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ABSTRACT

Birth Order Effects in the Developed and Developing World: Evidence from International Test Scores

This paper examines the effect of birth order and family size on human capital using a consistent measure of cognitive skills across a diverse set of countries with different levels of development from PISA dataset. Using a birth order index that is orthogonal to family size, as well as controlling for student and family covariates, we find negative family size and birthorder effects in both developed and developing countries. Moreover, estimating the effects by country, there is no evidence of a relationship between birth order effects and the level of development, while the effect of family size is slightly higher in developing countries. The results also show that birth order effects are declining in birth order and that birth order matters more among smaller families than larger families.

JEL Classification: I2, J1

Keywords: birth order, family size, human capital

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1 Introduction

That the fate of an individual is dependent upon the order in which s/he is born in a family is a robust finding attested by numerous empirical studies.[1] Paradoxically, the relative fate of siblings exhibits an asymmetry in developed and developing countries: older siblings fare better in developed countries, while younger siblings fare better in developing countries. While the former conclusion is based on ample studies relying on rich datasets, the latter conclusion is based on relatively fewer studies. Drawing conclusions between effects in developed and developing countries is, however, limited as a consequence of relying on datasets, empirical methodologies, and outcomes, that are dissimilar and inconsistent across studies.

This paper investigates the effect of birth order and family size on human capital using a consistent measure of cognitive skills across a diverse set of countries with different levels of development. Specifically, we use Programme for International Student Assessment (PISA) dataset, which assesses the cognitive skills of students, from randomly selected schools worldwide, at the end of their compulsory schooling education (fifteen-year-old students). The PISA dataset has the unique advantage of being consistent across and representative of a large and diverse set of countries, and capturing multiple dimensions of human capital. The dataset also allows controlling for student characteristics, such as age and gender, as well as family characteristics, such as family size and parental education.

Using a birth order index that is orthogonal to family size, as well as controlling for student and family covariates, we find negative birth-order effects in both developed and developing coun-

[1] The literature is extensive and spans multiple disciplines including economics, sociology, psychology, among others. Economic studies in the context of developed countries include, Conley and Glauber (2006); Gary-Bobo et al. (2006); Kantarevic and Mechoulan (2006); Booth and Kee (2009); De Haan (2010); Silles (2010); Lehmann et al. (2018); Black et al. (2011); Heiland (2011); Pavan (2016), whereas studies in developing countries include Ejrnæs and Pörtner (2004); Tenikue and Verheyden (2010); De Haan et al. (2014).

tries. In particular, the results suggest that birth-order effects are similar in both developed and developing countries. Moreover, estimating birth order effects by country, there is no evidence of a relationship between birth order effects and the level of development. We also estimate various flexible functional specifications, allowing birth order effects to be non-constant and dependent on family size.

This paper advances the literature along a few dimensions. First, by using a consistent measure of cognitive skills and empirical methodology across countries, we demonstrate that older siblings fare better in both developed and developing countries, thereby reconciling the incongruous findings in the literature. The asymmetry in birth order effects documented in the literature is therefore likely due to inconsistency in the measurement of cognitive skills or differences in the empirical strategies. Second, by estimating flexible functional specifications, we document several nuances regarding birth-order effects. In particular, among all family sizes, we find that birth order effects are declining in birth order, particularly in developed countries. Relatedly, birth-order effects are larger for smaller families, both incremental differences between siblings and differences between first and last born siblings. Finally, most of birth order effects can be explained by the significant differences between the first and second born children, which is present in all families with more than 2 children.

1.1 Why birth order matters

Social scientists have investigated birth order effects for over a century and have produced a number of theories to explain the phenomenon.[2] We briefly review the primary hypotheses (see (Behrman and Taubman, 1986; Blake, 1989; Strauss and Thomas, 1995) for more detailed discus-

[2]Francis Galton (1874) has been credited in the literature as one of the first studies (Behrman and Taubman, 1986; De Haan et al., 2014).

sions).

Birth order effects might be the consequence in the evolution of parental preferences or household production over the life cycle. For example, if parents invest in children with benefits accruing when the child becomes an adult, then parents might favour earlier-born children. Moreover, if parenting exhibits diminishing marginal utility then earlier-born children, and firstborns in particular, might be favoured. On the other hand, parents might learn from raising successive children, with successive children benefitting from more mature parents (Behrman et al., 1984). More mature parents might also be less concerned about advancing their careers, and more concerned about the prosperity of future generations of the family. In some cultures, however, the firstborn is responsible for caring for elderly parents, giving parents the incentive to care more for firstborns.

Biological factors might also explain birth order effects. Because birth order is inextricably linked to the age of the parents, later-born children are disadvantaged to the extent that older parents have less healthy children. For example, older parents may have lower egg and sperm quality, implying that later-born children might have lower genetic endowments (Kidd et al., 2001). Moreover, chromosomal abnormalities (birth defects) are also increasing with age.

Capital market imperfections might distort intra-household investment in human capital. For example, if human capital is financed from savings, investment in earlier-born children may result in depleted savings, thereby constraining investment for later-born children. On the other hand, household income tends to increase over the life cycle, implying that capital market imperfections might advantage later-born children. Motivated by the observation that earlier-born children receive more parent-child time than later-born children, a related hypothesis argues that time constraints explain birth order effects (Lindert, 1977; Birdsall, 1991; Price, 2008). Because parent-child time is thought to be an important factor in human capital development and cannot be readily saved, earlier-born children, especially the first-born child, have less competition for parent time. Of course, later-born children might receive more parent-child time as earlier-born children mature, but early child investments are particularly critical (Currie and Almond, 2011).

