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Abstract

Using instrumental variables approach this paper studies the effect of kindergarten starting age jointly with that of school starting age. We show that estimating the effect of kindergarten or school enrolment timing on later human capital outcomes separately, without taking their inter-relatedness into account, may confound the two effects and produce endogenous results. The instruments originate from exogenous birthdate-related enrolment cutoffs in kindergarten and school admissions. Using a rich Hungarian database, we show that both earlier kindergarten enrolment and later school enrolment have a significant and non-negligible positive effect on standardised test scores in grade 6, 8, and 10, class marks given by the teacher, aspirations for higher education, and track choice. These effects tend to decrease over time and are heterogeneous across mother's education, as earlier kindergarten enrolment age seems to matter only for the children of low educated mothers.

Keywords: Kindergarten enrolment age; School enrolment age; Instrumental Variables

JEL codes: I21, I26

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Az óvodai és iskolai beiratkozás időzítésének humántőke hatásai

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Összefoglaló

A tanulmány instrumentális változók módszerével egyszerre vizsgálja az óvodai és az iskolai beiratkozási életkor hatását. Megmutatjuk, hogy ha az óvoda- vagy iskolakezdés időzítésének humántőkére gyakorolt hatását külön-külön becsüljük, az összemossa a hatásokat és torzítja az eredményt. Az instrumentumokat a gyermek születési dátumából képezzük, az így létrejött instrumentális változók erősek és egzogének. Részletes magyar adatok segítségével megmutatjuk, hogy mind a korábbi óvodai beiratkozásnak, mind a későbbi iskolai beiratkozásnak szignifikáns és jelentős hatása van a 6., 8., és 10. osztályban mért standardizált teszteredményekre, a tanárok által adott jegyekre, a továbbtanulási tervekre és a pályaválasztásra. Ezek a hatások időben többnyire csökkennek, és heterogének az anyák iskolázottsága szerint, mivel a korábbi óvodai beiratkozás csak az alacsony végzettségű anyák esetében számít.

JEL: I21, I26

Tárgyszavak: Óvodai beiratkozási életkor, iskolai beiratkozási életkor, instrumentális változók

1. INTRODUCTION

Human capital investments made at different points in time are imperfect complements of each other. Also, investments in earlier periods have a higher return than investments in later periods (Heckman, 2007; Johnson and Jackson, 2017). One early investment consists of attending kindergarten, while a slightly later investment involves the enrolment in formal education. As OECD PISA 2015 data show, the timing of enrolment in kindergarten is strongly related to the timing of enrolment in formal education: children who enter kindergarten at a later age tend to enrol into school at a later age and spend *less* time in kindergarten. The opposite holds for children starting kindergarten at an earlier age as they enrol into school at a younger age and spend *more* time in kindergarten (see Table A1). Despite being intertwined, the effect of kindergarten starting age is usually studied separately from that of school starting age, resulting in endogenous estimates. Estimating the effect of kindergarten or school enrolment timing on later human capital outcomes separately, without taking their inter-relatedness into account, may confound the two effects and produce biased results. This paper accounts for these confounders by estimating both starting ages in a joint model.

There is general agreement that the quality of the kindergarten program matters (Cascio, 2017; Duncan and Sojourner, 2013; Esping-Andersen et al., 2012; García et al., 2017) and that high quality programs have positive effects on student achievement (Almond and Currie, 2010; Heckman et al., 2013) such that more universal access to kindergarten results in higher academic achievement (Berlinski et al., 2008, 2009; Felfe et al., 2015). The effects of kindergarten are shown to be heterogeneous as participation is particularly beneficial for children with disadvantaged backgrounds, for whom the marginal productivity of parental time is, on average, lower in the human capital production function (Chiappori et al., 2017). However, the evidence concerning enrolment timing in kindergarten is mixed. Earlier literature observes both positive effects of earlier kindergarten enrolment on later academic performance (Drange and Havnes, 2015; Fletcher and Kim, 2016), the absence of any impact (Datta Gupta and Simonsen, 2010), and even negative effects (DeCicca and Smith, 2013; Elder and Lubotsky, 2009; Fort et al., 2016).

One explanation for these mixed results may be that the studies are prone to endogeneity issues, as they ignore an important confounding factor: school enrolment timing or so-called redshirting. Redshirting refers to the decision to delay school enrolment by one year. When choosing the school enrolment age, parents choose between staying one more year in kindergarten or sending their child to school (Black et al., 2010). Staying in kindergarten for an additional year has a lower marginal benefit for children who started kindergarten earlier;

thus, they are less likely to decide to delay the school enrolment time. Moreover, due to capacity constraints, the kindergarten is likely to encourage children who have been attending the early childhood institution for a longer time to enrol in school. Omitting school enrolment timing from the regressions may lead to biased estimates of the effect of kindergarten enrolment timing. The direction of the bias is likely to be in the negative direction, as earlier school enrolment has a negative effect on human capital (Bedard and Dhuey, 2006; Elder and Lubotsky, 2009; McEwan and Shapiro, 2008; Puhani and Weber, 2008).

