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Beyond the cradle: effects of family income in the first 1,000 days on educational achievement later in life

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This study examines the impact of family income across various developmental stages of early and later childhood on educational achievement in fifth-grade among Israeli students born between 2000 and 2005. Utilizing administrative data, we analyze the effects of family income during distinct childhood segments, with a particular focus on the critical first 1,000 days of life. Our findings reveal that family income during this early period—from the beginning of pregnancy up to the child's second birthday—has a pronounced and lasting effect on educational outcomes, significantly surpassing the effects of family income in subsequent age segments. Notably, these early effects remain large and significant despite later changes in family income. This research highlights the importance of considering specific age segments within early childhood to achieve a comprehensive understanding of educational stratification dynamics. By delineating the critical role of early-life socioeconomic conditions, this research contributes valuable insights into the factors shaping long-term educational achievement.

Introduction

The socioeconomic circumstances of families during children's early childhood play a crucial role in shaping their physical, cognitive, emotional, and social development (Bailey *et al.*, 2001; Duncan, Morris and Rodrigues, 2011; Blossfeld *et al.*, 2017). Identifying the processes in early childhood that contribute to initial inequalities is essential, as these disparities often widen over the life course (Feinstein, 2003; Duncan *et al.*, 2007; Heckman, 2008; Skopek and Passaretta, 2021; Passaretta, Skopek and Van Huizen, 2022). Early advantages serve as pivotal resources that facilitate further relative gains for children and adults later in life (DiPrete and Eirich, 2006; Heckman, 2008). This study aims to estimate and compare the effects of family income during various stages of early and later childhood, including the pre-birth period, on the subsequent educational achievements of pupils.

We build upon the seminal work of Duncan and his colleagues, who have demonstrated in numerous influential studies that family income during early childhood significantly impacts subsequent life-course outcomes (e.g., Brooks-Gunn and Duncan, 1997; Duncan *et al.*, 1998). For instance, research indicates that a $1,000 increase in annual family income for children aged 2–5 years old corresponds to a 6 per cent of a standard deviation improvement in educational achievement (Duncan, Morris and Rodrigues, 2011). Another study reveals that a $3,000 annual income boost between a child's prenatal year and fifth birthday is associated with a 19 per cent increase in earnings and a 135-hr rise in work hours (Duncan *et al.*, 2010). Similar conclusions regarding educational achievement have also been drawn by Guo and Harris (2000) and Dahl and Lochner (2012). These findings, aligned with a life-course perspective, suggest that individuals or groups starting from a disadvantaged position in early childhood encounter challenges in catching up later in life (e.g., Feinstein, 2003; von Hippel and Hamrock, 2019; Skopek and Passaretta, 2021; Passaretta, Skopek and Van Huizen, 2022). According to this view, even minor advantages or disadvantages in early life can lead to relative gains or losses over time, exacerbating differences between individuals and socioeconomic classes throughout their lifespan (DiPrete and Eirich, 2006).

Studies advocating this perspective asserts that disparities in educational achievements begin to take shape as early as gestation and infancy, preceding the start of formal schooling such as daycare, kindergarten, or preschool (Farkas and Beron, 2004; von Hippel and Hamrock, 2019; Riser, Rouse and Dorius, 2022). For

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instance, Feinstein (2003) observed that differences in developmental and cognitive milestones between socioeconomic groups, evident at age two, expand between ages three and five, and further escalate between ages 5 and 10. These findings, and others of similar nature, suggest that disparities—be they in cognitive development, income, or health—that emerge in early childhood tend to widen over time because advantage tends to beget further advantage (DiPrete and Eirich, 2006).

The research literature identifies several mechanisms that mediate the relationship between family income during early childhood and children's educational development. The *Family Stress Model* (FSM; Conger and Elder, 1994) posits that economic hardship increases parental stress, which in turn negatively impacts children's development. For instance, stress during pregnancy, particularly in the first trimester, is linked to lower birth weight, potentially hindering later development (Torche, 2011; Bilgin, Mendonca and Wolke, 2018). Furthermore, chronic poverty and economic hardship throughout early and later childhood stages are known to affect parental psychological well-being, leading to increased distress influencing the quality of parent–child interactions. These disruptions can have profound effects on children's cognitive performance and overall development (Chase-Lansdale and Pittman, 2002; Masarik and Conger, 2017; McEwen and McEwen, 2017). Consequently, high levels of parental stress may contribute to lower scholastic achievement, poorer emotional regulation, and behavioral problems in children.

The Family Income Model (FIM) provides another perspective on the relationship between family socioeconomic status (SES) and children's educational achievement, highlighting how parents' allocation of resources and time mediates this impact (Mayer, 1997). Higher-income families can afford high-quality early childhood education and care (ECEC), prestigious schools, and remedial educational services that establish a strong foundation for cognitive and social skills crucial for academic success (Early and Burchinal, 2001; Lareau, 2011; Raudenbush and Eschmann, 2015; Blossfeld *et al.*, 2017; Kulic *et al.*, 2019). In contrast, low-income families face significant challenges in affording essential early childhood expenses, including healthcare, housing, nutrition, and childcare. High healthcare costs, especially for prenatal care and pediatric check-ups, can be substantial without insurance coverage. Similarly, housing costs, especially when relocating to larger homes to accommodate a growing family, present a financial burden. Nutrition costs, such as specialized infant formulas and nutritious foods to support healthy development, also represent major expenses that wealthier families can more easily afford (Navon and Bowers, 2023). Finally, childcare expenses are another major financial burden, as many families opt for private daycare or kindergartens to ensure high-quality early education (Blossfeld *et al.*, 2017). Low-income Families spend nearly four times less on private preschool compared with wealthier families, often due to limited access to high-quality childcare options (Navon and Bowers, 2023). These disparities underscore the critical necessity of a stable family income to effectively support the optimal development of preschool-aged children.

The FIM also highlights the role of parental education and SES in shaping parental behavior and the cognitive environment provided to children. Highly educated mothers, for instance, dedicate more time to actively caring for their infants compared with less educated mothers and tailor this time to meet their developmental needs (Guryan, Hurst and Kearney, 2008; Kalil, Ryan and Corey, 2012). Additionally, SES significantly influences the cognitive environment provided by parents, as lower-income parents often lack the time and resources for cognitive stimulation activities like access to books, educational toys, or extracurricular activities that support learning and development outside the classroom (Hart and Risley, 1995; Hoff, 2003; Fernald, Marchman and Weisleder, 2013; Rosen *et al.*, 2020). These stimuli, including exposure to home and shared reading, play a pivotal role in shaping early brain development (Hutton *et al.*, 2015; Barone *et al.*, 2019).

Neuroscientific research indicates that young children from economically disadvantaged families often exhibit reduced cerebral cortex areas in regions linked to cognitive function, language, and reading (Noble *et al.*, 2015; Johnson, Riis and Noble, 2016). Similar differences in brain volume are also observed in the hippocampus and the amygdala, likely due to variations in home linguistic environments and stress exposure (Noble *et al.*, 2012). For instance, higher maternal stress correlates with altered brain activity in one-year-olds born into poverty (Troller-Renfree *et al.*, 2023). A recent randomized trial showed that substantial cash gifts to low-income families positively affected infants' brain activity, especially in areas tied to cognition and language, whereas smaller gifts had no comparable effects (Troller-Renfree *et al.*, 2022). These findings highlight the significant impact of SES on early brain development.

As we explore the complex interplay between family income and educational attainment, it's essential to recognize this relationship's multifaceted nature. While studies highlight the significance of early childhood income on later educational outcomes, our understanding remains incomplete. Mayer (1997) suggests that factors beyond income—such as parental education,

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family structure, access to quality education and healthcare, neighborhood environment, and social support networks—play pivotal roles in shaping children's well-being and opportunities. Therefore, the direct effects of family income on children's life chances may be overstated, as they are largely mediated by various factors. Heckman's research (2008, 2011) on skill formation further underscores that the effect of socioeconomic factors on child development extends beyond income, highlighting the intricate interplay between cognitive and non-cognitive skills, parental investments, and environmental influences, all contributing to long-term educational outcomes.

As such, children from affluent families typically receive more positive stimulation both at home and in educational settings, whereas those from impoverished backgrounds often encounter inhibiting effects from stressful experiences (Raudenbush and Eschmann, 2015; Kulic *et al.*, 2019; Barone, Fougère and Pin, 2021). Guo and Harris (2000) demonstrated various mechanisms mediating the negative impact of poverty on children's intellectual development, revealing that parenting style, cognitive stimulation, and the physical home environment fully mediate this relationship. This literature supports the causal effects of early childhood family income on long-term outcomes and emphasizes the need to explore the specific mechanisms through which income and its timing influence educational achievement.