Social psychologists have explained birth-order effects for intelligence using a "confluence” model (Zajonc, 1976). The model posits that a child’s intelligence depends on the intellectual environment of the family–specifically the average intelligence. Because average intelligence declines as families increase in size, first-born children are born into more favourable intellectual environments (adults-only families), while later-born children are born into less favourable intellectual environments. Moreover, because older children gain more from teaching younger children than the younger children learn, the last child is denied the opportunity to teach younger children. Consequently the model explains the observed negative birth-order effect, as well as explaining why children with younger siblings may eventually surpass only children.

While less discussed in the literature, birth-order effects can also be explained as a consequence of random genetic endowment “draws” and endogenous fertility decisions (Behrman and Taubman, 1986). For example, if parents get a “bad” draw (or realize that they dislike parenting) then they may be less likely to have more children. Or, if the first child is a “good” draw then they may be more likely to have more children with genetic draws exhibiting reversion towards mediocrity. While the above example suggests negative birth order effects, the opposite is possible if parents stop having children after above average draws, which has been used to explain positive birth order effects (Ejrnæs and Pörtner, 2004).

1.2 Previous Empirical Studies

Several recent empirical papers, starting with the influential study by Black et al. (2005) estimate the effect of birth order, as well as family size, on educational attainment and cognitive development. Black et al. (2005) use an administrate sample of all Norwegians over an extended period of time, finding negative birth order effects, but negligible family size effects, on educational attainment. Since then, many empirical studies in developed countries, using primarily administrate datasets, confirm that higher birth order adversely affects human capital (Conley and Glauber, 2006; Gary-Bobo et al., 2006; Kantarevic and Mechoulan, 2006; Booth and Kee, 2009; De Haan, 2010; Silles, 2010; Lehmann et al., 2018; Black et al., 2011; Heiland, 2011; Pavan, 2016).

While studies in developed countries document consistent evidence of negative birth-order effects, there is less evidence about the effect in developing countries. Interestingly, studies in developing countries find birth-order effects in the reverse order as studies in developed countries: earlier-born children fare better in developed countries, whereas later-born children fare better in developing countries. Relying on the insights advanced by Basu and Van (1998), one possible explanation is that poverty forces parents to send children out to work, with earlier-born being more likely candidates to engage in child labor.[3]

While economists have been interested in the intrahousehold allocation of resources in developing countries for many years, Ejrnæs and Pörtner (2004) is one of the first studies to investigate birth order effects on educational attainment in a developing country.[4] Using a longitudinal dataset

[3] Several papers explore birth order effects in terms of school attendance and child labor in developing countries: Edmonds (2006) finds that earlier-born siblings tend to work more in Nepal; Dammert (2009) finds that earlier-born boys spend more time in market work and earlier-born girls spend more time in domestic work in Nicaragua and Guatemala; and Emerson and Souza (2008) find that earlier-born siblings are less likely to attend school and more likely to work in Brazil.

[4] For example, examining child nutritional status, Behrman (1988) finds that earlier-born are favored in rural India, whereas Horton (1988) finds the opposite in the Philippines.

from the Philippines and family fixed effects, Ejrnæs and Pörtner (2004) find that later-born siblings spend more time in school and complete more years of education, with acute effects among low-education families. Similarly, Tenikue and Verheyden (2010) find that later-born siblings complete more years of schooling, especially in poor families, using data for children aged between 6 to 18 in 12 Sub-Saharan African countries. Most recently, De Haan et al. (2014) also find positive birth order effects on preschool cognition and secondary school enrollment in Ecuador, and uncover potential mechanisms, including parent-child time and breastfeeding. Similar to previous studies, they find that poverty is inextricably linked to the pattern of birth order effects–the largest birth order effects are observed in poor and low-educated families. Lafortune and Lee (2014) find that, among credit-constrained families, birth order and family size are positively correlated with schooling in the US, Mexico, and South Korea, but the effects are not present among families with large assets. Finally, Hervé et al. (2022) find insignificant birth order effects on reading and mathematics test scores of children between the ages of 8 and 14 years in two Indian districts (Palghar and Kurnool).

2 Empirical Methodology

2.1 Data

This paper uses the 2000 Programme for International Student Assessment (PISA) dataset. PISA is an international assessment of skills and knowledge of 15-year-old students that are near the end of the compulsory schooling.[5] The 2000 PISA dataset includes reading, mathematics and science

[5]PISA test scores are standardized to 500 with a standard error of 100. More details on PISA can be found on the following webpage: http://www.oecd.org/pisa.

test scores for 15-16 year old students in 43 countries (16 developing and 27 developed countries).[6] Each testing cycle emphasis a "major domain" in which two-thirds of the testing time are devoted (the other two provide summary assessments of skills), and the major domain in 2000 was reading literacy. Consequently, we emphasize reading test scores in the empirical analysis, but we also provide baseline results for the other two testing domains. The dataset also contains information on student and family characteristics. The sample of analysis contains 167,901 observations divided among of 57,376 and 110,525 observations from developing and developed countries, respectively. Table 1 reports concise variable descriptions and summary statistics. The average reading, mathematics, and science test scores in the sample of analysis are 494, 492, and 494, respectively. Table 2 reports average reading test scores with their associated standard deviation for each country. Netherlands has the highest reading test scores, while Peru has the lowest reading test scores in the sample of analysis.

Student and family characteristics include family size, defined as the number (N) of siblings (ranging from 0-9), and birth order (ϕ), which is defined in descending order of age (1 is the eldest, 2 is the second eldest, and so on).[7] Because birth order is mechanically correlated with family size (the correlation between family size and birth order is 0.674 in the sample of analysis), disentangling the independent effects of each is challenging. This paper constructs a birth order index, following Booth and Kee (2009), to eliminate the mechanical correlation between family

[6] We used data on GDP per capita in 2000 by World Bank to classify developing and developed countries (http://data.worldbank.org/indicator/). Developing countries include Albania, Argentina, Brazil, Bulgaria, Chile, Czech Republic, Hungary, Indonesia, Latvia, Mexico, Peru, Poland, Romania, Russian Federation, Thailand, and Macedonia; while developed countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong-China, Iceland, Ireland, Israel, Italy, Japan, Korea, Liechtenstein, Luxambourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States.

