in the day at age 13 as they were at age 9. To describe these patterns, we construct a summary measure of substitutions, which we define as the average number of minutes that are transferred from an activity in wave 1 to another activity in the same time slot in wave 2. These substitutions refer exclusively to how the *same child* changed their time use as they aged, as opposed to differences in average cohort time use (therefore information on children who were only present in a single wave is not used). To summarize this information, we sum over each child (c), time slot (t), and activity (a), the number of minutes per day transferred from one activity to each of the other activities (Eq. 2).

$$(2) \qquad Sub_{a_{ij}} = \frac{15}{N} * \left(\sum_{c=1}^{N} \sum_{t=1}^{T} \sum_{i=1}^{12} \sum_{j=1}^{11} I(a_{c,t,i,\,wave=1} = a_{c,t,j,\,wave=2}) \right) \forall i \neq j$$

Here, $a_{c,t,i,wave=1}$ is activity i for child c in timeslot t in wave 1, $a_{c,t,j,wave=2}$ is activity j in the corresponding timeslot for the same child in wave 2, and $I(.)$ is the indicator function evaluating whether these activities are the same. We multiply by 15 because the time slots are in 15-minute intervals. $N = 1{,}585$, the total number of children present in both wave 1 and wave 2, and $T = 98$, the total number of 15-minute timeslots in a day. We report the net figures between activities, e.g. 10 minutes transferred from homework to reading and 5 minutes transferred from reading to homework results in an overall 5 minutes transferred from homework to reading. This measure is shown for all activities in matrix form as Table A5 in the Appendix and summarized in Figure 3 as a chord diagram. In the figure, we aggregate some categories to simplify the presentation, so that all leisure activities (hobbies, media, family, playing) are categorized as "leisure", while categories of personal care, housework, and other are categorized as "other". The arrows indicate the direction of substitution from one activity to another, with the size of the arrows proportional to the average number of minutes transferred per day. The numbers around the outside give the total inflow and outflow of minutes for each activity. Note that most activities have both inflows and outflows. An exception is sleep, for which all of the total change (100 minutes per day) is an outflow. About 35 minutes of sleep are substituted with time in the "other" category, while about the same amount of time is substituted away from "other" to school, indicating that children are ultimately substituting sleep time with school. Another 35 minutes of sleep time are substituted with leisure time. In addition, we find that reading minutes flow mainly to leisure. For sport, the largest outflow is to homework, followed by leisure, school, and other.

3.5. *Modelling Heterogeneity in Children's Time Use: Empirical strategy*

To test our two research hypotheses (whether SES differences are present in children's time use, and if so, whether they widen with age), we implement regression models to examine heterogeneity in children's time use at ages 9 and 13. The data allow us to consider both extensive and intensive margins of time use. We begin by examining heterogeneity in time use on the extensive margin, focusing