Some research distinguishes between the effects of family income during different segments of early childhood on later outcomes (Brooks-Gunn and Duncan, 1997; Guo, 1998). However, to the best of our knowledge, few studies have directly compared the relative effects of family income during the first 1,000 days of life to its effects in later childhood on subsequent educational attainment. Notably, the first 1,000 days of a child's life—from pregnancy up to the child's second birthday—are regarded as the most critical period in child development. Studies emphasizing the significance of this period often focus on the role of nutrition, as well as the impact of poverty and deprivation on brain development, neurodevelopment, and lifelong mental health (Cusick and Georgieff, 2016; Johnson, Riis and Noble, 2016; Martorell, 2017; Schwarzenberg *et al.*, 2018; Araujo and Macours, 2021; Troller-Renfree *et al.*, 2022). A supportive environment providing enriching experiences and stimuli during this early period has profound effects on later outcomes (Bailey *et al.*, 2001; Blossfeld *et al.*, 2017). Our study aims to fill this gap by examining the longitudinal impact of family income during the first 1,000 days on educational outcomes in later childhood.

A study by Shay, Shavit, and Sasson (2024) analyzed data from the Israeli population censuses of 1995 and 2008 to assess the impact of family income during two critical developmental stages—birth to age two and ages 3 to 5—on the educational achievements of Israeli pupils born between 1990 and 1995. The findings indicated that poverty during the earlier stage had a stronger association with educational outcomes than poverty at the later stage. However, the study faced several important limitations. First, income was measured at only two cross-sectional points—early childhood and adolescence—preventing analysis of income trajectories, volatility, or cumulative exposure to poverty. Second, income during adolescence was recorded at varying ages (13–18), often after the outcome of interest (fifth-grade test scores), raising concerns about temporal misalignment and threats to causal inference. Third, the study did not include income data from the prenatal period—a developmental phase increasingly recognized as critical for cognitive growth within the first 1,000 days. Finally, due to data constraints, Israeli-Arab children were excluded from the analysis, limiting the generalizability of the findings across Israel's major sociocultural groups.

Similar limitations are prevalent in other studies. For instance, Johnson *et al.* (2022) found a positive association between parental income, education, and occupation during gestation and the cognitive performance of 7-year-old children born in the US between 1959 and 1965, controlling for socioeconomic background at age 7. However, like Shay, Shavit and Sasson (2024), this study only assesses SES at two points in childhood, potentially overlooking changes in SES over time. Other studies, such as that by Riser, Rouse and Dorius (2022), examines the effects of SES during the first 1,000 days on early cognitive outcomes but fails to evaluate its long-term impact on educational attainment. This limited scope may restrict comprehensive conclusions regarding the lasting effects of family income on educational achievement.

Our study addresses these limitations in several ways: First, we utilize longitudinal data with annual income measurements up to age 11, eliminating the temporal gap in previous studies and enabling precise analysis of how economic conditions during the first 1,000 days influence later educational outcomes. Second, we trace families' economic mobility profiles over time to assess whether changes in income later alter the impact of family income during this critical early period, testing if upward social mobility can mitigate the effects of early economic deprivation. Third, our data includes measures of family income during pregnancy, providing a more comprehensive view of early economic influences on cognitive development. Finally, unlike prior research, our study includes both Hebrew- and Arabic-speaking students in Israel, ensuring a representative analysis that accounts for ethnic and linguistic

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diversity and a broader range of socio-cultural and economic factors affecting educational outcomes.

Our study aims to contribute to the literatures on educational stratification and early childhood by examining the effects of family income at different age segments, from the year before birth to age 11 on fifth-grade pupils' educational achievements. We test the hypothesis that family income during the first 1,000 days has a stronger effect than income at later ages. Additionally, we investigate whether income during later ages can mitigate or exacerbate the effects observed during the first 1,000 days. This inquiry is crucial as it explores the reversibility of advantages associated with affluence and disadvantages linked to poverty in early childhood. By addressing these questions, our research examines how early economic conditions contribute to inequalities that emerge in the earliest years of life and influence educational trajectories.

Data

The study utilizes a comprehensive database from the Israeli Central Bureau of Statistics (ICBS), which includes population data from various administrative sources. At its core is the Population Registry, containing detailed information about the focal subjects, their parents, and siblings, such as birth dates, country of birth, gender, and ethnicity. This information is crucial for constructing family profiles, including family size and parents' educational attainment. Records were integrated with fifth-grade standardized test scores in mathematics, science, Hebrew, and English from the National Authority for Measurement and Evaluation in Education (RAMA). Approximately one-third to one-half of each birth cohort took these assessments, which are representative of the entire cohort (Blank and Shavit, 2016). Data from the Ministry of Health was added to include the child's birth weight, and parents' tax records from 1999 to 2016 provided insights into their annual income from work, covering the year before birth to age 11. The study focuses on individuals born in Israel between 2000 and 2002, and those born in 2004 and 2005, who participated in fifth-grade exams. The 2003 birth cohort is excluded due to discrepancies in the format of standardized tests during their fifth-grade year in 2013/2014 (RAMA, 2014), which affected result comparability.

Variables

Table 1 presents the means and standard deviations of both the dependent and independent variables used in the analysis. The data is segmented by quintiles of family income during the first 1,000 days of life.

The study's dependent variables include fifth-grade Meitzav test scores in mathematics, science, English (as a second language), and Hebrew (for students in Hebrew schools). These exams, known as Meitzav, were administered to a representative national sample of about 25 per cent of schools. While Arabic reading tests were conducted, they were excluded from our analysis due to concerns about their integrity (RAMA, 2012). The mathematics, science, and English tests were uniformly translated into Hebrew and Arabic for valid comparisons between Jewish and Arab students (RAMA, 2018). Raw scores ranged from 0 to 100 and were standardized annually to a mean of 0 and a standard deviation of 1 for valid year-to-year comparisons. Most children born between 2000 and 2005 participated in Meitzav testing between 2010 and 2016, with 90 per cent tested at age 11. To maintain sample consistency, we excluded the 10 per cent tested at age 12, as they were either held back from preschool to first grade or repeated a grade. Additionally, data for 10 per cent of students born in 2002, who would have been tested late, were unavailable because Meitzav was not administered in 2014.

We examine the influence of family income on child development through two distinct measures: cumulative income and age-specific income. Cumulative income encompasses the total income a family receives from pregnancy until fifth-grade, reflecting the overall financial resources available to the family during this period. Cumulative income can have lasting effects on child development by influencing the family's ability to provide essential resources, such as housing quality, neighborhood safety and amenities, and access to quality educational services (*e.g.*, Ayalon *et al.*, 2019). Previous research by Duncan *et al.* (1998) and Guo (1998) has also employed cumulative income measures in early childhood to investigate their effects on developmental outcomes. Families' cumulative income from work was measured from the commencement of pregnancy (i.e., in the year preceding the subject's birth) up to age 11, when most students typically attend fifth-grade. To ensure methodological consistency, annual income from work of all working parents in the household was adjusted to 2020 prices using the consumer price index for each year. This adjustment accounts for inflation and allows for a more accurate comparison of income across different years. Additionally, income data were standardized according to the square root of household size for each year, ensuring that the income data reflect the resources available per person within the household.[1]

While our dataset lacks direct measurements of additional economic factors like house tenure, wealth, or specific indicators of neighborhood and school quality, we used cumulative income as a reliable proxy for the

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Table 1 Means (and standard deviations) of variables by quintiles of family income in the first 1,000 days of life

	Quintiles of family income in first 1,000 days			Total	*N*
	First quintile	Middle quintiles	Fifth quintile		
Mathematics test-score	−.39	−.05	.48	.01	98,945
	(1.05)	(1.10)	(.81)	(.99)	
Science test-score	−.36	−.05	.43	.01	53,043
	(1.05)	(1.05)	(.86)	(.99)	
English test-score	−.29	−.10	.40	.00	98,623
	(1.01)	(1.07)	(.88)	(.99)	
Hebrew test-score	−.27	.09	.32	.05	67,134
	(1.12)	(1.03)	(.82)	(.97)	
Mother's education	.12	.34	.72	.38	153,201
	(.33)	(.47)	(.45)	(.49)	
Father's education	.10	.24	.65	.30	152,556
	(.30)	(.43)	(.48)	(.46)	
Number of siblings	4.74	2.82	2.14	3.07	160,279
	(3.94)	(1.91)	(0.99)	(2.51)	
Gender (1 = girls)	.54	.52	.51	.52	160,789
	(.50)	(.50)	(.50)	(.50)	
Ethnicity (1 = Arabs)	.69	.33	.04	.34	156,514
	(.46)	(.47)	(.19)	(.47)	
Low birth weight (1 = 2.5 kg. or below)	.07	.08	.08	.08	159,973
	(.26)	(.27)	(.27)	(.27)	
Cumulative family income (in 000s of Shekels)	243.26	976.06	2,792.20	1,211.48	157,674
	(308.44)	(549.29)	(1,588.60)	(1,197.08)	

family's capacity to provide stable resources impacting child development. Cumulative income captures the long-term financial stability of a household, which is crucial for understanding the sustained access to resources necessary for positive developmental outcomes.