Delaying school with one more year may have a positive effect on academic achievement through various channels. First, the *age effect* implies that those who entered school one year later are, on average, older at the time of the tests, which may result in higher scores if they are measured by a test at the same calendar date in the same grade. Black et al. (2010) show that a large part of the positive effects of later school enrolment stems from the age effect. In fact, the net effect of later school starting is estimated to be small and negative, while age at testing was positive and significant. Second, the *maturity effect* denotes that entering school as a more developed child (e.g., better fine motor skills, higher perseverance, patience, and higher ability to concentrate) could foster self-confidence and motivation towards school activities which could last for years and result in higher grades, further increasing self-confidence. Bedard and Dhuey (2006) find that the oldest children in a class have 2-9% higher marks in 8th grade compared to their classmates, due to maturity differences at school entry. Borghans and Diris (2015) use a skill technology function to show that learning is more effective when the child is more mature. Third, the *relative maturity effect* accounts for the fact that children entering school one year later are more mature relative to their peers. This effect underlines the importance of the relative advantage of older children among their peers. Finally, we argued before that besides these three traditional channels, the choice to postpone school entry is likely to be correlated with kindergarten enrolment age, which may also impact the results of previous estimates.

This paper contributes to the literature by estimating the effect of later school enrolment age separately from that of kindergarten enrolment age. While we are not able to distinguish the age, maturity, and relative maturity effects, we are, to our best knowledge, the first to distinguish the interplay between kindergarten and school enrolment age. This is relevant from both an academic and policy perspective, as these enrolment dates trigger different mechanisms. In particular, children with earlier kindergarten enrolment benefit from earlier exposure to an institutional environment, socialisation, and learning opportunities, but also an increase in the time spent in kindergarten. Later school enrolment, on the other hand, may be beneficial due to the higher maturity level of children when they start their schooling (maturity effect); however, it also increases the time spent in kindergarten, as well as the age

of children when testing takes place (age effect). To gain more insight into the effects of kindergarten and school enrolment timing, we estimate a joint model where kindergarten and school enrolment decisions are likely affected by unobserved heterogeneity, for instance, in children's ability and other factors.

Our identification strategy exploits two exogenously set cutoff dates which determine the eligibility age for kindergarten (January 1st) and school (June 1st). Our paper is closely related to Black et al. (2010), who used a cutoff date and constructed an instrument that predicts the individuals' expected school enrolment ages based on their birthdates. In a similar vein, we use two variables to instrument the observed kindergarten and school enrolment ages, and as a result, we can estimate the effect of kindergarten enrolment age conditional on school enrolment age, and the effect of school enrolment age conditional on kindergarten enrolment age.

This paper focusses on Hungary, which makes an interesting application. First, we have exceptionally rich data to study the effect of the timing of kindergarten and school enrolment on human capital formation at later ages. Second, the Hungarian law defines strict cutoff dates, which we exploit in our identification strategy. Third, the correlation between kindergarten and school enrolment age is around 0.35, which is approximately the average of the OECD countries, so our findings have a large external validity (see Figure A1).

Our results suggest that both earlier kindergarten enrolment and later school enrolment have significant and non-negligible positive effects on reading and math scores. Nevertheless, the estimated effect is fading out over time, as the estimates are gradually decreasing from grade 6 through grade 8 till grade 10. This decreasing effect is more pronounced for school starting age than for kindergarten starting age. Our results further point to heterogeneous effects as the children of low educated mothers, and disadvantaged children in general, benefit more than others from earlier kindergarten enrolment as well as delayed school entry. In fact, while later school enrolment seems to benefit both high and low status children, an earlier kindergarten enrolment age seems to matter only for the children of low educated mothers.

This paper unfolds as follows. In Section 2 we describe the institutional framework. Section 3 discusses the data and identification strategy, while Section 4 presents the baseline results and various robustness tests. A final section concludes.

2. INSTITUTIONAL FRAMEWORK

In Hungary at age 3, children can enrol in state-subsidized kindergartens, which have a country-wide coverage rate of about 90 percent. Enrolment is compulsory only from the age of 5 onwards. There are clear rules for eligibility as children older than 3 on September 1 are

entitled to enrol, but if places remain available, younger children can also apply. Practically, this results in a cutoff birthdate at January 1st, implying that most children born in September-December can enrol once they reached the age of 3, while those born on January 1st or later can only enrol by September.[1]

Contrary to nursery schools, kindergartens focus on educating children. All kindergartens have a pedagogical program that follows centrally set guidelines. In these programs, there are practically no pre-school elements, such as making children familiar with the letters of the alphabet. Rather, they focus on the improvement of social competencies and are quite rich in visual and musical arts, drama, basic mathematics, and physical education, including the development of fine motor skills.

At the age of 6 or 7, children can enrol in formal education. The rules for eligibility result in two cutoff dates. Those born in September-December are required to enrol in primary school in September after they turn 6 unless a parental request for redshirting is submitted and approved by their childcare institution and the local government Developmental Advisory Board. The process includes a standardised evaluation process conducted by developmental experts, which is free of charge but imposes time and travel costs on parents. Those born in January-May are also required to enrol at age 6; however, they face a smaller administrative barrier to redshirting, in that the parental request only requires the approval of the childcare institution. Those born in June-August are required to enrol in a primary school in the September following their 7th birthday.

3. DATA

Our data, the National Assessment of Basic Competencies (NABC), consists of a rich and comprehensive standard-based assessment of mathematics and reading that follows the model of the Programme for International Student Assessment (PISA). This assessment is conducted yearly in May and covers all students in grades 6 and 8 (lower secondary education), and grade 10 (upper secondary) during the period 2008 to 2015.[2] In addition to test scores, the database contains extensive information on students' backgrounds, including proxies for the socio-economic status of the students.