[7] Students were asked how many brothers and sisters they had older than themselves or younger than themselves (or the same age). We exclude students reporting more than four older/younger siblings due to top-coding (approximately 7% of sample).

size and birth order. In particular, the birth order index is the ratio of birth order ϕ to average birth order in the family $A = (N+1)/2$. The birth order index $B = \phi/A$ is thus birth order relative to the average birth order of the family, which is independent of family size (the correlation between family size and the birth order index is 0.015). Table 1 reports that the mean birth order index of the sample is approximately 1, which is consistent with expectations as the sample of students is random.

Additional student characteristics used as control variables include the age and gender of the student ("age (in months)" and "female"), a dummy indicating whether a student was born in the country of the test ("born in other country"), and a dummy indicating whether a student speaks a different language than the test language at home most of the time ("speak different language at home"). Table 1 reports that the average age is 15 years 7 months and 51% of the students are female. Moreover, around 8% are born in other countries than the test country and 16% speak a different language than the test language.

Additional family characteristics used as control variables include measures of parental education, labor force participation, household income and wealth, the household learning environment, and family structure. Specifically, we proxy for parental education using dummy variables indicating whether students' mom/dad completed primary or lower secondary education, upper secondary education, and tertiary education. We proxy for labor force participation using dummy variables indicating whether the mom/dad is working full time, working part time, looking for a job, and doing other work at the time of the survey (retired, home duties, etc.). An international socio-economic index of occupational status ("ISEI") is used as a proxy for household income and wealth.[8] We proxy for the learning environment and cultural background of the family using the

[8] The ISEI ranks the socioeconomic status of parents professions, ranging from 16 to 90, where 90 is the highest score (Ganzeboom et al., 1992).

number of books in the home.[9] Finally, we account for family structure using dummy variables indicating whether the student lives in a nuclear, single headed, mixed, or "other' family type. (nuclear family is the base category in the empirical analysis). Table 1 reports that 29% (32%) of mothers (fathers) completed tertiary education and 47% (78%) of mothers (fathers) were working full time at the time of the survey, while 11% of students have more than 500 books in their home and 79% live with both parents.

Table 3 reports average test scores by family size (number of children in the family) and birth order, as well as the percentage representation among the sample (indicated in parentheses). Around 8% of the sample is one-child family, 44% is two-child family, 29% is 3-child family, 13% is 4-child family, and 5% is 5 or more-child family. As expected, average test scores are declining in family size, with the exception of children from one-child families, which score slightly less than children from two-child families. First-born children account for 41% of the sample, second born account for 34%, third born account for 14%, fourth born account for 5%, and fifth (or greater) account for the remaining 5%. Table 3 demonstrates that average test scores are monotonically declining in birth order.

2.2 Methodology

To estimate the effects of birth order and family size on cognitive skills, the following model is employed using OLS[10]

$$Y_i = \alpha + \beta N_i + \theta B_i + \delta X_i + \varepsilon_i \tag{1}$$

[9]Students were asked how many books there are in their home, excluding magazines. We constructed dummy variables indicating whether there are 1-10, 11-50, 51-100, 101-250, 251-500, and more than 500 books. The omitted category in the empirical analysis is the dummy indicating no books at home.

[10]By construction, variation in birth order is measured in terms of its deviation from the within-family mean, and the estimate is therefore akin to family fixed effects (Booth and Kee, 2009).

where Y_i is a measure of cognitive skills (reading, mathematics and science test scores), N_i is family size, B_i is birth order, and X_i is a vector of controls, including student and family characteristics and country fixed effects. The primary coefficients of interest are β and θ, which represent the marginal effects of family size and the birth order index on cognitive skills. Translating the marginal effect of the birth order index into birth order is straightforward by recognizing that the derivative of the birth order index with respect to birth order is $2/(N+1)$. The marginal effect of birth order on cognitive skills is therefore $\theta(2/(N+1))$, which is dependent on family size.

Because the effect of birth order might be non-monotonic, a more flexible functional specification is also estimated following Booth and Kee (2009):

$$Y_i = \alpha + \beta N_i + \gamma_1 D_{1i} + \gamma_2 D_{2i} + \delta X_i + \varepsilon_i \tag{2}$$

where D_{1i} and D_{2i} are dummy variables indicating whether child i's birth order index is less than 0.8 and greater than 1.2, respectively. In this specification, children from families with only one child are excluded from the analysis. The reference group is the middle child in an odd-numbered family, or the two middle children in an even-numbered family, except when the family is two-child family in which case there is no child in the reference group.

3 Results

3.1 Baseline results

Table 4 reports the coefficient estimates of family size and birth order using reading test score as a dependent variable and family and student characteristics and country fixed effects as controls.

In particular, column (1) includes only family and student characteristics and fixed effects, column (2) adds family size, column (3) adds family size and birth order, and column (4) is similar to column (3) but excludes only-child families. We restrict the sample to exclude only-child families as there is no variation in birth order.

Table 4 documents that test scores are positively related to parental education and socioeconomic status. Column (2) demonstrates that test scores are inversely related to family size, while column (3) demonstrates that the effect is similar after controlling for birth order. Column (3) demonstrates that test scores are inversely related to birth order. Column (4) demonstrates that results are similar after excluding students from only-child families.

We find that an additional sibling reduces the reading test score by around 6 points, which corresponds to 6% of a standard deviation or a 1.2 percent reduction relative to the mean. Moreover, we find that siblings with a 1-unit higher birth order index have lower reading test scores by around 14 points, which corresponds to 14% of a standard deviation or 2.8 percent reduction relative to the mean. The estimates are statistically significant at the 1-percent significance level.