Given our focus on the year-by-year influence of family income on educational achievement, complete income data throughout childhood were essential for accurate analysis. This study utilizes administrative data covering the entire population rather than a sample, allowing us to use listwise deletion for missing data without significant concerns about reducing sample size. Listwise deletion ensures analyses are based on cases with complete income information for each year considered. While this method can reduce sample size in survey research, our use of complete population data avoids potential biases from imputation techniques when estimating income effects during critical developmental stages. The percentage of missing data for each income variable ranged from 2 per cent to 5 per cent, with an overall missing rate of 4 per cent. The implementation of listwise deletion resulted in sample sizes between 40,000 and 90,000 cases, varying by the subject of the exams.

It is important to note that our measure of family income does not account for benefits and transfers due to data constraints, which likely represent a significant share of income for low-income families. While excluding these factors simplifies the analysis and highlights direct effects, it may underestimate the true economic position of these families and the extent of economic inequality. Future research could explore methodologies to incorporate benefits and transfers for a more comprehensive understanding of families' economic circumstances and their impact on children's outcomes (e.g., Adi-Japha and Shavit 2025). Despite this shortcoming, our rich longitudinal data still provide valuable insights into how economic circumstances in the first 1,000 days affect later educational achievements.

In addition to the cumulative measure of family income, relative family income within specific age intervals was also measured. The influence of age-specific income may vary depending on the child's developmental stage. Research suggests that the brain's adaptability fluctuates at specific ages, potentially influencing how income affects development (Johnson, Riis and Noble, 2016). For example, studies have shown that the adverse effects of poverty on cognitive development tend to be more pronounced in very early childhood compared with later age segments (e.g., Brooks-Gunn and Duncan, 1997; Duncan *et al.*, 2012). Therefore, our models encompass both cumulative and age-specific

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Table 2 Pearson correlations of family income in each two-year age segment, means, and standard deviations

	First 1,000 days	Ages 2–3	Ages 4–5	Ages 6–7	Ages 8–9	Ages 10–11
First 1,000 days	—	.72	.51	.59	.54	.54
Ages 2–3		—	.64	.78	.71	.70
Ages 4–5			—	.60	.71	.58
Ages 6–7				—	.84	.80
Ages 8–9					—	.87
Mean (in 000s of Shekels)	265.85 (326.44)	182.35 (184.56)	190.03 (282.40)	201.87 (201.62)	207.68 (210.39)	220.58 (212.79)

Note: All correlations are significant at the 0.01 level (2-tailed).

income measures to provide a comprehensive examination of their impact on educational outcomes. These intervals include pre-birth to age 1, ages 2–3, 4–5, 6–7, 8–9, and 10–11. The first interval spans the first 1,000 days of life, encompassing the 9 months of pregnancy and the subsequent two years. Subsequent intervals commence on the month of birth in the corresponding year and conclude in the month preceding the birthday, 2 years later. For each interval, the family's economic income was cumulated, standardized to 2020 prices, and adjusted for family size at the midpoint of the interval, and finally recoded into income quintiles. These recoded income quintiles create two dummy variables within each age interval, representing the lower and upper quintiles compared with the middle three quintiles. This approach allows us to compare the effects of income across different age categories and test the hypothesis that the impact of family's relative income during the first 1,000 days of life on educational achievements is more substantial than the effects in other age segments.

Table 2 displays the Pearson correlations of income in each 2-year age segment (First 1,000 days, Age 2-3, Age 4–5, etc.), along with their means and standard deviations. Notably, the income measures exhibit high collinearity and may demonstrate excessive multicollinearity when simultaneously included in regression equations. Therefore, we assessed the degree of multicollinearity using the Variance Inflation Factor (VIF) for all independent variables in the regressions. VIF is a statistical measure that indicates how much the variance of an estimated coefficient is inflated due to collinearity with other independent variables. The findings revealed that all VIF values were lower than 2.5, indicating acceptable levels of multicollinearity (Hair *et al.*, 1995).

In addition to the family income indicators, we control for socio-demographic variables. Mother's and father's education are represented as dummy variables, with 1 indicating higher education (Bachelor's, Master's, or PhD) and 0 for lower levels. Lower education includes individuals with no formal diploma, those who completed elementary or junior high school, or those with a high school diploma without a matriculation certificate or a certificate from a vocational school. To enhance clarity and simplify interpretation, we opted for a binary representation of parents' education, despite its ordinal scale measurement. Initial analyses using parental education as a continuous variable yielded similar results to the binary classification (see Table 1 in the Supplementary Materials).

The distinction between Arabs and Jews is represented as a dummy variable, with 1 for Arab pupils and 0 for Jewish pupils. In Israel, this distinction encompasses both ethnic and cultural identities, not just religious affiliation. Arabs in Israel are a diverse group, including Muslims, Christians, and others, while Jews primarily belong to the Jewish ethnicity and often adhere to Judaism. Arabs constitute a disadvantaged minority, and residential segregation between the two groups is prevalent, with approximately 79 per cent of the population being Jewish and the remainder Arab (ICBS, 2023). Most Arabs live in Arab-majority towns or separate neighborhoods within Jewish cities, leading to distinct schools for Arab and Jewish children (Khamaisi, 2013). Controlling for ethnicity is crucial to account for the socio-cultural context affecting children's access to resources, educational opportunities, and social support systems, which may influence their developmental outcomes.

The number of siblings is calculated as the total number of siblings of the focal subject when they attended fifth-grade. Gender is coded as a dummy variable, with 1 representing girls and 0 representing boys.

Finally, birth weight is included as a control variable due to its strong association with prenatal and perinatal factors like maternal health, prenatal care, and gestational age, which significantly influence developmental outcomes. Moreover, birth weight serves as a crucial indicator of an infant's initial health status. By controlling

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for birth weight, we mitigate bias from these confounding factors, ensuring that the relationships between household income in early childhood and later outcomes are not distorted by differences in birth weight. An analysis excluding birth weight yielded similar results, as detailed in Table 2 of the Supplementary Materials. We measure birth weight as a dummy variable, with 1 indicating weights of 2.5 kg or less and 0 for higher weights. This classification, widely accepted in the literature on the relationship between birth weight and later life outcomes (e.g., Bilgin *et al.*, 2018), allows us to focus on low birth weight's impact, which is associated with various adverse developmental outcomes.

Table 1 show that students in the bottom quintile of family income during the first 1,000 days scored lower in mathematics, science, English, and Hebrew than those in the top quintile. Additionally, parents' education levels and cumulative family income are lower in the bottom quintile, which has a higher proportion of Arabs than Jews, reflecting the documented poverty disparity between these groups in Israel (Endeweld *et al.*, 2023). Families in the bottom quintile also tend to have more children, indicating the trend of larger family sizes in low-income households (Weinreb, Chernichovsky and Brill, 2018).

Analysis

Family income dynamics across childhood segments

Table 3 displays OLS regression estimates for fifth-grade test scores in mathematics, science, English, and Hebrew. Alongside the control variables, the models incorporate cumulative family income and dummies representing income quintiles for each age segment—the first 1,000 days, ages 2–3, 4–5, 6–7, 8–9, and 10–11. As anticipated, parents' education exerts a considerable positive impact on their children's educational achievements. Additionally, there is a negative association between sibship size and children's educational achievements, as well as a significant negative effect of low birth weight. Notably, Arabs performed worse than Jews in Mathematics and English, while girls exhibited lower achievement levels in Mathematics but higher levels in both language tests of English and Hebrew, consistent with prior research findings (RAMA, 2018).