[1] Between ages of 5 months to 3 years, state subsidized nursery school is available for around 13% of children. Children with employed parents and from disadvantaged backgrounds, single parents, or those with siblings are given priority in the acceptance rules. Eligibility and acceptance are not linked to the date of birth in any case. Nevertheless, the parents of children who have, due to the date of birth, a disadvantage in kindergarten enrolment at age 3 may have stronger incentives to ensure a place in nursery school for their child and to enrol at an earlier age in nursery. If this is the case, our measurement of the effect of kindergarten enrolment age is biased towards zero, that is, we are underestimating the kindergarten enrolment timing effect.

[2] Due to data consistency issues with the coding of some of the variables in 2008 we use subsample of the data for years 2009-2015.

Due to missing data issues in some key variables, the regressions are run on 64% of the original data. Most of the observations had to be dropped due to missing values. [3] However, to avoid endogeneity issues resulting from measurement errors or unobserved heterogeneity, we disregard individuals who started school either before age 6 or after age 8, or started kindergarten before age 2 years and 7 months. This corresponds to about an additional 5% of the regression sample, resulting in a final sample of about 1.33 million student level observations. In the 2009-2015 sample, there are at least 229,654 students per year, and at least 75,788 students in a grade.[4]

In the NABC data, we observe several cognitive outcomes: standardised literacy and numeracy test scores, class marks as given by the teacher, as well as the student's grade point average (GPA) in 6th, 8th and 10th grade. We also observe a non-cognitive outcome, specifically the student's plans to continue studies in higher education. For students in the 10th grade, we observe the type of track the student had chosen, i.e. academic versus non-academic, and those offering maturity certificates versus those that do not. Table 1 summarises the statistics of the outcome variables we study. The mathematics and reading scores are standardised to have mean zero and standard deviation 1 in each year. Grades given by the teacher go from 1, standing for the worst, to 5, indicating the best possible performance. "Higher education plans" is a dummy variable equal to 1 if the student plans to go on with their studies, and 0 otherwise.

Table 1

The NABC database – mean and standard deviation of all outcome variables

Outcome variable	Mean	SD
Standardized math score	0.010	0.996
Standardized reading score	0.012	0.995
Plans to enter higher education	0.526	0.499
Student's grade point average of last term	3.811	0.811
Mark of last term: literacy	3.308	1.140
Mark of last term: grammar	3.605	1.039
Mark of last term: literature	3.751	1.066
Mark of last term: mathematics	3.278	1.148

Note: 'Mark of last term' is given by the teacher and ranges from 1 to 5.

[3] See Table AR.1 in the "appendix for review" for the reasons of data dropping. To test whether the dropped cases have affected our estimation we have regressed our instruments (see below) on the missing dummy (=1 if a case is still in our baseline regression). Apparently, the instruments are orthogonal to missing observations (see table AR.2 in the" appendix for review").

[4] To test whether this dropping of observations have affected the results, we have tried a couple of imputations (see tables AR.4 and AR.5). Results are robust to the deletion of these cases.

Table 2

The NABC database – mean and standard deviation of all independent variables

Control variable	Mean	SD
Female	0.499	0.500
Special Education Needs	0.002	0.041
Entitled for cheap meal	0.183	0.386
Entitled for free meal	0.135	0.342
Student receives textbook free in school	0.385	0.487
Student lives in own family	0.860	0.347
Number of siblings living together	1.317	1.082
Mother's education: elementary	0.147	0.354
Mother's education: vocational	0.236	0.425
Mother's education: high school	0.264	0.441
Mother's education: university	0.205	0.404
Father's education: elementary	0.137	0.344
Father's education: vocational	0.224	0.417
Father's education: high school	0.192	0.394
Father's education: university	0.135	0.342
Age of student's mother/foster-mother	41.04	5.784
Age of student's father/foster-father	44.03	7.131
At least one car in the HH	0.618	0.486
At least one bathroom in the HH	0.821	0.384
At least 150 books in the HH	0.414	0.493
Internet connection in student's home	0.757	0.429
Student has own desk	0.785	0.411
Mother is employed	0.651	0.477
Father is employed	0.710	0.454
Family helps in HW at least once in a week	0.366	0.482
Large city	0.411	0.492
City	0.396	0.489
Small city	0.192	0.394
Region: Central Hungary	0.272	0.445
Region: Central Transdanubia	0.108	0.310
Region: Western Transdanubia	0.096	0.295
Region: Southern Transdanubia	0.092	0.289
Region: Northern Hungary	0.130	0.336
Region: Northern Great Plain	0.175	0.380
Region: Southern Great Plain	0.128	0.334

Finally, we observe a variety of individual and parental background characteristics, including gender, special education needs,[5] entitlement to a cheap or free meal, whether student is living with their own family, their mother's and father's level of education, employment status, and age, whether the student's family has a car, a bathroom with public

[5] Table AR.6 in Appendix shows the results of a sample without special needs students. The results suggest that our baseline results are very robust for dropping special needs students.

utilities, an internet connection at home, the number of books at home, whether the student has a desk, and whether the family helps the student with her homework (see Table 2). To reduce the problem of missing data, as most background variables were self-reported, we transform all variables into dummies and include a dummy for missing values.

4. EMPIRICAL METHODOLOGY

There are three intertwined factors that potentially affect the students' human capital: kindergarten starting age (KSA), the length of enrolment in kindergarten (years in kindergarten, YKG), and school starting age (SSA). As the SSA equals the KSA plus the YKG, only two out of the three factors can be simultaneously included in the estimation. Consequently, the effects cannot be clearly separated.[6] These three factors are likely endogenous for several reasons. First, enrolment decisions and decisions to stay in kindergarten may reflect unobserved heterogeneity in the cognitive and psychological development or ability level of the child. Second, parental tastes and preferences influence these decisions, which may be related to complementary human capital investments such as the allocation of parental time. Third, there might be residential selection if high socio-economic status groups migrate to locations with higher institutional availability, since both kindergarten and school enrolment decisions are constrained by the availability of local kindergarten spots.