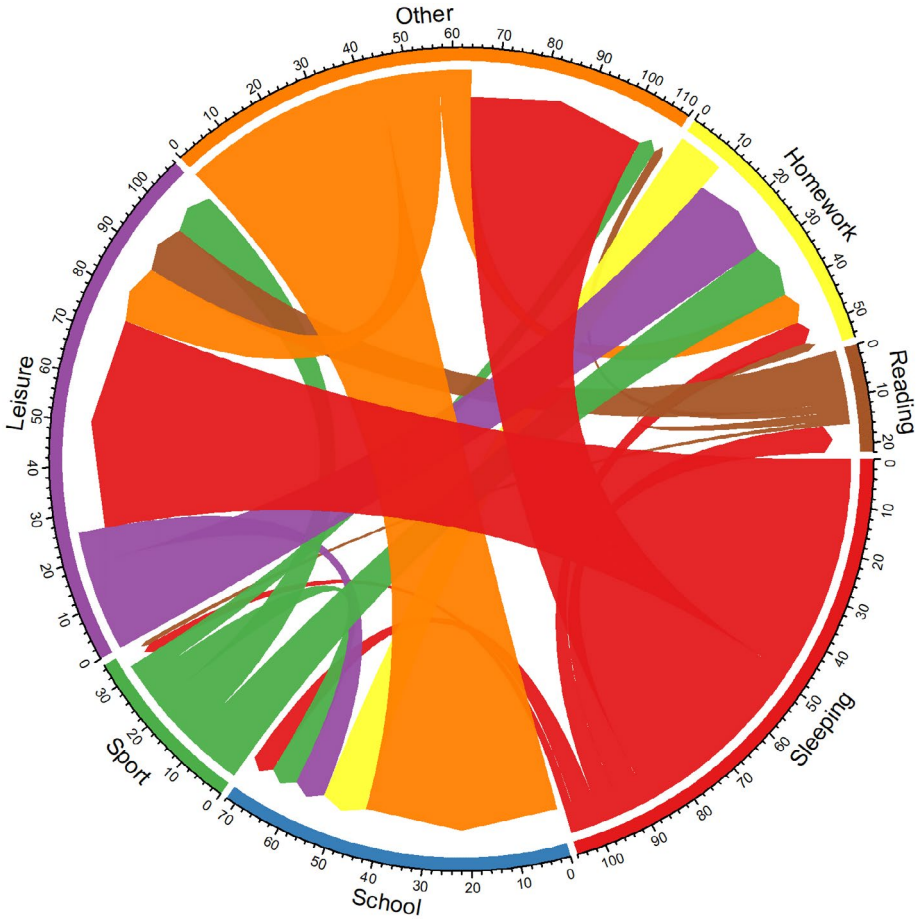

Figure 3. Chord Diagram of Time Use Substitution Patterns from Age 9 to Age 13
Notes: Leisure includes the categories of playing, media, family, and hobbies. Other includes the categories of personal care, housework, and "other". [Colour figure can be viewed at wileyonlinelibrary.com]

on maternal education. We apply both pooled linear regression models and logistic regression models, with standard errors clustered at the child level and weighted with wave-specific GUI time use sample weights. In this setup, the outcome, Y, is a binary indicator for any time spent in a particular activity a for child c in period t. We include an interaction between mother's education for child c in period t and an indicator for wave, and also control for TUD characteristics (day of week, month of year, who completed diary, and when it was completed) in Z_{ct} . The specification for the linear predictor representation is shown below (Eq. 3):

$$(3) \qquad Y_{ct}^{a} = \alpha_1 + \gamma_1 Wave_t + \beta_1 MotherEd_{ct} + \delta_1 Wave_t * MotherEd_{ct} + Z_{ct}\mu_1^{'} + \varepsilon_{ct}$$

In this model, the coefficients β_1 and δ_1 allow us to test our hypotheses. If there are no SES differences in children's participation in activities at wave 1, β_1 will be 0.

The coefficient δ_1 estimates the additional change in participation from wave 1 to wave 2. Therefore, if SES gaps in children's participation do not widen over time, δ_1 will be 0. We extend this model by examining alternative specifications, but in each case we will test the corresponding coefficients (e.g. β_2 and δ_2 in equation 4) to assess whether the data support our two research hypotheses.

We next examine socioeconomic heterogeneity in time use on the intensive margin, again focusing on maternal education. We apply linear regression models with standard errors clustered at the child level. The outcome is the number of minutes spent in a particular activity and the right-hand side of the model is the same as above. The specification is shown in Eq. (4):

$$(4)\quad TimeUse^{a}_{ct} = \alpha_2 + \gamma_2 Wave_t + \beta_2 MotherEd_{ct} + \delta_2 Wave_t * MotherEd_{ct} + Z_{ct}\mu_2' + \varepsilon_{ct}$$

where $TimeUse^{a}_{ct}$ is the amount of minutes spent on a particular activity a for child c at time t. As a robustness check, we also apply generalized linear negative binomial models with a log-link with the same covariate specification. We use generalized linear modelling (GLM) instead of a two-part model because the negative binomial accounts for over-dispersion whilst allowing for more straightforward interpretation of coefficients without the requirement of splitting the sample. Previous research has found very little difference in performance between GLM and two-part models (Buntin and Zaslavsky, 2004). Moreover, we present separate results for participation. In both base-case extensive and intensive margin analyses, we do not control for covariates such as parental employment, household income, and mother's marital status as these variables are likely to be on the causal pathway between maternal education and time use.

Next, we extend our model to explore possible mechanisms through which SES affects children's time use by including both mother's education and household income as measures of SES in the model, focusing on the intensive margin. The corresponding specification is shown in Eq. (5):

$$(5)\quad \begin{aligned} TimeUse^{a}_{ct} &= \alpha_3 + \gamma_3 Wave_t + \beta_3 MotherEd_{ct} + \delta_3 Wave_t * MotherEd_{ct} \\ &\quad + \psi_3 LogIncome_{ct} + \varphi_3 Wave_t * LogIncome_{ct} + Z_{ct}\mu_3' + X_{ct}\nu_3' + \varepsilon_{ct} \end{aligned}$$

where $LogIncome_{ct}$ is the natural log of equivalized household income for child c at time t. In this model, we also additionally control for mother's and father's employment, mother's marital status, and household size in X_{ct}. We show results without these additional controls in the Appendix. We also show results of this model controlling for an even wider range of variables including mother's age, father's education, mother's and father's employment, mother's marital status, number of children in the household, and child health status in the Appendix. To assess the role of income as a mechanism, we examine whether the coefficients on maternal education (β_3 and δ_3) are attenuated with the addition of this covariate compared to the magnitude of the coefficients in equation 4. We also test whether income plays an independent role in predicting differences in time use (ψ_3) and again whether these differences grow as children age (φ_3).