What do the birth order index coefficients imply in terms of the role of birth order for a given family size? For two siblings, the difference in reading test scores between siblings (first and second) would be 9.3. For three siblings, the difference in reading test scores between siblings (first and second, and second and third) would be 7. Similarly, for four siblings and five siblings, the difference in reading test scores between siblings would be 5.6 and 4.7, respectively. For three, four, and five siblings, the difference in reading test scores between the first born and the last born would be 14, 16.8, and 18.7, respectively.

Recall that we emphasize reading test scores as the major domain of the 2000 PISA focused on reading literacy. Tables 5 and 6 report the coefficient estimates of family size and birth order on mathematics and science test scores as dependent variables and family and student characteristics and country fixed effects as controls, respectively. The results are similar, demonstrating that mathematics and science test scores are inversely related to family size and birth order. In particular, we find that an additional sibling reduces the mathematics and science test scores by around 6 points, which corresponds to 6% of a standard deviation or a 1.2 percent reduction relative to the mean of both scores. The estimates are statistically significant at the 1-percent significance level. The birth order index coefficients suggest that for two siblings, the difference in mathematics (science) test scores between siblings (first and second) would be 9.3 (11.3). For three siblings, the difference in mathematics (science) test scores between siblings (first and second, and second and third) would be 7 (8.5). Similarly, for four siblings and five siblings, the difference in mathematics (science) test scores between siblings would be 5.6 (6.8) and 4.7 (5.7), respectively. For three, four, and five siblings, the difference in mathematics (science) test scores between the first born and the last born would be 14 (17), 16.8 (20.4), and 18.7 (22.7), respectively.

3.2 Effects by level of development

This section investigates whether the effect of family size and birth order depends on a country's level of development. To this end, the sample is divided according to level of development (developing and developed as defined in footnote 6). We focus on reading test scores and provide results for mathematics and science test scores in an Online Appendix.

Table 7 reports family-size and birth-order coefficients for the subsamples of developing countries (columns 1 and 2) and developed countries (columns 3 and 4). All specifications include country-fixed effects and family and student characteristics, while columns 1 and 3 include only-child families, columns 2 and 4 exclude only-child families.

Consistent with the previous results, test scores are inversely related to family size and birth order in both developing and developed countries. Moreover, the family-size and birth-order coefficients are remarkably similar for both developing and developed countries. In particular, we do not find statistically-significant differences in the birth-order coefficients between developed and developing countries (p-val. of the equality test between the coefficients in column 1 (2) and 3 (4) is 0.954 (0.871)). Similarly, the difference in the family-size coefficients between developing and developed countries is not statistically significant when we include only-child families (p-val of the equality test between the coefficients in column 1 and 3 is 0.468), but it is statistically significant when we exclude only-child families (p-val of the equality test between the coefficients in column 2 and 4 is 0.024). We find a similar pattern when we explore the effects of family size and birth order on mathematics and science test scores in developing and developed countries (see Online Appendix). In sum, we find that the effect of birth order is very similar in developing and developed countries, while the effect of family size is also similar, there is some suggestive evidence that effect of family size might be slightly larger in developing countries than developed countries.

To further investigate the role of economic development in the effect of birth order, we estimate country-specific birth order effects to explore whether there is a relationship between GDP per capita and the birth order coefficients. The country-specific birth-order index coefficients are obtained by estimating birth-order effects on country-level subsamples using our preferred specification (Table 4, column 3). Figure 1 plots country-level birth-order index coefficients for reading test scores and national GDP per capita (in 2000 US$).[11] There does not appear to be any systematic relationship between birth-order effects and GDP per capita, suggesting that the effect of birth order does not depend on a country's level of development.

[11] The estimated coefficients of birth order on reading test scores for each country is provided in an Online Appendix.

3.3 Flexible functional specifications

3.3.1 Birth-order dummies

For a given family size, the previous specifications impose constant marginal effects of birth order between siblings. This is a strong assumption as the difference in test scores between the first born and the second born, might be dissimilar from the difference in test scores between the second and third born, or between siblings with higher birth orders more generally. This subsection estimates a flexible-function specification by creating dummies for earlier-born siblings and later-born siblings, which we compare to the excluded group consisting of the middle child (or the two middle-born children when the number of siblings is even).

Table 8 reports the coefficient estimates using a flexible functional specification (equation 2), for the full sample (column 1), developing countries (column 2), and developed countries (column 3).[12] In particular, among all countries (column 1), earlier-born children score 9.60 points higher, whereas later-born children score 2.5 points lower, than the middle-born child (or middle two children when there are an even number of siblings). In developing countries (column 2), earlier-born children score 7.4 points higher, whereas later-born children score 4.1 points lower, than the middle-born child. In developed countries (column 3), the premium to earlier-born children is larger (earlier-born score 10.7 points higher), but the penalty to later-born children is smaller (later-born score 1.6 points lower). Consistent with the linear model, birth order is inversely related to test scores. However, birth order effects tend to be more acute among earlier-born child and then dissipate in later-born siblings, particularly among siblings in developed countries.

[12]The results are similar using mathematics and science test scores as the dependent variables for the whole sample as well as the subsamples of developing and developed countries (see Online Appendix).

3.3.2 Birth order effects by family size

While the previous section accounts for non-linear birth order effects by estimating a flexible functional specification, this subsection allows birth order effects to vary over different family sizes. To this end, we estimate the effect of birth order index on subsamples of similar family sizes, ranging from 2 siblings to 5+ siblings. Table 9 reports the birth order coefficient estimates for subsamples of families, where Panel A reports the coefficient estimates for all countries, and Panels B and C report the estimates for developing and developed countries, respectively.