To account for these sources of endogeneity, we apply an instrumental variables technique where the instruments mimic the expected enrolment ages such that the endogenous part of the enrolment age is captured. In particular, we define the Expected School Starting Age (ESSA) as an instrument for actual school starting age (in line with Black et al., 2010). This is defined as:

$$ESSA = \begin{cases} 6 + \frac{(9-mob)}{12} \; if \; mob < 6 \\ 7 + \frac{(9-mob)}{12} \; if \; mob \geq 6 \end{cases} \qquad (1)$$

where *mob* denotes the month of birth. The ESSA is calculated for each individual based on the actual enrolment rules, which, in practice, may be overridden by the parents' decision. As a result, ESSA is determined merely by the date of birth and enrolment rules, but it is correlated with actual enrolment age. Similarly, we define the Expected Kindergarten Starting Age (EKSA) as an instrument of the actual kindergarten starting age (2). This is defined as:

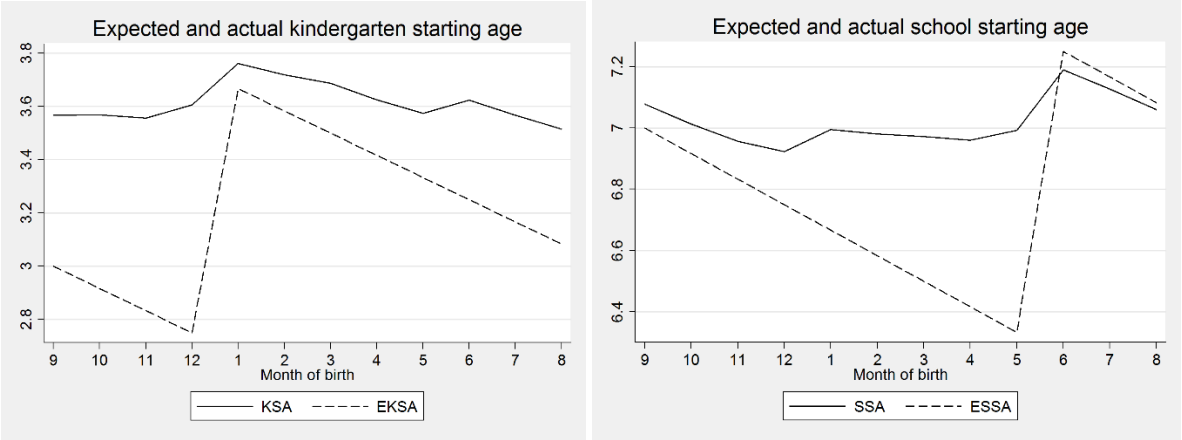
[6] Theoretically, it is possible that someone misses a year in kindergarten, and thus this equation would not hold for everyone. However, in practice, this is an unlikely event.

$$EKSA = 3 + \frac{(9-mob)}{12} \quad (2)$$

Figure 1 presents the actual and expected (i.e. the instrument) starting age in kindergarten and school, by month of birth. The figure suggests that, on average, the actual and the expected starting age of the children are correlated, and the expected age variables are potentially strong instruments.

Figure 1

Expected and actual enrolment ages in kindergarten (left panel) and school (right panel)



Note: (E)KSA denotes the (Expected) Kindergarten Starting Age, while (E)SSA stands for (Expected) School Starting Age.

Using these two instruments, we estimate a two-stage least squares (2SLS) model with a first stage for each instrument. The first stage equations are:

$$KSA_{iys} = \delta_{10} + \delta_{11} EKSA_{iys} + \delta_{12} ESSA_{iys} + \gamma_1{}' X_{iys} + \mu_{1y} + \vartheta_{1s} + \varepsilon_{1iys} \quad (3)$$

$$SSA_{iys} = \delta_{20} + \delta_{21} EKSA_{iys} + \delta_{22} ESSA_{iys} + \gamma_2{}' X_{iys} + \mu_{2y} + \vartheta_{2s} + \varepsilon_{2iys} \quad (4)$$

where $EKSA_{iys}$ and $ESSA_{iys}$ denote the EKSA and ESSA for child *i* in year *y* and school *s*. X_{iys} is a vector of a rich set of individual and family characteristics that include gender, special education needs, entitlement to a cheap or free meal, and all other variables defined in section 3. Finally, we include year fixed effects, μ_y, and school fixed effects, ϑ_s, to control for time and school specific unobserved heterogeneity.

The second stage structural equation is the following:

$$Y_{iys} = \beta_0 + \beta_1 \widehat{KSA}_{iys} + \beta_2 \widehat{SSA}_{iys} + \gamma_3{}' X_{iys} + \mu_{3y} + \vartheta_{3s} + \xi_{iys} \quad (5)$$

where Y_{iys} denotes the outcome variable of child i. We consider five cognitive and non-cognitive outcome variables. For two of them, math and reading test scores, the scores are annually standardized to mean 0 and standard deviation 1. In addition, we use class marks given by the teacher, higher education aspirations and track choice as outcome variables. We estimate robust standard errors clustered at the kindergarten catchment area level.[7] Our main variables of interest are β_1 and β_2, which estimate the causal effect of KSA (SSA) conditionally on SSA (KSA), respectively.[8]

5. RESULTS

5. a FIRST STAGE RESULTS

The first stage results, as presented in Table 3, suggest that the instruments strongly correlate with the endogenous variables.