Finally, we exploit the longitudinal nature of our data to investigate the impact of changes in SES on time use in the short-term by applying individual fixed effects

(FE) models. The FE models control for unobserved time-invariant characteristics of children and families, such as initial conditions like birth weight and parental background. By eliminating potential omitted variable bias from unobserved factors that do not vary over time and that may confound the relationship between income and time use, we can better assess whether changes in income are likely to result in changes in time use. Because maternal education changes for less than 10% of families across waves, we focus instead on household income as our measure of SES. The fixed effects model is shown in Eq. 6:

$$TimeUse^{a}_{ct} = \alpha_c + \delta_t + \beta LogIncome_{ct} + Z_{ct}\mu_4^{'} + X_{ct}v_4^{'} + \epsilon_{ct} \tag{6}$$

where $LogIncome_{ct}$ is the log household equivalized income for child c at time t, X_{ct} is the same matrix of time-varying variables as above, δ_t is the time fixed effect, and α_c is the child fixed effect. We show results with and without controlling for X_{ct}. We cluster standard errors at the child level.

Because we have a large number of outcomes, we adjust for multiple hypothesis testing. For all models, we adjust critical α-levels using a family-wise Bonferroni method that adjusts for correlation in the outcomes, referred to as the Dubey/Armitage-Parmar (D/AP) procedure (Sankoh et al., 1997). The "family" refers to all outcomes for a given sex in each model specification.

4. Results

4.1. *Extensive Margin*

Table 3 shows the results of the pooled linear regression models for girls and boys for participation in after-school activities as a function of maternal education. Logit and linear regression models reach similar conclusions (Appendix Tables A6 and A7 show the full set of coefficients for both models for girls and boys, respectively). Of note is that we find no difference in sports participation by mother's education for girls at age 9, at which time about 46 percent of girls participate. While girls across all levels of SES decrease their sports participation from age 9 to 13, this trend is differential by mother's education: there is a 37 percentage point drop in participation among girls whose mothers have less than secondary education, while there is only a 22 (−37 + 15) percentage point drop for girls whose mothers have more than secondary education, a difference that appears substantial given the baseline participation rate.

Results for reading describe a different pattern. By age 9, a gap in reading participation by mother's education has already emerged: girls whose mothers have more than secondary education are 17 percentage points more likely to read for pleasure than girls whose mothers have less than secondary education. The corresponding odds ratio from the logit model indicates that girls whose mothers have more than secondary education are twice as likely to read in wave 1 as girls whose mothers have less than secondary education (Appendix Table A6). This reading gap persists at wave 2, but does not widen (the coefficient on the interaction between maternal education and wave is not statistically significant).

TABLE 3
LINEAR REGRESSION RESULTS FOR PARTICIPATION IN ACTIVITIES FOR GIRLS AND BOYS

Variables	Girls							Boys						
	Any Sport	Any Reading	Any Homework	Any Playing	Any Media	Any Hobbies	Any Family	Any Sport	Any Reading	Any Homework	Any Playing	Any Media	Any Hobbies	Any Family
W2	−0.37***	−0.26***	0.07	0.01	0.03	−0.01	0.34***	−0.32***	−0.20***	0.01	0.07	0.06	−0.02	0.38***
	(0.05)	(0.05)	(0.04)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)	(0.04)	(0.05)	(0.06)	(0.04)	(0.03)	(0.06)
Mother's Education														
Secondary	−0.01	0.11**	−0.00	0.07	0.04	0.05	0.06*	0.03	0.11**	−0.03	0.04	0.02	0.05	0.00
	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
> Secondary	−0.03	0.17***	−0.01	0.04	0.01	0.14***	0.04	0.05	0.25***	−0.07**	0.09**	0.02	0.12***	−0.01
	(0.04)	(0.04)	(0.02)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Secondary * W2	0.04	−0.04	−0.03	−0.15	−0.03	−0.06	0.02	0.00	−0.08	0.04	−0.06	−0.08	0.04	−0.06
	(0.06)	(0.06)	(0.05)	(0.07)	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)	(0.05)	(0.07)	(0.05)	(0.04)	(0.06)
> Secondary * W2	0.15*	−0.01	−0.03	−0.13	−0.03	−0.06	−0.02	−0.00	−0.12	0.06	−0.13	−0.07	0.00	−0.07
	(0.06)	(0.06)	(0.04)	(0.07)	(0.05)	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)	(0.07)	(0.04)	(0.04)	(0.06)
Constant	0.46***	0.47***	0.88***	0.51***	0.87***	0.27***	0.16***	0.61***	0.34***	0.92***	0.50***	0.85***	0.16***	0.21***
	(0.06)	(0.06)	(0.04)	(0.06)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.06)	(0.04)	(0.04)	(0.05)
N	3,606	3,606	3,606	3,606	3,606	3,606	3,606	3,574	3,574	3,574	3,574	3,574	3,574	3,574
R^2	0.13	0.10	0.18	0.02	0.01	0.03	0.15	0.15	0.12	0.19	0.02	0.01	0.03	0.14

Notes: "W2" indicates wave 2. "> Secondary" indicates more than secondary education. The omitted category for mother's education is less than secondary. Clustered standard errors are shown in parentheses. Critical alpha values of 0.01, 0.05, and 0.1 are adjusted for multiple hypothesis testing using the D/AP procedure with correlation = 0.05 resulting in corresponding p-value cut-offs:

***$p < 0.0016$;**$p < 0.008$;*$p < 0.016$.

After adjusting for multiple hypothesis testing, there is no evidence of statistically significant differences in playing, media, family time, or homework participation across levels of maternal education in either wave for girls. In contrast, girls whose mothers have more than secondary education are 14 percentage points more likely to participate in hobbies at age 9, though this gap narrows at age 13.