Our discussion centres on the patterns of predicted fifth-grade test scores by family income quintiles across different age segments, as illustrated in Figures 1–4. These values represent average marginal effects based on the regression models in Table 3, estimated using Stata's *margins* command. The Figures illustrate the predicted marginal effects of being in the upper- or lower-income quintile at different ages on fifth-grade test scores, indicating the average score differences while all other variables are held at their observed values. These estimates reflect the expected differences in the real population, without making strong assumptions about the covariance structure between predictors. The highlighted columns denote statistically significant differences between students from lower or upper-income quintiles and those from middle-income families (quintiles 2–4). Overall, the Figures demonstrate how family income influences educational achievement across age segments, highlighting when income-related disparities are most pronounced.

The differences in test scores between children in the lower- and upper-income quintiles during the first 1,000 days consistently appear larger than those in other ages. This indicates a lasting impact of family income during this early period on fifth-grade educational achievements, even after controlling for later family income and other variables. For example, students from the lowest income quintile during the first 1,000 days score about 4 per cent of a standard deviation lower in mathematics ($b = -.04$, $P \leq 0.001$), while those from the highest quintile score approximately 11 per cent of a standard deviation higher than middle-income peers ($b = .11$, $P \leq 0.001$). The 0.11 SD advantage for children in the top income quintile, for example, corresponds to approximately 2.5 points on the raw math score (out of 100), suggesting that high income during the first 1,000 days contributes to children's educational outcomes at fifth-grade. While the standardized coefficients may appear modest, they are statistically significant and substantively meaningful, especially given that the models adjust for a comprehensive set of covariates. Similar significant results were observed in science, English, and Hebrew. Conversely, coefficients for other age segments are generally smaller and often insignificant. These findings underscore the crucial role of the early childhood period, especially the first 1,000 days, in influencing long-term educational outcomes.[2]

Our study's effect sizes align closely with previous research linking early SES to long-term educational outcomes. For instance, Duncan, Morris and Rodrigues (2011) found that a $1,000 increase in annual income between ages 2 and 5 boosts child achievement by 6 per cent of a standard deviation. Similarly, Dahl and Lochner (2012) reported that a $1,000 increase in family income leads to a 6 per cent of a standard deviation rise in math and reading scores for children aged 8 and 14. However, our study uniquely focuses on income during the first 1,000 days, including the prenatal period. Notably, our identified effect size is slightly larger than in earlier studies, indicating a potentially stronger

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Table 3 OLS regression coefficients (and SEs) of fifth-grade test score in mathematics, science, English and Hebrew

		Mathematics	Science	English	Hebrew
Mother's education		.27** (.01)	.29** (.01)	.20** (.01)	.28** (.01)
Father's education		.24** (.01)	.21** (.01)	.21** (.01)	.21** (.01)
Number of siblings		−.03** (.00)	−.07** (.00)	−.08** (.00)	−.03** (.00)
Gender (1 = girls)		−.11** (.01)	−.02 (.01)	.07** (.01)	.27** (.01)
Ethnicity (1 = Arabs)		−.16** (.01)	.02 (.01)	.23** (.01)	(omitted)
Low birth weight		−.06** (.01)	−.05** (.02)	−.06** (.01)	−.03* (.01)
Cumulative family income[a]		.03** (.00)	.04** (.00)	.09** (.00)	.01** (.00)
The first 1,000 days	1st quintile	−.04** (.01)	−.04* (.02)	−.05** (.01)	−.05** (.02)
	5th quintile	.11** (.01)	.06** (.02)	.09** (.01)	.10** (.01)
Ages 2–3	1st quintile	−.01 (.01)	−.03* (.02)	−.02 (.01)	.00 (.02)
	5th quintile	−.00 (.01)	.03 (.02)	.02 (.01)	.00 (.01)
Ages 4–5	1st quintile	−.02 (.01)	.01 (.02)	.05 (.01)	.01 (.02)
	5th quintile	.03* (.01)	.01 (.02)	.02 (.01)	.03* (.01)
Ages 6–7	1st quintile	−.00 (.01)	−.04* (.02)	.01 (.01)	−.03 (.02)
	5th quintile	−.00 (.01)	−.02 (.02)	−.01 (.02)	.03 (.02)
Ages 8–9	1st quintile	−.03* (.01)	−.01 (.02)	.01 (.02)	−.08** (.02)
	5th quintile	.03 (.02)	.01 (.02)	.01 (.02)	.01 (.02)
Ages 10–11	1st quintile	−.05** (.01)	−.05** (.02)	−.06** (.01	−.04* (.02)
	5th quintile	.03* (.01)	.05* (.02)	.00* (.01)	−.01 (.01)
Constant		.03** (.01)	.01 (.01)	−.16** (.01)	−.28** (.01)
N		87,451	46,945	87,707	61,758
R Square		.14	.12	.11	.10

Significance levels: $*P \leq .05$ $**P \leq .001$.
[a]From pregnancy to fifth-grade Meitzav exams (in millions).

influence of early-life income on educational achievement. This highlights the critical role of the prenatal and early infancy periods in shaping child development.

Interestingly, the estimated positive effect of being in the top income quintile during the first 1,000 days is somewhat larger than the negative effect of being in the bottom quintile during the same period. This asymmetry suggests that early economic advantage may confer developmental benefits that go beyond the mere absence of deprivation. One possible explanation lies in the cumulative nature of early investments: higher-income families often have greater access to high-quality nutrition and healthcare, cognitively stimulating home environments, well-resourced early childhood education settings, and reduced exposure to chronic stress (e.g., Lareau, 2011; Blossfeld *et al.*, 2017). These advantages may compound over time, setting in motion a Matthew effect, whereby early developmental gains facilitate further skill acquisition and academic success (DiPrete and Eirich, 2006). In contrast, while early-life poverty clearly poses risks, some of its negative consequences may be partially buffered through universal provisions such as public healthcare and subsidized early education, as well as targeted programs designed to support low-income families. Taken together, these findings suggest that the developmental returns to early advantage may be especially powerful, underscoring the need to consider both ends of the income distribution when addressing long-term educational inequality.

The coefficient for cumulative income reflects the long-term association between household resources and children's educational achievement. Using observed values in our sample—where average cumulative income ranged from 243,000 NIS in the lowest group to 2.79 million NIS in the highest (see Table 1)—we estimate that the expected difference in standardized performance between these groups is approximately 0.08 in mathematics, 0.10 in science, 0.23 in English, and 0.03 in Hebrew. These can be compared with results from the model using income quintiles during the first 1,000 days (Table 3), which show corresponding differences of 0.15 in mathematics, 0.10 in science, 0.14 in English, and 0.15 in Hebrew. While both specifications underscore the importance of early-life income, the findings suggest that in mathematics and Hebrew, income differences specifically during the first 1,000 days are more predictive of later outcomes than cumulative income over time—highlighting the particular developmental sensitivity of this early window.

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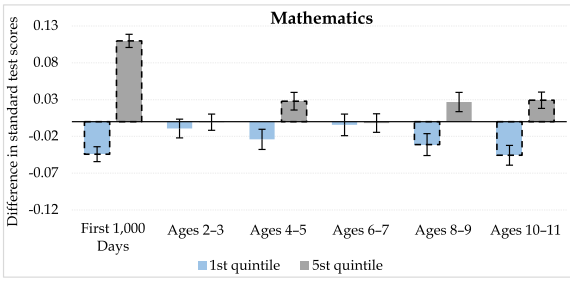


Figure 1 Predicted fifth-grade mathematics test scores by family income quintiles and age

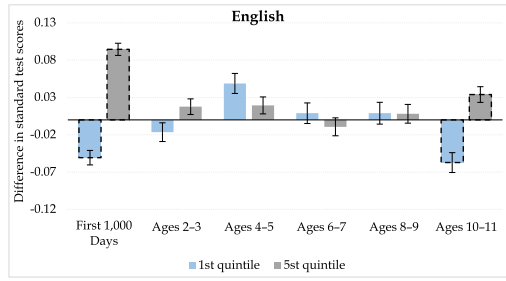


Figure 3 Predicted fifth-grade English test scores by family income quintiles and age

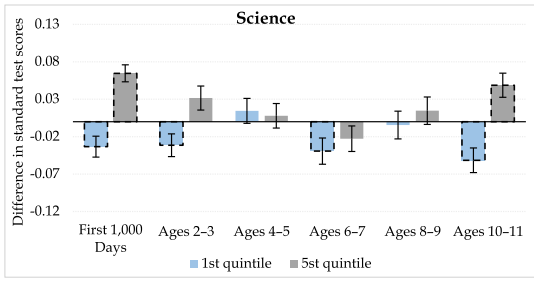


Figure 2 Predicted fifth-grade science test scores by family income quintiles and age