Table 3

First-stage results as presented in Equation 3 and 4

	KSA	SSA
Expected Kindergarten Starting Age (EKSA)	0.261***	0.162***
	(0.000)	(0.000)
Expected School Starting Age (ESSA)	-0.058***	0.234***
	(0.000)	(0.000)
N	448,898	448,898
Adj. R2	0.149	0.098
Time FE	Yes	Yes
School FE	Yes	Yes
Demographic controls	Yes	Yes
Number of clusters (KG catchment area)	1,734	1,734

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

In particular, conditional on the ESSA, an increase in the EKSA results in an increase in the KSA, and similarly, conditional on the EKSA, an increase in the ESSA lowers the KSA. The latter negative correlation is likely driven by children born in the summer, as those

[7] Catchment areas are based on actual kindergarten commuting data, and the areas are constructed so that commuting is maximized within areas and minimized between areas.

[8] The IV identification strategy estimates the local average treatment effect (LATE) for the compliers (i.e. these children who enrol in kindergarten or school based on the expected starting age). Oreopoulos (2006) argues that the LATE converges to the average treatment effect if the percentage of compliers increases in the sample. In our sample 67.5% comply with kindergarten and 75.3% with school enrolment rules.

children have a high ESSA, but a relatively low KSA. As can be observed from the second column, both the EKSA and the ESSA correlate positively with the SSA.[9]

5.b SECOND STAGE RESULTS

Table 4 (reading) and Table 5 (math) present the endogenous OLS results, as well as the causal second stage IV estimates for the grade 6 sample, which serves as the baseline sample. Columns 1-4 show the unconditional effects of KSA and SSA on reading (Table 4) and math (Table 5) test scores. The OLS estimates suggest that the later a child starts kindergarten, the lower her later test scores are. However, the instrumented 2SLS regressions indicate that later kindergarten enrolment has an insignificant effect on test scores (small and marginally significant negative effect on reading and no effect on math). This result is in line with the findings of Datta Gupta and Simonsen (2010), and Kühnle and Oberfichtner (2017) where school starting age is not controlled for directly in the estimates. Columns 3-4 indicate that, while the naive association of SSA and test scores is negative (possibly due to selection issues), the instrumented regressions suggest that later school enrolment increases later test scores. This finding is in line with the related literature (Altwicker-Hámori and Köllő, 2012; Bedard and Dhuey, 2012; Elder and Lubotsky, 2009; McEwan and Shapiro, 2008; Puhani and Weber, 2008).

Columns 5-6 demonstrate that including both KSA and SSA in the regression simultaneously changes the coefficients significantly. This suggests that ignoring these confounding variables (as in columns 1-4), might result in biased estimates. For instance, the 2SLS coefficient of KSA in column 2 of Table 5 suggests that enrolling into kindergarten has no effect on later math test scores, while the coefficient in column 6 is negative and highly significant. As KSA is positively correlated with SSA, and SSA likely has a positive impact on test scores, the KSA coefficient in the separate specification suffers from an upward bias. When KSA and SSA are included simultaneously in the regression, both coefficient estimates decrease and become significant at the 1% level. The instrumented effect of KSA on test scores decreases from -0.017 to -0.073 in reading and -0.005 to -0.058 in math, while the effect of SSA decrease from 0.396 to 0.299 in reading and from 0.359 to 0.279 in math.

[9] Additional empirical tests indicate that EKSA and ESSA serve as strong instruments. In particular, the Kleibergen-Paap rk Wald F-statistic is with 514.65 high, as well is the Cragg-Donald Wald F-statistic (5140.09). The underidentification test (Kleibergen-Paak rk LM statistic equal to 57.42) and the Stock-Yogo weak ID test (7.03) do not signal any issues. The correlation of ESSA with KSA is only negative conditional on the EKSA, which shows the importance of measuring both variables in a joint model.

Examining columns 5-10 together offers deeper insight into the interpretation of the estimated coefficients. When we look at the effect of increasing KSA while holding SSA constant in columns 5-6, we must also consider the consequent decrease in the number of years spent in kindergarten. That is, the effect of KSA, conditional on SSA, shows the *joint effect* of increasing kindergarten enrolment age and decreasing the number of years spent in kindergarten. Similarly, if we look at the effect of SSA on test scores and hold KSA constant, we actually estimate the joint effect of increased school enrolment age and increased years spent in kindergarten. Columns 7-10 represent the flip side of the coin. In Columns 7-8 we can see the effect of SSA on test scores, conditional on the years spent in KG. Here, the 2SLS coefficient of SSA (0.237 for reading and 0.234 for math) shows how much the test score would increase if we increased SSA and KSA at the same time while holding years spent in kindergarten constant. The 2SLS coefficients of years spent in kindergarten (0.072 for reading and 0.053 for math) show the effect of an additional year spent in kindergarten, holding SSA fixed, which can only be achieved by enrolling into kindergarten a year earlier. Note that the coefficient estimates of years spent in kindergarten in columns 7-8 are – by definition – the same (but reversed in sign) as the KSA coefficients in columns 5-6. The estimates in columns 9-10 can be interpreted similarly. Notice that our results show that it is difficult to interpret any causal estimates of kindergarten or school enrolment age, as they necessarily correlate with each other and years spent in kindergarten.