Overall, the participation results for boys are similar to girls across activities, except for boys' sports participation, where there is no evidence of a gap by maternal education in either wave. In addition, at age 9 boys with mothers with more than secondary education are more likely to participate in playing and less likely to participate in homework.

4.2. *Intensive Margin*

Table 4 shows the results of the linear regression models for girls and boys separately for the time spent in each activity as a function of maternal education. Coefficients from negative binomial models, which produce the same conclusions, and the full set of coefficients for the linear regression models are shown in Appendix Tables A8 and A9 for girls and boys, respectively.

The gradients in time spent in activities by maternal education are similar to those in participation. In wave 1, girls whose mothers have more than secondary education spend 8 fewer minutes in sport. However, by wave 2 the gradient has reversed and girls whose mothers have more than secondary education spend $25 - 8 = 17$ additional minutes on sport per day. In the negative binomial model, compared with girls with mothers with less than secondary education, girls with mothers with completed secondary education spend twice as much time in sports, while girls with mothers with more than secondary education spend roughly 3 times as much time daily doing sports at wave 2 (Appendix Table A8). As with participation, the maternal education reading gap is present at age 9 (7 minutes more for girls with mothers with more than secondary education compared to less than secondary education). While no gap exists at age 9 for playing time, it is large at age 13 (20 fewer minutes for girls with mothers with more than secondary education compared to less than secondary education, a reduction of nearly 40 percent). In fact, girls with mothers with secondary education and more than secondary education reduce their playing time from wave 1 to wave 2, while girls with mothers with less than secondary education increase their daily playing time over the waves.

For boys, results are similar, though there are a few noticeable differences. Though the coefficients on sports time and playing for mother's education show similar trends as for girls, the standard errors are larger. Additionally, we see substantial gaps in homework time which was not present for girls, with an additional $16 - 7 = 9$ minutes in wave 2 for boys whose mothers have more than secondary education compared to less than secondary education.

Next, to examine possible mechanisms, we show the results of models that include both mother's education and household income as measures of SES (Table 5). These models also include further adjustment for mother's and father's employment, mother's marital status, and household size. Results for models without these additional controls were nearly identical and are shown in Appendix Table A10. Results with an even wider set of controls are shown in Appendix Table

TABLE 4
LINEAR REGRESSION RESULTS FOR TIME SPENT IN ACTIVITIES FOR GIRLS AND BOYS

	Girls							Boys						
Variables	Sport (Min)	Reading (Min)	Homework (Min)	Playing (Min)	Media (Min)	Hobbies (Min)	Family (Min)	Sport (Min)	Reading (Min)	Homework (Min)	Playing (Min)	Media (Min)	Hobbies (Min)	Family (Min)
W2	−40.80***	−9.02**	31.88***	14.15	41.68***	6.91	28.56***	−38.76***	−7.65***	15.52**	19.27	38.16***	−1.12	37.41***
	(4.13)	(2.93)	(6.81)	(7.35)	(11.00)	(5.35)	(6.19)	(6.44)	(2.16)	(5.50)	(8.38)	(8.52)	(2.60)	(8.62)
Mother's Education														
Secondary	−5.28	3.97	−0.16	0.95	2.77	3.52	3.66	−1.67	4.09	−4.09	2.34	−2.21	0.77	−1.92
	(4.38)	(2.17)	(2.54)	(4.36)	(4.21)	(2.67)	(2.87)	(5.54)	(1.87)	(2.66)	(3.86)	(4.95)	(2.05)	(4.96)
> Secondary	−8.37	6.82***	−3.39	−0.25	−2.08	7.87***	1.61	−3.42	11.40***	−6.94**	3.34	−4.22	4.47	−4.04
	(4.25)	(1.95)	(2.36)	(4.13)	(4.01)	(2.44)	(2.96)	(5.10)	(2.04)	(2.45)	(3.52)	(4.84)	(2.00)	(4.77)
Secondary * W2	14.15**	−2.17	2.36	−16.98	−12.90	−9.06*	4.73	20.00	−2.81	13.35	−8.21	−10.53	5.89	−8.96
	(5.37)	(3.23)	(7.25)	(8.31)	(11.98)	(5.48)	(7.04)	(11.44)	(2.67)	(6.27)	(9.51)	(9.99)	(3.49)	(9.54)
> Secondary * W2	25.38***	0.09	3.36	−20.26*	−20.13	−9.09	−0.73	11.71	−5.19	16.10**	−18.50	−11.92	2.37	−9.45
	(5.15)	(3.36)	(7.19)	(8.03)	(11.56)	(5.29)	(6.84)	(7.04)	(2.79)	(5.96)	(8.78)	(9.56)	(3.00)	(9.14)
Constant	35.11***	22.25***	52.17***	40.92***	84.91***	17.94***	11.08	46.15***	15.31***	52.83***	31.36***	84.99***	9.79***	15.67
	(5.51)	(3.90)	(4.45)	(7.47)	(8.50)	(4.68)	(5.23)	(7.82)	(2.63)	(4.41)	(5.56)	(7.47)	(2.85)	(6.74)
N	3,606	3,606	3,606	3,606	3,606	3,606	3,606	3,574	3,574	3,574	3,574	3,574	3,574	3,574
R^2	0.14	0.05	0.17	0.04	0.07	0.02	0.11	0.12	0.07	0.15	0.03	0.06	0.02	0.11