In all specifications, the effects of birth order on test scores are negative and statistically significant, although the sample of families with five or more children is less precisely estimated due to the reduction in sample size. The estimates demonstrate that the birth order coefficient is decreasing in family size, ranging from -18.4 for 2 child families to -6.5 for 5+ child families. These coefficients imply that, for two siblings, the difference in reading test scores between siblings (first and second) would be 12.3. For three siblings, the difference in reading test scores between siblings (first and second, and second and third) would be 6.7. Similarly, for four siblings and five siblings, the difference in reading test scores between siblings would be 3.4 and 2.15, respectively. These results imply that birth order plays a markedly more important role among smaller families than larger families. For example, the difference in test scores between consecutive-born siblings in a 2-child family is 3.5 (5.5) times larger than the difference between consecutive-born siblings in a 4-child (5+ child) family. Moreover, the difference in test scores between the first-born and last-born child in 4-child (5+ child) family is slightly larger (smaller) than the difference in test scores between siblings in a 2-child family.

The effects of birth order by family size are nearly identical for developing countries (Panel B) and developed countries (Panel C). The only exception is birth-order effects for families with more than five siblings, which is slightly larger in developing countries, although the coefficients are less precisely estimated and the differences are not statistically significant.

3.3.3 Full-interaction model

Finally, we employ a full-interaction model that combines elements of the previous two subsections to allow birth order effects to be both non-linear and dependent on family size. To this end, we create two-way dummies for family size (2, 3, and 4 siblings) and birth order (1, 2, 3, and 4), in order to estimate all 9 possible family-size and birth-order combinations.[13] We use these dummies in our preferred specification (4) of Table 4, which includes controls for family and student characteristics and country-fixed effects.

Figure 2 plots the predicted values for Reading Test Scores for students for all possible family sizes and birth order.[14] Three key findings are noteworthy. First, for a given birth order, test scores are always declining in family size (with one exception, all differences in test scores are statistically significant). Second, for all family sizes, there is a steep decline in test scores between the first and second child. This second-child penalty for all family sizes tends to be larger than family-size effect for a given birth order. Third, for all family sizes, the birth order effect is declining in birth order, and for children born after the second child, the effects are modest in magnitude and statistically indistinguishable from zero.

[13] Similar to specification (4) of Table 4, we exclude only-child families.

[14] The predicted values are adjusted for differences in family characteristics and country-fixed effects.

4 Conclusion

This paper estimates the effect of birth order and family size on human capital in a diverse set of countries with different levels of development. We use reading, mathematics, and science test scores of students at the end of their compulsory schooling education from PISA dataset as measures of cognitive skills of students. To remove the mechanical relationship between family size and birth order, we use a birth order index that is orthogonal to family size, and control for student and family covariates. We explore the role of economic development in birth order effects by estimating the relationship for developed and developing countries. Moreover, we estimate country-level effects to investigate the relationship between GDP per capita and birth order effects. Finally, we estimate various flexible functional specifications, to allow birth order effects to depend on birth order and family size.

We find that test scores are inversely related to family size and birth order, and are similar in magnitude in both developed and developing countries. Moreover, we do not find evidence of a relationship between birth order effects and the level of development. We find suggestive evidence that the effect of family size on test scores is slightly higher in developing countries, and that birth order effects are declining in birth order relatively more in developed countries (that is, there are larger differences among earlier-born siblings but smaller differences among later-born siblings). Among all family sizes, we find that birth order effects are declining in birth order, which is primarily explained by significant differences between the first and second born children. Finally, we find that birth-order effects are larger for smaller families.

While several studies find negative effects of birth order on educational outcomes and cognitive development in developed countries, most recent studies find positive birth order effects in developing countries. Our findings demonstrate that this asymmetry does not exist when using a consistent empirical strategy and measure of cognitive skills across countries with a wide-range of economic development. While we conclude the effects are similar in developing and developed countries, it is also plausible that the underlying mechanisms could be different. One avenue for future research could be to shed light on the channels through which birth order affects human capital in developing and developed countries.