In the following sections, we focus on estimates in column 6 in Table 4 and Table 5. These indicate that in the same year and same school, holding various demographic variables constant and also holding SSA fixed, enroling in kindergarten one year later and at the same time decreasing the years spent in kindergarten by one year decreases reading (math) test scores significantly, by 7.3% (5.8%) of a standard deviation. Similarly, ceteris paribus, increasing SSA as well as the years spent in kindergarten by 1 year, increases reading (math) test scores significantly by 29.9% (27.9%) of a standard deviation.

Table 4

Reading scores in grade 6 (OLS and 2SLS results)

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS	(7) OLS	(8) 2SLS	(9) OLS	(10) 2SLS
KG starting age (KSA)	-0.058***	-0.017			-0.048***	-0.073***			-0.145***	0.225***
	(0.003)	(0.017)			(0.003)	(0.014)			(0.004)	(0.026)
School starting age (SSA)			-0.119***	0.396***	-0.097***	0.299***	-0.135***	0.237***		
			(0.004)	(0.025)	(0.004)	(0.021)	(0.004)	(0.023)		
Years in KG							0.039***	0.072***	-0.097***	0.299***
							(0.003)	(0.013)	(0.004)	(0.021)
Observations	448903	448898	477420	477414	448903	448898	454509	454502	448903	448898
Adjusted R^2	0.343	0.343	0.341	0.304	0.345	0.323	0.348	0.326	0.345	0.323
AIC	1057125.251	1057493.388	1131210.820	1157299.563	1056250.376	1070668.130	1070100.146	1085269.578	1056250.376	1070668.130

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

Table 5

Math scores in grade 6 (OLS and 2SLS results)

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS	(7) OLS	(8) 2SLS	(9) OLS	(10) 2SLS
KG starting age (KSA)	-0.076***	-0.005			-0.061***	-0.058***			-0.207***	0.221***
	(0.003)	(0.018)			(0.003)	(0.014)			(0.004)	(0.023)
School starting age (SSA)			-0.170***	0.359***	-0.147***	0.279***	-0.194***	0.234***		
			(0.004)	(0.028)	(0.004)	(0.021)	(0.004)	(0.022)		
Years in KG							0.050***	0.053***	-0.147***	0.279***
							(0.002)	(0.013)	(0.004)	(0.021)
Observations	448903	448898	477420	477414	448903	448898	454509	454502	448903	448898
Adjusted R2	0.321	0.319	0.320	0.281	0.324	0.299	0.326	0.301	0.324	0.299
AIC	1077106.235	1078156.529	1150799.789	1177269.785	1075190.145	1091516.814	1089773.953	1106682.132	1075190.145	1091516.814

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

Next, consider the estimates of the model specification in Table 6, where KSA and SSA are jointly estimated in a 2SLS model for grade 6, 8 and 10. The estimates suggest that all effects decrease significantly over time. While the effect of SSA on test scores in grade 6 is over a quarter of a standard deviation for both math and reading, by grade 10, it decreases to 0.019 and becomes insignificant in math, and decreases to 0.056 but remains significant in reading. This corresponds to a decrease in effect size of 93 and 81 percent, respectively. A decrease in the effect sizes of KSA is also apparent through the grades, but is smaller in magnitude, around 65 percent. The initial 0.058-0.073 effects in grade 6 decrease to around 0.019-0.025 by grade 10. While the effects of both the SSA and the KSA are decreasing as new human capital is added in later grades (such that the effect of the enrolment starting age fades out), the larger decrease in SSA compared to KSA might be explained by the fact that age effects in later school enrolment diminish through grades.

Table 6

Math and reading scores in grade 6, 8 and 10 (2SLS results)

	Math			Reading		
	Grade 6	Grade 8	Grade 10	Grade 6	Grade 8	Grade 10
KG starting age (KSA)	-0.058***	-0.024*	-0.019	-0.073***	-0.046***	-0.025*
	(0.014)	(0.012)	(0.013)	(0.014)	(0.013)	(0.012)
School starting age (SSA)	0.279***	0.155***	0.019	0.299***	0.189***	0.056***
	(0.021)	(0.017)	(0.015)	(0.021)	(0.019)	(0.015)
Observations	448898	450898	438440	448898	450898	438440
Adjusted R2	0.299	0.315	0.474	0.323	0.338	0.491
AIC	1091516.814	1085375.649	950054.422	1070668.130	1064921.378	931554.078

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects. The full list of coefficients are reported in Table AR.3.*

As earlier literature suggests that the effect of school and kindergarten starting age is larger for low status families (Chiappori et al., 2017), Table 7 presents the heterogeneous effects for low (upper panel) and high (lower panel) educated mothers.[10] As expected, both SSA and KSA have a higher effect on the test scores of children with low educated mothers in all grades, except for KSA in grade 10 in reading. This indicates that low status students benefit more from earlier kindergarten enrolment or a later school enrolment age (and the corresponding increase in years spent in kindergarten) than their high-status peers, which is in line with parental human capital investments being substitutes.

The estimations are carried out for various further outcome variables in the Appendix Tables A1-A6. The results are in line with those presented so far. A one-year increase in KSA (SSA) decreases (increases) average literacy, grammar, literature and mathematics marks by .03-.04 (.19-.26) in 6th grade, which is about 2.5% (18%) of the standard deviation. The KSA effects fade out in grade 8, but some of the SSA effects remain significant until grade 10. KSA and SSA have a significant effect on the probability that a student plans to enter higher education, but the effects are higher and more significant for students with lower educated mothers.