Notes: "W2" indicates wave 2. "> Secondary" indicates more than secondary education. The omitted category for mother's education is less than secondary. Clustered standard errors are shown in parentheses. Critical alpha values of 0.01, 0.05, and 0.1 are adjusted for multiple hypothesis testing using the D/AP procedure with correlation = 0.15 resulting in corresponding p-value cut-offs:

***$p < 0.0019$;**$p < 0.0096$;*$p < 0.02$.

A11 and reach the same conclusions. We find that even after controlling for household income, gaps in time use by mother's education widen for sports time for girls, and for homework and playing time for boys. We also find evidence of large reading gaps present at age 9 for both girls and boys by maternal education. With the addition of income into the model, we find that for boys, higher income is associated with more sports time at ages 9 and 13. However, income is not associated with time spent in any other activities for either girls or boys.

4.3. *Fixed Effects Results for Income and Time Use*

Table 6 shows the results of the fixed effects regressions of time use on income for girls (panel A) and boys (panel B). We show models adjusted for time diary characteristics only, as well as models that also include additional controls. The full set of coefficients for these models is shown in Appendix Tables A12 and A13.

After adjusting for multiple hypothesis testing, none of the coefficients on income for either girls or boys is significantly different from 0 for any activity in the fixed effects models, indicating that a change in income from age 9 to 13 is not associated with a change in children's time use. We return to the interpretation of these results in the discussion.

5. Discussion

We conducted a longitudinal analysis of heterogeneity in children's time use to understand differences in activity participation by family socioeconomic background. In particular, we examined two main research hypotheses. First, we determined the extent to which socioeconomic gaps in children's time use exist. Second, we examined whether and how these gaps change over time. We focused on comparing activities that can be most viewed as investments in human capital which have been shown in the literature to be beneficial for skill acquisition (reading, physical exercise and sport, and homework time) with leisure activities.

Our main results highlight several key messages. First, in terms of our first research hypothesis, we identify substantial differences in sports, reading, homework, and playing time by socioeconomic status that are largely consistent with the theoretical framework outlined in Section 2. At age 9, girls from high SES backgrounds spend 7 more minutes each day reading than girls from low SES backgrounds. At age 13, girls with high SES backgrounds spend 17 more minutes each day on sport and 20 fewer minutes each day on unstructured play than girls from low SES backgrounds. A similar pattern exists for boys, where we also find differences in homework time at ages 9 and 13. Both linear and corresponding nonlinear models for participation and time spent in activities show consistent results (Tables 2 and 3).

Next, in terms of our second research hypothesis, we find that while gaps in children's time use at age 9 are generally small, they widen as children age for sports, homework, and playing time (Tables 2 and 3). For example, girls from low SES backgrounds spend slightly more time on physical exercise and sport at age 9, but by age 13 the trend has reversed. Similarly, there is no difference in playing time at age 9, but while girls