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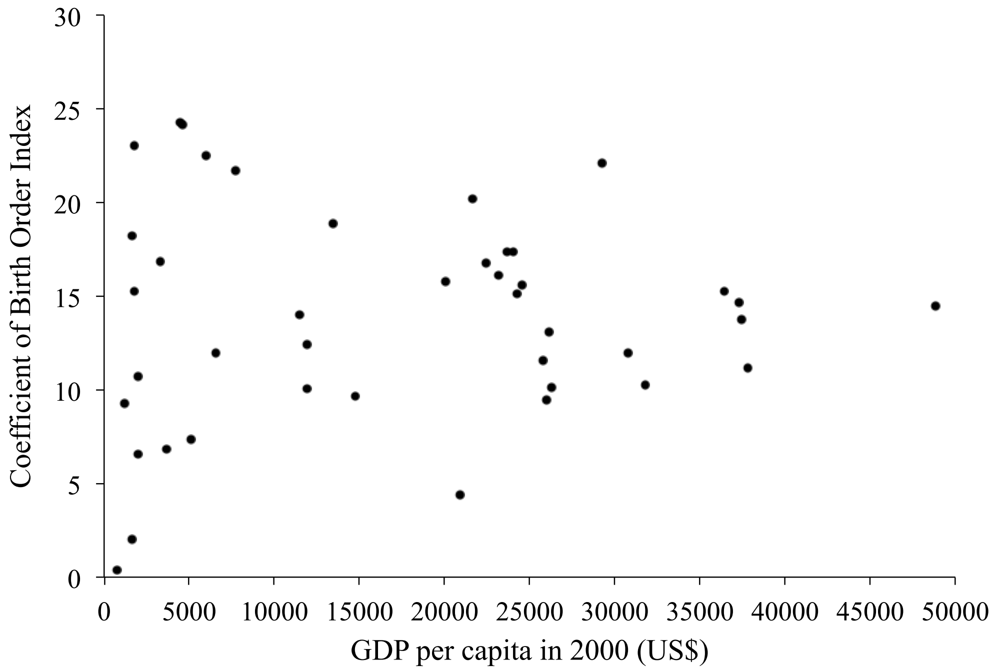
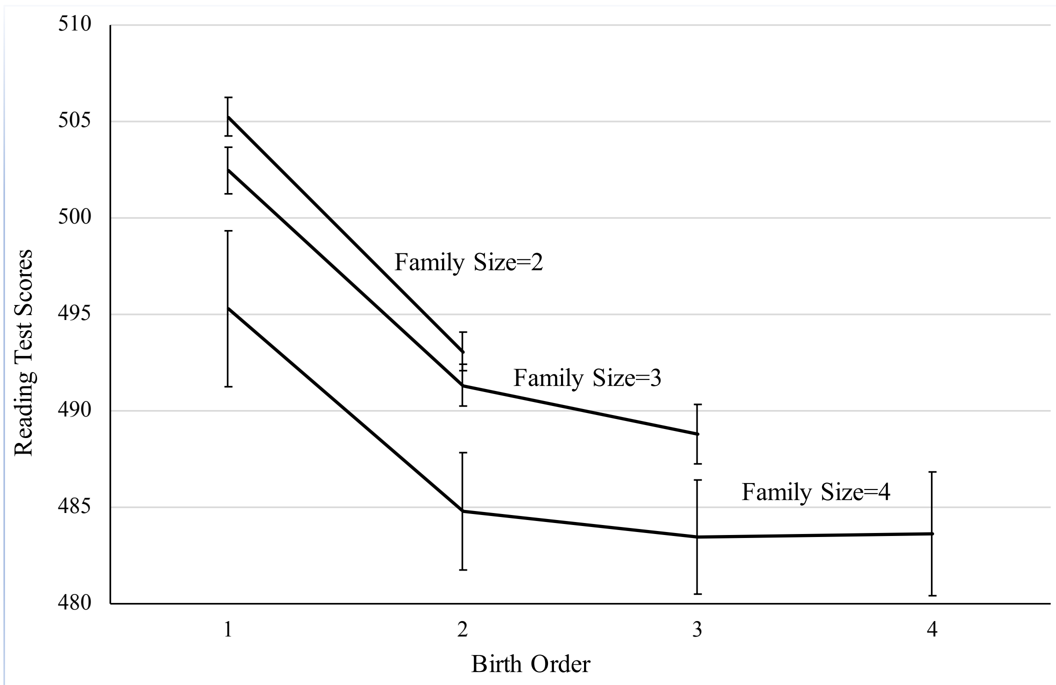
Figure 1: Reading Test Scores by GDP



Notes: This Figure plots country-specific coefficients of the birth order index on reading test scores using a similar specification as Table 4, Column 3. Specifically, we run separate regressions for each country using a similar set of controls for student and family characteristics, with the exception of country fixed effects. We plot the country-specific coefficients with corresponding GDP per capita in 2000 (current US$) from the World Bank.

Figure 2: Predicted Reading Test Scores



Notes: This Figure presents the predicted values for Reading Test Scores for students for all possible family sizes (2, 3, and 4 siblings) and birth order (1, 2, 3, and 4) that are adjusted for differences in family characteristics and country-fixed effects and plots the respective 95% confidence intervals of each predicted value.

Table 1: Variable Descriptions and Summary Statistics

Variable	Description	Mean	S.D.
PISA reading score	Reading test score	493.571	102.774
PISA mathematics score	Mathematics test score	491.922	107.896
PISA science score	Science test score	493.741	102.555
Student Characteristics			
Age (in months)	Age of the student in months	188.316	3.933
Female	1 if student is female	0.512	0.500
Born in other country	1 if born in other country	0.081	0.273
Speak different language at home	1 if speaks a different language than the test language at home most of the time	0.160	0.366
Family Characteristics			
ISEI	Socio-economic index (values 16-90)	48.702	16.807
Mom: No education[a]	1 if mom did not go to school	0.015	0.122
Mom: primary & lower secondary education	1 if mom completed primary or lower secondary education	0.293	0.455
Mom: upper secondary education	1 if mom completed upper secondary education	0.402	0.490
Mom: tertiary education	1 if mom completed tertiary education	0.290	0.454
Dad: No education[a]	1 if dad did not go to school	0.015	0.120
Dad: primary & lower secondary education	1 if dad completed primary or lower secondary education	0.282	0.450
Dad: upper secondary education	1 if dad completed upper secondary education	0.384	0.486
Dad: tertiary education	1 if dad completed tertiary education	0.320	0.467
Mom: Full time work	1 if mom is working full time	0.471	0.499
Mom: Part time work	1 if mom is working part time	0.196	0.397
Mom: Other work	1 if mom is doing other work (retired, home duties, etc.)	0.258	0.437
Mom: Looking for job	1 if mom is looking for a job	0.058	0.234
Mom: Unknown[a]	1 if mom's working status is unknown	0.018	0.132
Dad: Full time work	1 if dad is working full time	0.781	0.413
Dad: Part time work	1 if dad is working part time	0.089	0.285
Dad: Other work	1 if dad is doing other work (retired, home duties, etc.)	0.066	0.249
Dad: Looking for job	1 if dad is looking for a job	0.043	0.203
Dad: Unknown[a]	1 if dad's working status is unknown	0.021	0.142
Books at home: None[a]	1 if there are no books at home	0.017	0.128
Books at home: 1-10	1 if there are 1-10 books at home	0.106	0.308
Books at home: 11-50	1 if there are 11-50 books at home	0.213	0.409
Books at home: 51-100	1 if there are 51-100 books at home	0.206	0.405
Books at home: 101-250	1 if there are 101-250 books at home	0.201	0.401
Books at home: 251-500	1 if there are 251-500 books at home	0.147	0.354
Books at home: 500+	1 if there are more than 500 books at home	0.110	0.313
Nuclear family[a]	1 if student lives with both parents	0.793	0.405
Single headed family	1 if student lives with only one adult person	0.115	0.319
Mixed family	1 if at least one of the adults is not the father or the mother	0.058	0.234
Other type family	1 if none of the adults is the father or the mother	0.028	0.165
Family type unknown	1 if family type is unknown	0.006	0.079
Family size & birth order index			
Family size	Number of student's siblings, highest value at 9	1.642	1.042
Birth order index	Constructed birth order index	1.001	0.354
Only-child families	1 if the student is the only child in the family	0.084	0.278