Finally, we examine the effects by gender. Table 8 indicates that boys are much more affected by kindergarten and school enrolment timing decisions both in terms of their reading and math scores. SSA increases test scores by about 35% of a standard deviation, while the same effect is less than 70 percent of that, around 24% in case of females. The KSA effect is 7.5% on math and 10.7% on reading scores for males, and 25 and 30 percent lower (6.4 and 7.5 percent) for females, respectively. This is in line with previous literature, which finds that the cognitive outcomes of low status boys are more sensitive to early environmental influences compared to their high-status or female peers of any background (Chetty et al., 2016; Currie and Schwandt, 2016).

[10] Low (high) educated is measured as mothers without (with) maturity exam.

Table 7

Math and reading scores in grade 6, 8 and 10 by mother's education (2SLS results)

	Low educated mothers					
	Math			Reading		
	Grade 6	Grade 8	Grade 10	Grade 6	Grade 8	Grade 10
KG starting age (KSA)	-0.101**	-0.053*	-0.005	-0.094***	-0.050*	-0.001
	(0.031)	(0.024)	(0.022)	(0.028)	(0.023)	(0.024)
School starting age (SSA)	0.342***	0.186***	0.062**	0.384***	0.231***	0.117***
	(0.036)	(0.028)	(0.024)	(0.032)	(0.029)	(0.024)
Observations	184309	174655	163258	184309	174655	163258
Adjusted R2	0.230	0.242	0.377	0.225	0.256	0.410
AIC	440355.085	415047.707	352418.207	433657.832	411547.846	352997.663
	High educated mothers					
	Grade 6	Grade 8	Grade 10	Grade 6	Grade 8	Grade 10
KG starting age	-0.034*	-0.012	-0.027	-0.060***	-0.047**	-0.038**
	(0.017)	(0.015)	(0.018)	(0.016)	(0.015)	(0.015)
School starting age	0.237***	0.128***	-0.009	0.241***	0.154***	0.014
	(0.026)	(0.020)	(0.019)	(0.026)	(0.021)	(0.020)
Observations	264515	276171	275139	264515	276171	275139
Adjusted R2	0.204	0.239	0.436	0.218	0.245	0.443
AIC	644902.700	663216.029	593673.944	632060.103	647079.867	574286.347

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects. The panel above presents the results for low educated mothers, while the panel below shows the estimates for the high educated mothers.*

Table 8

Math and reading scores in grade 6 by gender (2SLS results)

	Math		Reading	
	Male	Female	Male	Female
KG starting age	-0.075**	-0.064***	-0.107***	-0.075***
	(0.025)	(0.018)	(0.023)	(0.018)
School starting age	0.341***	0.239***	0.366***	0.252***
	(0.039)	(0.022)	(0.043)	(0.024)
Observations	233903	232058	233950	232096
Adjusted R2	0.312	0.316	0.317	0.346
AIC	580413.544	546208.485	566620.312	540074.651

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

6. CONCLUSION

This paper examined the effect of school enrolment age separately from that of kindergarten enrolment age on standardised math and reading test scores in grade 6, 8, and 10, on class marks for four subjects as given by the teacher, on track choice, and on aspirations for higher education. Using a rich and comprehensive Hungarian dataset, we showed that estimating the effect of kindergarten or school enrolment timing on later human capital outcomes separately, without taking their inter-relatedness into account, confounds the two effects and produces biased results. This may explain why previous studies on earlier kindergarten enrolment find little or no effect on later outcomes: earlier kindergarten enrolment decreases the likelihood of later school enrolment, and the beneficial effect of the first may be confounded by the negative effect of the latter.

We show that both earlier kindergarten enrolment and later school enrolment have a significant and non-negligible positive effect on (almost) all outcomes. These effects decrease over time: they are larger in grade 6 than in grade 8, and much larger than in grade 10. This decline in the effect over the grades is more pronounced for school starting age than for kindergarten starting age, which we assume to be due to the decreasing importance of age effects (being a year older in grade 6 matters more than in grade 10). As the effect of kindergarten starting age cannot be driven by age effects, the decrease over grades is less pronounced. The analysis further shows that the children of low educated mothers and the disadvantaged benefit more than others from earlier kindergarten enrolment as well as later school enrolment. In fact, while later school enrolment seems to benefit both high and low

status children, earlier kindergarten enrolment seems to matter only for the children of low educated mothers.

Our estimates need to be interpreted with an important caveat in mind. Decreasing the kindergarten enrolment age while keeping the school enrolment age constant increases, by definition, the number of years spent in kindergarten, which also affects human capital development. Thus, our estimate of the effect of an earlier kindergarten enrolment age includes the direct effects of earlier kindergarten enrolment (for instance, the substitution of family resources in childcare to institutional resources), as well as those of increased time spent in kindergarten. Similarly, postponing school enrolment age, conditional on kindergarten enrolment age, will increase the number of years spent in kindergarten. Thus, the estimated effect of later school enrolment might come from being older than the others at the time of the test (age effect), being more mature than others at the time of school enrolment (maturity effect), *or* spending more time in kindergarten. What we estimate is the (joint) effect of kindergarten starting age (and years spent in kindergarten) and school starting age (and years spent in kindergarten) on various schooling outcomes.

In terms of policy implications, we believe that earlier kindergarten enrolment has some straightforward policy implications. Postponing the school enrolment age of all children might not increase their human capital as much as our estimates suggest, due to the age effect, however, an earlier kindergarten enrolment age has a clear, direct effect on the future outcomes of the children, especially for the disadvantaged.