TABLE 5

LINEAR REGRESSION RESULTS FOR TIME SPENT IN ACTIVITIES FOR GIRLS AND BOYS INCLUDING BOTH MATERNAL EDUCATION AND INCOME

	Girls							Boys						
Variables	Sport (Min)	Reading (Min)	Homework (Min)	Playing (Min)	Media (Min)	Hobbies (Min)	Family (Min)	Sport (Min)	Reading (Min)	Homework (Min)	Playing (Min)	Media (Min)	Hobbies (Min)	Family (Min)
W2	−36.88***	−8.47**	34.85***	11.90	36.51***	5.84	28.98***	−30.84***	−5.65*	11.13	22.27*	36.12***	−4.62	37.25***
	(4.67)	(3.00)	(7.69)	(8.43)	(10.74)	(5.79)	(6.65)	(7.12)	(2.34)	(6.12)	(8.98)	(9.49)	(2.65)	(8.14)
Mother's Education														
Secondary	−2.83	5.02	−0.77	0.00	4.63	2.72	3.50	−5.51	4.91*	−4.10	4.55	−3.56	−0.28	0.03
	(4.36)	(2.41)	(2.67)	(4.52)	(4.45)	(2.72)	(3.14)	(5.88)	(1.90)	(2.81)	(3.89)	(5.26)	(2.12)	(5.08)
> Secondary	−7.48	7.45***	−2.20	−0.57	−0.53	5.96	1.04	−9.19	11.84***	−7.04**	6.63	−5.85	2.71	−1.89
	(4.56)	(2.25)	(2.59)	(4.38)	(4.48)	(2.66)	(3.02)	(5.71)	(2.20)	(2.70)	(3.60)	(5.39)	(2.11)	(4.98)
Secondary * W2	9.73	−2.65	1.41	−15.20	−9.76	−7.48	3.59	10.42	−3.76	17.32**	−12.32	−9.63	9.52**	−10.69
	(5.62)	(3.27)	(7.82)	(8.81)	(11.31)	(5.72)	(7.31)	(8.04)	(2.85)	(6.58)	(9.93)	(10.71)	(3.62)	(8.95)
> Secondary * W2	21.94***	−0.08	−0.08	−17.87	−14.70	−8.34	−2.32	7.07	−6.41	18.41**	−25.08**	−9.40	6.62	−9.58
	(5.78)	(3.40)	(8.02)	(9.07)	(11.51)	(6.01)	(7.11)	(7.63)	(2.95)	(6.66)	(9.39)	(10.70)	(3.10)	(8.83)
Log income	0.67	−0.00	−2.30	0.52	−0.65	0.08	−2.04	10.41*	−0.79	−0.27	−4.10	1.51	1.57	−5.14
	(6.25)	(1.88)	(2.11)	(3.47)	(3.75)	(2.18)	(2.73)	(4.02)	(1.64)	(2.39)	(3.35)	(4.38)	(1.51)	(3.28)
Log income * W2	0.25	0.63	4.30	−2.27	4.36	2.94	−1.75	16.19	3.01	−1.79	2.51	−14.35	−6.12	6.31
	(6.49)	(3.01)	(5.02)	(6.26)	(7.62)	(3.23)	(5.15)	(7.26)	(2.37)	(4.73)	(5.90)	(7.53)	(2.81)	(5.75)
Observations	3,338	3,338	3,338	3,338	3,338	3,338	3,338	3,340	3,340	3,340	3,340	3,340	3,340	3,340
R^2	0.14	0.06	0.18	0.04	0.07	0.02	0.12	0.16	0.07	0.16	0.06	0.07	0.03	0.11

Notes: "W2" indicates wave 2. "> Secondary" indicates more than secondary education. Regressions are adjusted for mother's and father's employment, mother's marital status, family size, and time diary characteristics. The omitted category for mother's education is less than secondary. Clustered standard errors are shown in parentheses. Critical alpha values of 0.01, 0.05, and 0.1 are adjusted for multiple hypothesis testing using the D/AP procedure with correlation = 0.15 resulting in corresponding p-value cut-offs:

***$p < 0.0019$;**$p < 0.0096$;*$p < 0.02$.

TABLE 6
RESULTS OF FIXED EFFECTS MODELS EVALUATING CHANGES IN HOUSEHOLD INCOME AND TIME SPENT IN ACTIVITIES FOR GIRLS AND BOYS

	Sport (min)	Sport (min)	Reading (min)	Reading (min)	Homework (min)	Homework (min)	Playing (min)	Playing (min)	Media (min)	Media (min)	Hobbies (min)	Hobbies (min)	Family (min)	Family (min)
Panel A: Girls														
Log income	−1.98	−5.40	1.83	2.89	0.20	1.89	5.38	5.21	0.06	0.19	−6.16	−7.67	−4.27	−4.04
	(6.21)	(6.33)	(3.14)	(3.48)	(3.94)	(4.07)	(5.80)	(6.21)	(7.11)	(7.51)	(4.24)	(4.52)	(5.29)	(5.49)
Adjusted	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Number of ID	1,764	1,764	1,764	1,764	1,764	1,764	1,764	1,764	1,764	1,764	1,764	1,764	1,764	1,764
Panel B: Boys														
Log income	−3.88	−2.09	−3.53	−3.91	−1.34	−2.36	−1.86	−2.07	−3.17	−2.57	−1.98	−0.78	5.52	1.45
	(6.85)	(7.34)	(2.62)	(2.56)	(4.89)	(4.91)	(6.20)	(6.31)	(7.74)	(8.23)	(4.25)	(4.28)	(6.18)	(6.56)
Adjusted	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Number of ID	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770	1,770

Notes: Income is household income, equivalized for family size. Clustered standard errors are shown in parentheses. Unadjusted regression models are adjusted only for time diary characteristics. Adjusted models are additionally adjusted for mother's and father's employment, mother's marital status, and family size. Critical alpha values of 0.01, 0.05, and 0.1 are adjusted for multiple hypothesis testing using the D/AP procedure with correlation = 0.15 resulting in corresponding p-value cut-offs:

$^{***}p < 0.0019$; $^{**}p < 0.0096$; $^{*}p < 0.02$.

with mothers with less than secondary education increase their daily playing time from age 9 to 13, girls with mothers with secondary education and above decrease this time, resulting in a large gap. We find a similar systematic widening of gaps for boys.