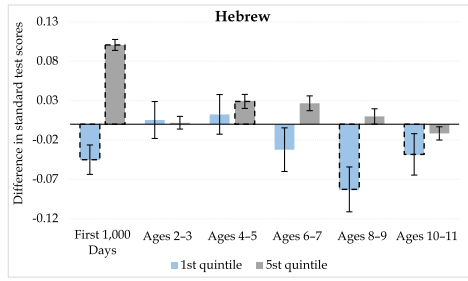


Figure 4 Predicted fifth-grade Hebrew test scores by family income quintiles and age

However, including multiple income measures at different ages may introduce over-control and endogenous selection biases (Elwert and Winship, 2014). Over-control bias arises when a controlled variable lies on the causal path between the treatment and outcome, while endogenous selection bias occurs when controlling for variables in a causal chain that relate to both the treatment and the outcome or their correlates. For instance, income at ages 2–3 or 4–5 might allow families access to high-quality childcare or educational resources that positively influence cognitive development. In such cases, controlling for income in later segments may inadvertently 'control away' the initial effect of early income, potentially underestimating its true impact on later educational outcomes. We acknowledge that the model presented in Table 3, which includes income measures across all childhood segments, may therefore be subject to such bias. To address this concern, we conducted a robustness check focused solely on income during the first 1,000 days (Table 3 in the Supplementary Materials). This analysis shows that the coefficients for the first- and fifth-income quintiles remain statistically significant and of similar magnitude to those in the full model, supporting the robustness of our findings regarding the effect of family income during the first 1,000 days on educational outcomes.

Our analysis also found a significant association between household income at the time of testing (ages 10–11) and fifth-grade test scores. While early-life income remains our primary focus, current income also plays a meaningful role in shaping educational outcomes. As shown in Table 3, the negative effect of low income during the first 1,000 days is remarkably similar in magnitude to that of low income at ages 10–11. In contrast, the positive association between high income and achievement is considerably stronger during the earliest stage of life and diminishes at later ages. This asymmetry suggests that escaping poverty is beneficial at any stage, but the developmental advantages of high income may be most pronounced in the first years of life. Nevertheless, household income at the time of testing likely continues to influence academic performance by shaping children's everyday learning environments. Children in higher-income families are more likely to benefit from access to high-quality schools, private tutoring, enriched learning resources, tailored parenting strategies, and structured preparation for standardized assessments (Lareau, 2011; Blossfeld *et al.*, 2017; Ayalon *et al.*, 2019). Moreover, current household income may directly support children's readiness and focus through more stable, less stressful home environments that are conducive to

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Table 4 Description of income mobility categories across childhood age segments

AAA	Family income surpasses the median across all age segments.
BBB	Family income is below the median throughout all age segments.
BAA	Family income is below the median in the first segment but exceeds it in the subsequent two segments.
BBA	Family income is below the median in the first two segments but surpasses it in the third segment.
BAB	Family income is below the median in the first and last segments, while exceeding it in the middle segment.
AAB	Family income is below the median in the third segment but surpasses it in the first two segments.
ABB	Family income is below the median in the second and third segments but exceeds it in the first segment.
ABA	Family income is below the median in the second segment but surpasses it in the first and third segments.

learning (*e.g.*, Buchmann, Condron, and Roscigno, 2010). Taken together, these findings reinforce the lasting significance of early-life income while also highlighting the importance of sustained socioeconomic investment throughout childhood.

Family income mobility across childhood

The findings in Table 3 and Figures 1–4 underscore the significant impact of early family income on a child's educational development. However, an essential inquiry arises regarding the extent to which these effects are moderated or exacerbated by subsequent changes in family income throughout childhood (e.g., Dahl and Lochner, 2012). Specifically, we inquire whether the influence of family income during the first 1,000 days is mitigated by income mobility in later ages. Addressing this question holds substantial policy implications. A positive finding would indicate that upward income mobility later in childhood can potentially mitigate the adverse effects of early-life poverty or deprivation. Conversely, a negative finding would suggest that the consequences of early deprivation persist despite subsequent improvements in income. This underscores the importance of longitudinal studies that track changes in family income and educational outcomes over the life course, providing valuable evidence for policymakers and practitioners striving to create more equitable opportunities for children.

To explore this research question, we refined our analysis by shifting from using income quintiles across different age segments to focusing on families' income mobility patterns throughout childhood. This analysis segmented childhood into three distinct age periods: the critical first 1,000 days (pre-birth to the child's second birthday), ages 2–5 (late early childhood), and ages 6–11 (school years up to the fifth-grade). For each age segment, cumulative family income from work was standardized as in the prior analysis, and categorized into two groups based on whether it exceeded or fell below the median. These categories were labeled *A* (above median) and *B* (below median), respectively. Subsequently, we constructed eight dummy variables representing various income mobility profiles across the three age segments, as delineated at Table 4.

The decision to use the median as the threshold for defining income mobility profiles was guided by both conceptual and empirical considerations. As shown in Table 3, we find that both low and high income during the first 1,000 days is significantly associated with later educational outcomes, underscoring the importance of examining not only poverty but also relative economic advantage. A median-based threshold enables us to capture both upward and downward mobility across childhood, offering a more symmetrical and comprehensive view of income dynamics over time. Methodologically, the median provides a robust and stable reference point that reflects typical economic circumstances, reducing the influence of extreme values and ensuring sufficient sample sizes across income trajectory groups. While this operationalization may not fully capture the effects of deep poverty or high affluence, it allows for a balanced assessment of how shifts in family income status—whether above or below the median—relate to children's academic development.

Table 5 presents the percentage distribution of income mobility profiles, along with means and standard deviations of the dependent and main independent variables. Notably, the economic status established in early childhood tends to persist throughout subsequent developmental periods, with the AAA and BBB profiles being most common (42 per cent and 37 per cent, respectively). This indicates that children from wealthier families typically remain economically advantaged, while those from poorer families continue to face hardships. As expected, the AAA profile shows the highest mean achievement levels, and BBB the lowest, aligning with research showing that prolonged childhood poverty hinders educational attainment (Brooks-Gunn and Duncan, 1997; Lee, 2014). However, 22 per cent of cases in the sample show economic mobility throughout childhood, raising the question of whether the impact of income during the first 1,000 days is contingent upon changes in income levels later in childhood. For example, an increase in income during later stages may help offset the negative effects of early poverty, or the advantages of early wealth may persist despite subsequent income fluctuations. This inquiry has significant implications for understanding how

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Table 5 Means, standard deviations, and distribution (per cent) of fifth-grade test scores, parental education, and cumulative income according to income mobility profiles

Income mobility profiles	Per cent	Mathematics	Science	Hebrew	English	Mother's education	Father's education	Cumulative family income (in 000s of Shekels)
AAA	42 per cent	.35 (.86)	.32 (.88)	.21 (.86)	.26 (.92)	.63 (.48)	.53 (.50)	2,263.39 (1,321.81)
BBB	37 per cent	−.25 (1.01)	−.23 (1.01)	−.25 (1.07)	−.22 (.98)	.16 (.37)	.10 (.30)	466.35 (206.18)
ABB	5 per cent	−.01 (.95)	.03 (.93)	−.04 (.96)	−.06 (.95)	.29 (.46)	.23 (.42)	798.20 (174.42)
BAA	4 per cent	.17 (.91)	.20 (.94)	.04 (.95)	.08 (.95)	.54 (.50)	.41 (.49)	1,320.82 (389.23)
AAB	4 per cent	.07 (.91)	.07 (.91)	.01 (.94)	.01 (.98)	.35 (.48)	.26 (.44)	1,116.65 (738.07)
BBA	4 per cent	.09 (.94)	.11 (.94)	.02 (.97)	−.01 (.99)	.48 (.50)	.35 (.48)	974.15 (206.10)
ABA	2 per cent	.17 (.89)	.15 (.92)	.11 (.89)	.08 (.96)	.48 (.50)	.39 (.49)	1,212.81 (333.58)
BAB	2 per cent	−.05 (.95)	.01 (.96)	−.15 (1.04)	−.04 (.99)	.33 (.47)	.21 (.41)	878.52 (121.52)

Note: A = above the median, B = below the median.

childhood economic conditions influence long-term educational outcomes.