[a]Base Category. 167,901 observations for all variables, excluding the PISA mathematics and science test scores (93,120 and 93,377 observations, respectively). Sources: Authors' calculations based on the 2000 PISA dataset.

Table 2: Summary Statistics of Reading Test Scores for Each Country

	Mean	S.D.		Mean	S.D.
Albania	375.22	89.87	Iceland	517.27	87.92
Argentina	446.54	96.76	Israel	492.40	95.63
Australia	538.00	99.38	Italy	496.71	87.07
Austria	512.19	88.74	Japan	549.66	79.28
Belgium	534.84	92.43	Korea, Repulic of	522.90	69.19
Bulgaria	438.77	96.62	Liechtenstein	499.58	87.68
Brazil	397.91	87.19	Luxemburg	464.42	88.81
Canada	531.41	93.66	Latvia	473.33	94.93
Switzerland	505.90	96.22	Mexico	444.68	83.05
Chile	424.49	85.45	Macedonia	389.18	87.28
Czech Republic	507.97	85.80	Netherlands	553.44	81.85
Germany	519.77	93.12	Norway	521.65	95.90
Denmark	518.57	88.67	New Zealand	551.49	97.07
Spain	501.58	81.39	Peru	357.32	95.56
Finland	553.34	85.08	Poland	484.82	93.85
France	519.15	85.93	Portugal	489.29	90.55
United Kingdom	543.68	93.90	Romania	457.34	93.41
Greece	478.75	95.48	Russian Federation	471.13	89.91
Hong Kong	532.55	78.16	Sweeden	526.27	88.04
Hungary	491.39	86.58	Thailand	441.71	74.69
Indonesia	373.41	68.47	United States	532.48	95.53
Ireland	537.23	89.87			

Sources: Authors' calculations based on the 2000 PISA dataset.

Table 3: Average Test Scores by Number of Children and Birth Order

	Total Number of Children in the Family			Birth Order		
	Reading	Mathematics	Science	Reading	Mathematics	Science
1	495.64	495.13	498.61	499.40	497.56	500.92
	(8.42%)	(8.33%)	(8.49%)	(41.33%)	(41.39%)	(46.66%)
2	498.92	499.19	500.94	489.27	489.42	489.48
	(43.91%)	(44.03%)	(43.80%)	(34.21%)	(34.21%)	(34.10%)
3	494.06	492.37	492.06	479.22	476.17	476.31
	(29.24%)	(29.29%)	(29.27%)	(14.09%)	(14.00%)	(14.12%)
4	475.52	469.92	473.94	458.79	451.13	458.35
	(13.24%)	(13.22%)	(13.29%)	(5.38%)	(5.41%)	(5.31%)
5+	449.06	441.96	449.92	428.26	416.03	429.77
	(5.19%)	(5.12%)	(5.15%)	(4.99%)	(4.99%)	(4.96%)

Notes: Table presents the average test scores by family size (number of children in the family) and birth order, as well as the percentage representation among the sample (indicated in parentheses). Sources: Authors' calculations based on the 2000 PISA dataset.

Table 4: Effects on Reading Test Scores

	Column (1)	Column (2)	Column (3)	Column (4)
Family Characteristics				
ISEI	1.00***	0.98***	0.98***	0.98***
	(0.05)	(0.05)	(0.05)	(0.05)
Mom: primary & lower secondary education	14.85***	13.10***	12.51***	12.10***
	(4.60)	(4.35)	(4.36)	(4.32)
Mom: upper secondary education	26.16***	23.69***	22.56***	22.46***
	(4.70)	(4.38)	(4.38)	(4.32)
Mom: tertiary education	27.89***	25.43***	24.15***	24.12***
	(4.45)	(4.18)	(4.16)	(4.14)
Dad: primary & lower secondary education	15.81***	14.96***	14.54***	13.55***
	(3.01)	(3.03)	(3.00)	(3.12)
Dad: upper secondary education	25.33***	24.04***	23.24***	22.06***
	(3.56)	(3.63)	(3.58)	(3.76)
Dad: tertiary education	27.71***	26.58***	25.98***	24.79***
	(3.30)	(3.43)	(3.37)	(3.61)
Family size & birth order				
Family size		-6.02***	-5.88***	-6.47***
		(0.56)	(0.56)	(0.69)
Birth order index			-14.36***	-14.23***
			(0.94)	(0.96)
Country Fixed Effects	Yes	Yes	Yes	Yes
Observations	167,901	167,901	167,901	153,768
Adjusted R-square	0.397	0.400	0.402	0.406

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors (in parentheses) are clustered at the country level. All specifications control for gender and age of the student, parental labor force participation, dummies indicating whether a student was born in the country of test and speaks the test language at home, and dummies indicating the number of books at home and type of family structure. Column (4) excludes only-child families.