Our results for reading, however, do not support our second hypothesis. Gaps in reading time are already formed by age 9 and stay stable from age 9 to 13. Reading requires skills formed in early childhood (Sparks *et al.*, 2014) and so it is not surprising that gaps in reading time are already present at age 9. However, it may be surprising that these gaps do not widen over time, as expected for an investment activity. One explanation may be due to the aggregate large drop in reading time, which is essentially halved from wave 1 to wave 2 for both girls and boys across all levels of SES. Figure 2 and Appendix Table A5 show that most of reading time at age 9 is shifted to media time at age 13, which increased 20-40 minutes per day across levels of SES. The period of 2007–2012 saw significant changes in technology, with rapid increases in broadband internet connections and smartphone ownership as well as the proliferation of social media and smartphone applications (Pew Research Center). These large technological changes, occurring concurrently with children's growth from middle childhood into young adolescence, may have resulted in a substantial cohort shift in time use from reading to technology and media. In our data, the percentage of children who have a mobile phone increased from 45 percent at age 9 to 59 percent at age 13. Findings from the European Union Kids Online survey conducted in 2010 found that while only 28 percent of 9 - 10 year olds have a social media profile, 59 percent of 11 - 12 year olds do, suggesting that the start of secondary school may correspond to an increase in the use of social networking (Livingstone *et al.*, 2010).

Third, we find that for boys only, household income is significantly associated with sports time (Table 4). For this activity, economically disadvantaged parents may be limited by the cost of equipment and fees for formal sports. The GUI data confirm that sports time is increasingly made up of formal organized activity as children grow older (as opposed to, for example, exercising through playing games outside with friends at age 9). Removing or subsidizing equipment or membership costs could therefore reduce income-related inequality in sports participation for boys. In the US, these costs are estimated at 10 percent of annual income for two-child families in the bottom income quintile (Putnam, 2016). Previous research in Ireland is consistent with this hypothesis, as a report on obesity and physical activity among the 13-year-old cohort found that 37 percent of children in the lowest social group never participated in organized sports, compared to 17 percent in the highest social group (ESRI, 2012). Collecting further data on these costs could provide a basis for determining whether there is justification for policy intervention in this area. Importantly, household income was not significantly associated with sports time for girls at any age, so an income-related policy intervention would not be expected to change sports time for girls from low SES backgrounds.

Finally, aside from boys' physical exercise and sport we find no association of income with time spent in any other activities for boys or girls, while we find strong associations between maternal education and children's time use. This points to parental education being a much more important factor in family investment decisions about children's time use than income, and is in line with previous evidence on differences in parenting styles and values by parental education (Lareau, 2003; Sayer *et al.*, 2004; Guryan *et al.*, 2008; Gimenez-Nadal and Molina, 2013). For

example, gaps in parental time spent with children by parental education have been shown to be quite similar across countries despite substantial cross-national variation in levels of social assistance and services for families (Sayer *et al.*, 2004).

An important consideration is that while we find that income is associated with boys' sports time in the pooled linear model (Table 4), these results do not hold in the fixed effects model (Table 5). During the time period under study in our data (2007–2012), the Great Recession resulted in a substantial income shock for many households and affected poorer households more severely than better-off households. Yet, despite these shocks, we do not see an impact on children's time use. There are a number of possible explanations for the contrasting results in the pooled and fixed effects models. One possibility is that the fixed effects models are adjusting for omitted variable bias from time-invariant factors. Conversely, there are several limitations to the fixed effects approach that provide alternative explanations, which we discuss below.

Examining the patterns of socioeconomic differences in time use may be useful for forming policy recommendations. Though no socioeconomic gap exists in sports and exercise participation at age 9, large differences emerge by age 13, particularly for girls. Conversely, for girls' and boys' reading time, the gap already exists by age 9. Therefore, for policies that seek to reduce socioeconomic inequality in girls' sports time, it may be most effective to aim to intervene before the time of puberty (normally at ages 12–14), when the fall-off in physical exercise and sports participation is greatest, while for policies that aim to reduce inequality in reading skills, it may be most effective to intervene before age 9. This would be consistent with the theoretical framework we outline in Section 3, which suggests there can be a high degree of path dependency in skill acquisition. Given the literature on the importance of childhood development for adult outcomes, there may be important implications of SES time use differences in early life for social mobility.

Moreover, the SES inequalities in time spent on physical exercise and sport, particularly for girls, are likely to have important implications for health. Previous research has found strong gradients in BMI and obesity rates by socioeconomic status within the GUI child cohort at both ages 9 and 13, with the gradient becoming steeper for girls at age 13 (Madden, 2017). Moreover, among 13-year-olds that participated in no sports or exercise activities, common reasons cited for non-participation were, "I am no good at games" and "I feel people laugh at me because of my size" (ESRI, 2012).