Table 6 presents OLS regression estimates for fifth-grade test scores in mathematics, science, English and Hebrew by income mobility profiles, with the AAA profile as the reference category. The results indicate significant effects of income mobility on educational outcomes, particularly for the BAA profile. For instance, individuals in the BAA profile, who experienced low income during the critical first 1,000 days but higher income later, show a 9 per cent decrease in Hebrew test scores ($b = -0.09$, $P \leq 0.001$) compared with those from families with consistent higher income (AAA profile). Similar patterns emerge in mathematics and English, with decreases of 7 per cent and 9 per cent, respectively. These findings suggest that poor income conditions during the first 1,000 days negatively affect educational achievement, even if family income improves later.

Table 5 reveals that the BAA profile characterized by high parental education and cumulative family income, ranking second only to AAA in both areas, suggesting upward mobility experienced by these families after their children's early years. However, despite this economic improvement, children in the BAA profile still face significant setbacks in educational achievement. This disparity likely stems from the formative influence of the critical first 1,000 days of life, during which they were raised in households with relatively limited financial resources. The significant negative association between the BAA profile and educational achievement suggests that experiencing low economic conditions during this sensitive window has a lasting impact on academic performance. This aligns with previous research emphasizing the lasting benefits of early childhood investments (Heckman and Masterov, 2007). Thus, closing educational gaps may be most effective through interventions during the first 1,000 days.

Our analysis revealed another notable finding: the coefficient for the ABA profile, indicating a temporary income dip during ages 2–5, did not significantly differ from the consistently high-income profile (AAA) regarding educational achievement. In simpler terms, children facing a short-term income decline during ages 2–5 performed similarly to those with stable high incomes, provided that this decline was preceded and followed by higher financial security. This result is intriguing, likely due to the timing of the income dip, as the ages 2–5 period may be less critical for long-term educational outcomes than the first 1,000 days of life, marked by rapid brain development and heightened sensitivity to economic factors (Phillips and Shonkoff, 2000). A stable, high income during this early period seems to provide a protective buffer against later income dips, emphasizing the importance of investing in early childhood development. Another potential explanation is that higher income during the first 1,000 days may have helped buffer against the negative effects of subsequent income declines. For example, early access to high-quality childcare could mitigate the impact

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Table 6 OLS regression coefficients (and SEs) of fifth-grade test scores, including income mobility profiles

	Mathematics	Science	English	Hebrew
Mother's education	.27** (.01)	.28** (.01)	.18** (.01)	.27** (.01)
Father's education	.24** (.01)	.20** (.01)	.20** (.01)	.22** (.01)
Number of siblings	−.03** (.00)	−.07** (.00)	−.08** (.00)	−.02** (.00)
Gender (1 = girls)	−.12** (.01)	−.02* (.01)	.07** (.01)	.27* (.01)
Ethnicity (1 = Arabs)	−.14** (.01)	.06** (.01)	.29** (.01)	(omitted)
Low birth weight	−.08** (.01)	−.04** (.02)	−.06** (.01)	−.03* (.01)
Cumulative family income[a]	.05** (.00)	.06** (.00)	.11** (.00)	.03** (.00)
BBB	−.16** (.01)	−.15** (.02)	−.15** (.01)	−.18** (.01)
BAA	−.07** (.02)	−.02 (.03)	−.07** (.02)	−.09** (.02)
BBA	−.09** (.02)	−.03 (.03)	−.10** (.02)	−.07** (.02)
BAB	−.12** (.02)	−.06 (.04)	−.06** (.03)	−.13** (.03)
AAB	−.07** (.02)	−.04 (.02)	−.02 (.02)	−.03 (.02)
ABB	−.08** (.02)	−.03 (.02)	−.05** (.02)	−.06** (.02)
ABA	−.04 (.02)	−.04 (.03)	−.02 (.02)	−.01 (.02)
Constant	.10** (.01)	.06** (.02)	−.09** (.01)	−.22** (.01)
N	79,724	42,294	80,211	58,700
R Square	.13	.11	.10	.10

Significance level: $*P \leq .05$ $**P \leq .001$.
[a]From pregnancy to fifth-grade Meitzav exams (in millions).

Table 7 Differences between coefficients of family income mobility profiles, including significance levels (*P*-values) of the differences

		Mathematics	Science	English	Hebrew
First 1,000 days	BBB−ABB	−7.74 per cent**	−15.25 per cent**	−10.42 per cent**	−12.23 per cent**
	BAA−AAA	−6.92 per cent**	.00 per cent	−6.58 per cent**	−8.79 per cent**
	BBA−ABA	−8.50 per cent**	.00 per cent	−9.77 per cent**	−7.30 per cent**
	BAB−AAB	−5.07 per cent*	.00 per cent	−5.96 per cent*	−13.44 per cent**
	Average	−7.06 per cent	−3.81 per cent	−8.18 per cent	−10.44 per cent
Ages 2–5	BBB−BAB	−4.19 per cent	−15.25 per cent*	−9.33 per cent*	−4.42 per cent
	BBA−BAA	−1.58 per cent	.00 per cent	−3.20 per cent	1.49 per cent
	ABB−AAB	−1.52 per cent	.00 per cent	−4.87 per cent	−5.63 per cent
	ABA−AAA	.00 per cent	.00 per cent	.00 per cent	.00 per cent
	Average	−1.82 per cent	−3.81 per cent	−4.35 per cent	−2.14 per cent
Ages 6–11	BBB−BBA	−7.36 per cent**	−15.25 per cent**	−5.52 per cent**	−10.56 per cent**
	BAB−BAA	−4.75 per cent	.00 per cent	.62 per cent	−4.65 per cent
	AAB−AAA	−6.60 per cent*	.00 per cent	.00 per cent	.00 per cent
	ABB−ABA	−8.12 per cent	.00 per cent	−4.87 per cent	−5.63 per cent*
	Average	−6.70 per cent	−3.81 per cent	−2.44 per cent	−5.21 per cent

$*P \leq 0.05$, $**P \leq 0.001$.

of later income fluctuations by providing stimulating environments and enriching experiences that promote cognitive development. If children in the ABA profile had access to such resources in the critical early years, it may have equipped them with a stronger foundation to better cope with the temporary income dip at ages 2–5. Further research is necessary to elucidate these possibilities and to explore the specific mechanisms at play.

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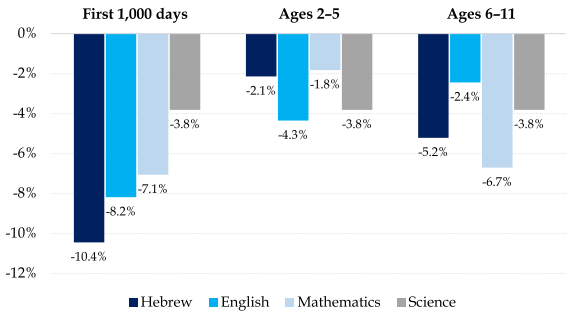


Figure 5 Average percent differences in achievement scores across age segments by regression coefficients of mobility profiles (per cent of S.D.)

To further explore whether the effect of family income during the first 1,000 days on educational achievement remains significant after accounting for income mobility throughout childhood, we conducted four pairwise comparisons of the regression coefficients presented in Table 6, focusing on different income mobility profiles. Each comparison analyzed variations in income during the first segment (the first 1,000 days) while keeping income constant across the other two segments (ages 2–5 and 6–11). The mobility profiles compared were: **B**BB–**A**BB, **B**AA–**A**AA, **B**BA–**A**BA, and **B**AB–**A**AB. Statistically insignificant coefficients from Table 6 were set to zero for these calculations.[3] The top panel of Table 7 shows the percent differences in achievement scores between these profiles, along with their averages. Similar comparisons for the second and third age segments are presented in the other two panels of Table 7. Furthermore, Table 7 presents the significance levels (*P*-values) for the differences between various income mobility profiles. Post-estimation tests, conducted using the Stata *test* command after the regression model in Table 6, assess whether these differences are statistically significant. Specifically, the tests compare pairs of income mobility profiles to determine if their effects on achievement scores differ significantly from one another, rather than just comparing them to the omitted reference category (AAA).