Table 5: Effects on Mathematics Test Scores

	Column (1)	Column (2)	Column (3)	Column (4)
Family Characteristics				
ISEI	0.92***	0.90***	0.90***	0.90***
	(0.05)	(0.05)	(0.05)	(0.05)
Mom: primary & lower secondary education	15.77***	14.24***	13.75***	12.50***
	(3.70)	(3.53)	(3.46)	(3.51)
Mom: upper secondary education	26.35***	24.12***	23.09***	22.31***
	(3.90)	(3.72)	(3.63)	(3.60)
Mom: tertiary education	28.34***	26.14***	24.96***	24.31***
	(3.49)	(3.35)	(3.25)	(3.23)
Dad: primary & lower secondary education	13.10***	12.12***	11.69***	11.58***
	(3.06)	(2.96)	(2.94)	(3.17)
Dad: upper secondary education	22.40***	21.00***	20.23***	19.88***
	(3.48)	(3.44)	(3.39)	(3.65)
Dad: tertiary education	25.21***	24.01***	23.40***	23.16***
	(2.92)	(2.88)	(2.84)	(3.10)
Family size & birth order index				
Family size		-5.63***	-5.49***	-6.19***
		(0.63)	(0.62)	(0.71)
Birth order index			-13.67***	-13.54***
			(1.17)	(1.19)
Country Fixed Effects	Yes	Yes	Yes	Yes
Observations	93,120	93,120	93,120	85,373
Adjusted R-square	0.415	0.418	0.420	0.424

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors (in parentheses) are clustered at the country level. All specifications control for gender and age of the student, parental labor force participation, dummies indicating whether a student was born in the country of test and speaks the test language at home, and dummies indicating the number of books at home and type of family structure. Column (4) excludes only-child families.

Table 6: Effects on Science Test Scores

	Column (1)	Column (2)	Column (3)	Column (4)
Family Characteristics				
ISEI	0.86***	0.85***	0.85***	0.85***
	(0.05)	(0.05)	(0.05)	(0.05)
Mom: primary & lower secondary education	9.10*	7.23	6.60	6.16
	(5.15)	(4.97)	(5.01)	(4.92)
Mom: upper secondary education	19.21***	16.64***	15.37***	15.16***
	(5.05)	(4.85)	(4.86)	(4.81)
Mom: tertiary education	23.36***	20.79***	19.36***	19.53***
	(5.39)	(5.19)	(5.18)	(5.19)
Dad: primary & lower secondary education	13.28***	12.67***	12.02***	9.81***
	(2.45)	(2.42)	(2.34)	(2.52)
Dad: upper secondary education	21.75***	20.73***	19.65***	17.48***
	(3.24)	(3.25)	(3.21)	(3.39)
Dad: tertiary education	26.12***	25.23***	24.39***	22.14***
	(3.37)	(3.47)	(3.43)	(3.52)
Family size & birth order index				
Family size		-5.75***	-5.59***	-5.98***
		(0.50)	(0.50)	(0.55)
Birth order index			-16.75***	-16.60***
			(1.07)	(1.08)
Country Fixed Effects	Yes	Yes	Yes	Yes
Observations	93,377	93,377	93,377	85,432
Adjusted R-square	0.353	0.356	0.359	0.361

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors (in parentheses) are clustered at the country level. All specifications control for gender and age of the student, parental labor force participation, dummies indicating whether a student was born in the country of test and speaks the test language at home, and dummies indicating the number of books at home and type of family structure. Column (4) excludes only-child families.

Table 7: Effects on Reading Test Scores by the Level of Development

	Developing Countries (16)		Developed Countries (27)	
	Column (1)	Column (2)	Column (3)	Column (4)
Family size & birth order				
Family size	-6.25***	-7.95***	-5.57***	-5.53***
	(0.62)	(0.74)	(0.72)	(0.74)
Birth order	-14.11***	-13.80***	-14.24***	-14.18***
	(2.15)	(2.21)	(1.01)	(1.01)
Country Fixed Effects	Yes	Yes	Yes	Yes
Exclude Only-child Families	No	Yes	No	Yes
Observations	57,376	51,923	110,525	101,845
Adjusted R-square	0.376	0.376	0.250	0.254

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors (in parentheses) are clustered at the country level. All controls are included in all specifications.

Table 8: Effects on Reading Test Scores (Flexible Specification)

	All Countries	Developing Countries	Developed Countries
	Column (1)	Column (2)	Column (3)
Family size & birth order			
Family size	-5.75***	-7.62***	-4.58***
	(0.72)	(0.82)	(0.74)
Dummy 1	9.60***	7.44***	10.65***
	(0.76)	(1.67)	(0.58)
Dummy 2	-2.54***	-4.11**	-1.57**
	(0.66)	(1.43)	(0.74)
Country Fixed Effects	Yes	Yes	Yes
Exclude Only-child Families	Yes	Yes	Yes
Observations	153,768	51,923	101,845
Adjusted R-square	0.406	0.376	0.254

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors (in parentheses) are clustered at the country level. All controls are included in all specifications.

Table 9: Effect of Birth Order by Family Size

	2-Child Family	3-Child Family	4-Child Family	5+ Child Family
Panel A: All Countries				
Birth Order Index	-18.40***	-13.39***	-8.52***	-6.45**
	(1.24)	(1.11)	(1.48)	(2.85)
Observations	74,032	49,131	22,072	8,533
Adjusted R-square	0.363	0.400	0.460	0.332
Panel B: Developing Countries				
Birth Order Index	-18.04***	-13.37***	-8.40***	-9.19**
	(2.98)	(2.26)	(1.81)	(3.61)
Observations	25,709	15,012	7,571	3,631
Adjusted R-square	0.341	0.344	0.360	0.221
Panel C: Developed Countries				
Birth Order Index	-18.54***	-13.03***	-8.54***	-5.98*
	(1.16)	(1.36)	(2.04)	(3.59)
Observations	48,323	34,119	14,501	4,902
Adjusted R-square	0.243	0.260	0.263	0.251

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors (in parentheses) are clustered at the country level. All controls (excluding family size) are included in all specifications.