Our analysis has a number of limitations. First, time diary data, though more accurate than stylized questions that estimate a respondent's time spent in activities, may suffer from measurement error, for example due to reporting bias. Second, the results may be affected by attrition and selection into who completes the TUD. The families in our analyses are a subset of those in the full sample and not all of those who completed the TUD data in wave 1 also completed the TUD in wave 2. Descriptive statistics do suggest some differences in the characteristics of those in the TUD data compared to the main survey; however, weights are provided to make the TUD families representative of the population as a whole. When we compared results in our analyses with and without weights we found conclusions were similar regardless of whether we adjusted for this selection. However, these weights can only account for observed characteristics; if families are selecting into the TUD data or dropping out of the survey in wave 2 on the basis of unobserved factors

which are also correlated with the relationships of interest (here, SES and time use), this could affect our estimates. Selection on unobserved variables is difficult to assess without an appropriate selection variable (which affects participation but not the outcome), which is not available in our data. Therefore, we cannot test this directly in this analysis and it is important to bear this limitation in mind. However, we do control for diary characteristics, and additional robustness checks including those participants who completed diaries on weekend days give very similar results (see Appendix Table A14). Future validation exercises for the survey testing attrition, in particular by family strata, would be beneficial. Third, we implement fixed effects models as a way of accounting for all time-invariant omitted variables such as family history and pre-natal conditions. However, there are also drawbacks to this approach in that we are not able to control for time-varying confounders, it is less efficient, and measurement error is a much greater concern in these models than random effects or pooled OLS, potentially leading to substantial attenuation bias (Kohler *et al.*, 2011). Additionally, pooled models include observations from participants present in any wave, while the FE models necessitate participants being present in both waves. Therefore, it is important to be cautious when interpreting results from these models, and to investigate causality in future research using alternative identification assumptions, for instance by using natural experiments which affect the activities available to children and their families (Castro, 2019).

An additional research and policy question that we did not pursue here is how school-level variation may affect educational and leisure opportunities, and therefore time use. Schools may differ, for example, in the amount, difficulty, or expectations relating to assigned homework. The Irish school system could be considered relatively homogenous compared to other countries in that 92 percent of children attend church-run primary schools (which are state supported and do not charge fees) and typically attend their local institution. Almost all secondary schools are state funded and nominally free to the public. Both primary and second level education in Ireland is overseen by a single body (the Department of Education and Skills); all institutions follow a common curriculum and participate in state-wide examinations. However, there is undoubtedly school-level variation in educational instruction, demonstrated, for example, by differences in school performance in the Junior and Leaving Certificate tests (the national state exams at the middle and end of secondary school). Although likely to be less of an issue at primary level, there is the potential for parental selection of schools at second level. Separating the influence of schools from the influence of family-level characteristics is an interesting question. However, because we are interested in documenting how gradients in time use by family background change over time in this paper, we do not wish to adjust for school characteristics as part of this analysis. Parental decisions taken about where to send children for secondary school are likely to partly represent outcomes of socioeconomic background characteristics and therefore adjusting for secondary school characteristics could potentially understate social gradients in the outcomes we examine. We therefore leave questions about the school-level influences on time use for future analysis.

Finally, more research on the consequences of these inequalities is needed to understand the impact of differences in time use on inequalities in future educational attainment and social and labor market outcomes. For example, unstructured playing time may be beneficial in that it may increase independence, resilience, and social

competence; however, little empirical work has examined this relationship. Future research should also further examine families' preferences and beliefs regarding which types of investments are optimal, the extent to which different types of investments are substitutes or complements (Leibowitz, 2003), how investments reinforce or reduce the effects of initial endowments (Almond and Mazumder, 2013), and the causal relationship between participation in certain activities and subsequent outcomes across the life course. Estimating the technology of skill formation is an active area of investigation (Cunha and Heckman, 2008). Such research would inform the extent to which policy interventions should target the time use differences we document and whether such policies could be used to improve children's life chances.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Table A1: Categorization of wave 1 and wave 2 activities

Table A2: Diary characteristics by wave, weighted

Table A3: Average time spent in activities (minutes) by socio-demographic group for girls

Table A4: Average time spent in activities (minutes) by socio-demographic group for boys

Table A5: Average substitution patterns (in minutes) from wave 1 activities to wave 2 activities

Table A6: Results for participation for girls (Full table)

Table A7: Results for participation for boys (Full table)

Table A8: Full table for girls' time

Table A9: Full table for boys' time

Table A10: Linear regression results for time spent in activities for girls (panel A) and boys (panel B) including both maternal education and income—with and without additional controls

Table A11: Linear regression results for time spent in activities for girls and boys including both maternal education and income—with all additional controls

Table A12: Full table for fixed effects models (girls)

Table A13: Full table for fixed effects models (boys)

Table A14: Results for time spent in activities for girls and boys using both weekday and weekend data

Figure A1: Construction of analysis data

Figure A2: Concentration curves for sports time for boys and girls at waves 1 and 2

Figure A3: Concentration curves for reading time for boys and girls at waves 1 and 2

Figure A4: Concentration curves for homework time for boys and girls at waves 1 and 2

Figure A5: Concentration curves for media time for boys and girls at waves 1 and 2

Figure A6: Concentration curves for playing time for boys and girls at waves 1 and 2

Figure A7: Concentration curves for hobbies time for boys and girls at waves 1 and 2

Figure A8: Concentration curves for family time for boys and girls at waves 1 and 2

Section A1: Theoretical Framework