The averages of the percent differences are illustrated in Figure 5, highlighting variations in the effects of income mobility on achievements across age segments. The results indicate that, after controlling for family income mobility throughout childhood and other sociodemographic covariates, family income during the first 1,000 days has a more substantial impact on educational attainment than income in later childhood stages (up to age 11). The average differences across the various profiles were −10.44 per cent in Hebrew, −8.18 per cent in English, −3.81 per cent in Science, and −7.06 per cent in Mathematics. Notably, nearly all comparisons between income mobility profiles demonstrate high statistical significance ($P \leq 0.001$) across various subjects, indicating income during these early years significantly influences children's academic performance. In contrast, for the age group of 2–5 years, the findings reveal minimal average differences between income mobility profiles, with most comparisons lacking statistical significance. The overall averages for this age group were −1.82 per cent in Mathematics, −3.81 per cent in Science, −4.35 per cent in English, and −2.14 per cent in Hebrew. This suggests that while income disparities during the first 1,000 days are crucial for educational achievement, their impact diminishes significantly during ages 2–5.

For the age group of 6–11 years, results indicate differences in educational outcomes linked to family income mobility (Mathematics: −7.36 per cent, Science: −15.25 per cent, English: −5.52 per cent, Hebrew: −10.56 per cent). However, these differences are not consistently statistically significant. Some comparisons, especially between the BBB and BBA profiles, show notable differences, while others, like AAB versus AAA, reveal minimal impact and often lack significance. Overall, while the averages indicate an effect of income mobility on educational achievement for the age group of 6–11 years, the magnitude of these differences is less pronounced than those observed during the first 1,000 days, suggesting a diminished significance of income during this later stage compared with earlier years.

These findings align with the trends in Figures 1–4 and underscore the lasting impact of family income during the first 1,000 days on subsequent educational outcomes. This period represents a critical window in which socioeconomic conditions exert a pronounced influence on children's long-term development, emphasizing the need for targeted interventions. Overall, our results highlight the significance of the first 1,000 days as a pivotal stage for development and the enduring effects of income during this formative time.

These patterns are particularly evident in Hebrew and English, suggesting that early-life socioeconomic disparities exert a stronger influence on language and reading skills than on other domains. These abilities are especially sensitive to environmental conditions in early childhood, such as parental interaction, maternal speech, and exposure to rich and diverse language input (Hart and Risley, 1995; Hoff, 2003; Barone *et al.*, 2019; Barone, Fougère, and Pin, 2021). Language acquisition involves memorization, vocabulary building, and grammatical development—processes that are highly responsive to early parental engagement and home-based learning environments (Fernald, Marchman, and Weisleder, 2013).

In contrast, science and mathematics show distinct patterns that diverge both from language-based

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subjects and from each other. The largest differences in science achievement—reaching 15.25 per cent—are consistently observed between children who remained in low-income status throughout childhood (BBB) and those whose families moved above the median income threshold in at least one stage of childhood (e.g., ABB, BAB, BBA). In contrast, differences among most other income mobility profiles are relatively small or statistically insignificant. This polarized pattern suggests that long-term socioeconomic deprivation may be particularly detrimental to science achievement, while upward mobility—even if it occurs in only one period—can help close the gap. In mathematics, however, the disparities are more moderate but more evenly distributed across mobility profiles, suggesting that math achievement may be more consistently influenced by socioeconomic resources throughout childhood. These patterns may reflect the fact that, while early family income plays a significant role in shaping language skills during the critical early years, the development of mathematical abilities is less concentrated in early childhood. This may reflect the fact that math skills are typically nurtured through curriculum-driven instruction in later stages of childhood, with a focus on critical thinking and problem-solving, which intensifies as education progresses (Muñez, Bull, and Lee, 2021).

Furthermore, while our study does not measure variables like parental beliefs, practices supporting math, and home mathematics environment, these factors have been shown to significantly influence SES disparities in early math achievement (Elliott and Bachman, 2018). A definitive explanation for these differences exceeds the current study's scope, but these observations underscore the necessity for further research into how early-life socioeconomic disparities uniquely affect educational achievement across different subjects.

To further interpret these findings, we examined the differences between key income mobility profiles—BBB (persistently below-median income), BAA (low income only during the first 1,000 days), and BBA (low income in early and middle childhood, with upward mobility in later childhood). As shown in Table 6, children in the BAA and BBA profiles consistently outperformed those in the BBB group across all subjects, with average score differences of 0.10 and 0.09 standard deviations, respectively ($P \leq 0.01$). These results suggest that transitions out of low-income status—whether during early or later childhood—are associated with meaningful improvements in educational outcomes. Notably, the difference between BAA and BBA is negligible (approximately 0.01 standard deviations), indicating that the precise timing of upward mobility may matter less than the fact that income improved at some point after the first 1,000 days. In other words, while early-life disadvantage has lasting effects, these findings point to a degree of developmental plasticity: improved economic conditions in later childhood can partially compensate for the adverse consequences of low income in the first 1,000 days.

To further refine our understanding of how income affects achievement across developmental stages, we conducted an additional analysis, subdividing childhood into four distinct segments instead of three: the crucial first 1,000 days, ages 2–4, ages 5–7, and ages 8–11. This change increased potential mobility profiles from 8 to 16, allowing for a finer analysis that could reveal income effects masked by broader age ranges. This approach is particularly relevant if income impacts specific developmental stages differently within early or later childhood (*e.g.,* during preschool versus elementary school). Our refined breakdown aimed to determine if a more segmented analysis would alter the significance of early income. Despite the increased complexity and potential challenges in interpreting results with more segments, our findings consistently highlight that family income during the first 1,000 days had a more pronounced average impact than income in later segments (Tables 4–5 and Figure 1 in the Supplementary Materials).

As an additional robustness check, we re-estimated the model using the bottom income quintile (i.e., the lowest 20 per cent of the income distribution) instead of the median as the threshold for defining low-income status, an alternative that aligns more closely with definitions commonly used in poverty research and social policy. The results, presented in Table 15 of the Supplementary Materials, are consistent with our main findings and reinforce the conclusion that early-life income, particularly during the first 1,000 days, is strongly associated with later educational outcomes. These additional findings underscore the critical importance of early-life socioeconomic conditions in shaping long-term educational outcomes, offering valuable insights for the development of targeted early intervention programs that can help mitigate disparities in childhood development.

Discussion

The income of families during early childhood significantly impacts children's life prospects and future achievements (Feinstein, 2003; Duncan, Ziol-Guest and Kalil, 2010; Duncan, Morris and Rodrigues, 2011). Neuroscience Research has highlighted the first 1,000 days of a child's life—from pregnancy to age two—as the pivotal period for cognitive development, marked by heightened sensitivity of the brain to environmental influences (Johnson, Riis and Noble, 2016). This phase, characterized by the plasticity of the developing brain, is critical for brain structure and growth, as well as physical and mental development, with adequate nutrition and healthy growth yielding enduring benefits across the lifespan (Black *et al.*, 2013; da

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Cunha *et al.*, 2015; Schwarzenberg *et al.*, 2018). Therefore, interventions targeting the first 1,000 days are essential for improving health, nutrition, and economic outcomes.

This study investigates the hypothesis that family income during the first 1,000 days of life has a greater impact on children's educational development than income in later childhood segments. Our findings indicate that family income during this critical period significantly influences the educational achievement of Israeli fifth-grade students more than income during subsequent early and late childhood stages (ages 2–9). Additionally, we observe a notable effect of family income during ages 10–11 on educational achievements, aligning with the time of examinations. Our analysis further reveals that the effects of income during the first 1,000 days endure despite income mobility throughout childhood up to age 11. Even among students who experienced increased family income after this initial period, those with low income during the first 1,000 days still face significant educational disadvantages by fifth-grade.

Our findings carry several implications. Firstly, previous research on the impact of early childhood family income on life-course outcomes often fails to differentiate between age segments within early childhood and typically excludes the pre-birth period (e.g., Duncan *et al.*, 1998; Duncan, Morris and Rodrigues, 2011; Dahl and Lochner, 2012; Lee, 2014). Consequently, these studies may underestimate the significance of early economic disparities in shaping educational stratification. Our study addresses this gap by distinguishing between income during the first 1,000 days and income in later early childhood stages. Our results not only confirm the critical role of the first 1,000 days but also emphasize the lasting effects of income during this period on educational achievement, even in the context of income mobility throughout childhood.

Secondly, Israel has notably high levels of income inequality compared with other OECD countries (OECD, 2023a), with a significant proportion of children experiencing poverty—one of the highest rates among OECD nations (OECD, 2023b). Poverty is especially prevalent among households with young children (birth to age 4), where 25 per cent live below the poverty line, compared with 16 per cent of households without young children (Navon and Bowers, 2023). Furthermore, educational disparities among Israeli children rank among the highest in the OECD (RAMA, 2019). These factors suggest a potential link between early childhood income inequality and later educational disparities, indicating that our study may illuminate the complex relationship between income and educational inequalities in Israel.

The third implication concerns policy considerations. Early childhood is a crucial period for developing both cognitive and non-cognitive skills, leading to arguments that investments made during this stage yield higher returns than those made later, especially for disadvantaged children (Heckman and Masterov, 2007; Heckman, 2008). For instance, intervention programs for disadvantaged 4-year-olds are estimated to provide annual social rates of return of 7 per cent to 10 per cent (Heckman *et al.*, 2010). However, it is likely that investments made even earlier, during the first 1,000 days of life, would yield even greater returns. Nevertheless, public expenditure for early childhood in Israel significantly lags behind the OECD average, particularly during the first two years of life (Vaknin, 2020). Therefore, there is an urgent need for policies that provide financial support to families with children in these critical early stages.

In Israel, child allowances provide uniform financial support to families with children from birth to eighteen. However, increasing evidence, including our findings, indicates that income during early childhood significantly influences later educational outcomes. Research by Heckman and Masterov (2007) links early investments to improved educational attainment, higher future earnings, and reduced generational poverty rates. Therefore, it may be beneficial to reconsider the equal distribution of child allowances, as prioritizing support for the earliest years—especially for low-income families—could help close achievement gaps and enhance educational equity (for example, see Shay, Adi-Japha and Shavit, 2025). Although such a shift necessitates careful planning to ensure older children are not adversely affected, the potential long-term benefits for educational equity and social outcomes are considerable. A balanced approach that gradually increases support for early childhood while maintaining assistance for older children may provide a more equitable solution. While our research does not advocate specific policy actions, it contributes to the discussion on reallocating resources toward the first 1,000 days of life. Further research is needed to assess the long-term effects of this strategy on educational and economic outcomes.

Moreover, our findings suggest that while exposure to low family income during the first 1,000 days has a lasting negative effect on children's educational outcomes, these effects are not entirely immutable. Upward income mobility—whether occurring shortly after this early window (BAA) or later in childhood (BBA)—is consistently associated with improved achievement, with performance gains of approximately 10 percentage points compared with children experiencing persistent disadvantage (BBB). The similarity in outcomes between BAA and BBA suggests that while early conditions matter greatly, later improvements in family circumstances can help mitigate early risks. This underscores a critical policy insight: while prioritizing support for the earliest years remains essential,

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complementary policies that promote upward mobility beyond infancy may also help reduce long-term educational disparities.

While our study offers valuable insights into the impact of family income during distinct childhood segments on long-term outcomes, we acknowledge several limitations. First, by focusing on academic achievement in fifth-grade, we may overlook the effects of early childhood income on later outcomes, such as matriculation eligibility, diploma attainment, and adult earnings. Future research should expand data collection to include later developmental stages and adulthood for a comprehensive view of family income's enduring impact during the first 1,000 days. Second, due to data constraints, our study does not account for other income sources, such as fringe benefits and government transfers, which are particularly relevant for lower-income families. While Fringe benefits make up approximately 23 per cent of all employee compensation in Israel (Kristal, 2017) and play an increasing role in accounting for income inequality (Kristal, Cohen and Navot, 2018), their impact on overall inequality during our study period was relatively small. For instance, in 1998, 2 years prior to the beginning of our study period, the Gini index of salaries and wages without benefits was only 0.006 points lower than the same index with benefits (Kristal, Cohen and Mundlak, 2011). Thus, including benefits is unlikely to significantly alter our conclusions. Transfer payments, on the other hand, make up a substantial share of net income in Israel and have an important (though diminishing) role in reducing inequality. While omitting this income source may underestimate the impact of household income on academic achievement, there is no reason to believe it would have a differential impact by age, which is the focus of this study. In fact, the share of transfer payments in the average net income declined throughout the study period (Dahan, 2017), indicating that low-income households were better off during the first 1,000 days compared with the time of the Meitzav assessments.

Third, income during the crucial first 1,000 days likely influences educational achievement through factors like access to high-quality early childhood education and parental investment in stimulating experiences, both essential for cognitive development. However, due to data limitations, our study cannot examine these mechanisms in detail. Future research should explore these potential mediating factors to better understand how socioeconomic conditions during this period affect long-term educational outcomes.

Finally, our study falls short in establishing a causal link between income in the first 1,000 days and later educational achievement. While quasi-experimental research has documented positive associations between early-life income increases and educational outcomes (e.g., Akee *et al.*, 2010; Duncan, Morris, and Rodrigues, 2011; Milligan and Stabile, 2011; Dahl and Lochner, 2012; Barr, Eggleston, and Smith, 2022; Shay, Adi-Japha and Shavit, 2025), the recent Baby's First Years randomized controlled trial found enhanced brain activity in one-year-olds (Troller-Renfree *et al.*, 2022) but no significant effects on socioemotional or language development at age three (Hart et al., 2024). This inconsistency suggests that while experimental studies like BFY offer strong causal insights, they also face limitations—including reliance on parent-reported outcomes, relatively modest transfer amounts, and the use of small samples drawn exclusively from low-income families—constraints that limit generalizability and may obscure longer-term impacts. While our observational study cannot make strong causal claims, it leverages rich longitudinal administrative data covering an entire national cohort of children, allowing us to examine how the timing of income exposure across early and middle childhood relates to later educational outcomes. Experimental and quasi-experimental designs are critical for identifying causal effects, but are often impractical in large-scale social policy contexts due to ethical or logistical constraints. Longitudinal observational studies, however—when theoretically informed and based on population-wide data—can reveal complex developmental dynamics and provide policy-relevant evidence that enhances our understanding of the role of early-life economic conditions in shaping educational trajectories. Ultimately, integrating insights across methodological approaches is essential for advancing the debate on whether, when, and how early-life income shapes educational trajectories.

While acknowledging the limitations of our study, we emphasize the critical significance of economic circumstances during the first 1,000 days of life in shaping long-term educational outcomes. Our findings reaffirm the widely acknowledged hypothesis that family income during this crucial period plays a vital role in children's educational development. Recognizing the importance of investing in the first 1,000 days has the potential to yield significant positive outcomes, particularly for children from disadvantaged backgrounds.

Notes

1. Due to data constraints, household size was estimated annually based on the focal child's number of siblings, along with two parents and the individual themselves. While this estimation may not perfectly capture every detail of household composition, it provides a reasonably accurate reflection of annual household size. Analyses using unadjusted income, while controlling for the number of siblings at each time point, yielded similar results to our original model, reinforcing the reliability of our standardized per capita income approach (see Table 6 in the Supplementary Materials).

   Additionally, to test robustness across the income distribution, we applied the inverse hyperbolic sine transformation to

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household income: log(sqrt(income^2 + 1) + income). Results were consistent with our original analyses, supporting our conclusions (see Table 7 in the Supplementary Materials).

Finally, our dataset includes a small but sufficient number of sibling pairs. To account for potential dependence between siblings, we employed a hierarchical random-effects model. This model controls for unobserved heterogeneity between families and compares siblings who share a common socioeconomic environment but may experience different income levels at various stages of childhood. This model supports the robustness of the study's conclusions (see Tables 8 and 9 in the Supplementary Materials).

2. To examine additional factors influencing educational achievement, we conducted analyses controlling for maternal employment status during infancy (at pregnancy, birth, and age 1), maternal age at birth, child's birth year, and the mother's marital status both in the year following the child's birth and during the testing year. Including these variables did not alter the effect size or significance of family income in the first 1,000 days on educational outcomes (see Tables 10–14 in Supplementary Materials).
3. When using the nominal coefficient values (including statistically insignificant ones), findings remain largely unchanged, except for Hebrew test scores, which appear unaffected by most income mobility variables.

Supplementary data

Supplementary data are available at ESR online.

Author contributions

Dana Shay (Formal analysis [lead], Methodology [lead], Writing—original draft [lead], Writing—review & editing [lead]), Yossi Shavit (Formal analysis [supporting], Methodology [supporting], Writing—original draft [supporting], Writing—review & editing [supporting]), Isaac Sasson (Formal analysis [supporting], Methodology [supporting], Writing—original draft [supporting], Writing—review & editing [supporting])

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Data availability

The data for this study were provided by the ICBS under strict confidentiality protocols. Access was restricted to authorized researchers within the ICBS research facility, where all data processing and analysis took place in a secure environment to ensure data protection and privacy.

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