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APPENDIX

Table A1

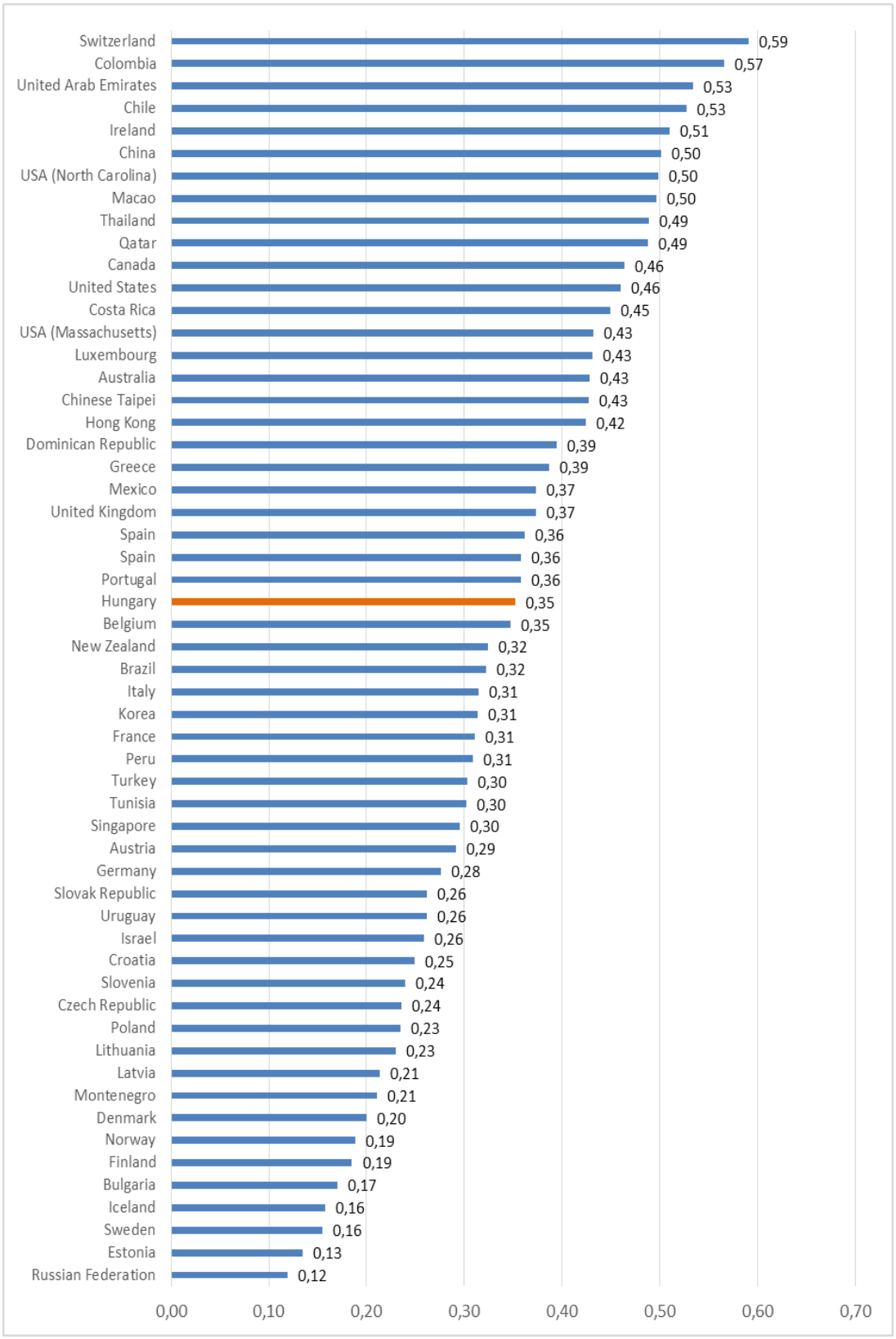
Correlation matrix of kindergarten starting age (KSA), school starting age (SSA) and years spent in kindergarten (YKG)

Pearson correlation	KSA	SSA	YKG
Kindergarten starting age (KSA)	1		
School Starting age (SSA)	0.301***	1	
Years spent in kindergarten (YKG)	-0.778***	0.216***	1

*Note: Significance: *** 1%; ** 5%; * 10%. Source: National Assessment of Basic Competencies, Hungary, 2009-2015.*

Figure A1

Correlation of kindergarten starting age (KSA) and school starting age (SSA) in OECD countries



Source of data: PISA 2015.

Table A2

Additional outcome variable: Plans to enter higher education

(2SLS, grade 6, 8 and 10)

	Plans for higher education		
	Grade 6	Grade 8	Grade 6
KG starting age	-0.017*	-0.021***	-0.015*
	(0.007)	(0.006)	(0.006)
School starting age	0.078***	0.053***	0.023**
	(0.012)	(0.009)	(0.008)
Observations	413410	397028	395632
Adjusted R2	0.332	0.340	0.449
AIC	428761.727	405906.132	335516.274

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects. The "Plans for higher education" indicate the change in the probability of a student reporting that she/he plans to continue her/his studies in higher education.*

Table A3

Additional outcome variable: Last term grade point average

(2SLS, grade 6, 8 and 10)

	Last term GPA		
	Grade 8	Grade 6	Grade 8
KG starting age	-0.007	-0.002	0.000
	(0.011)	(0.010)	(0.012)
School starting age	0.159***	0.114***	0.015
	(0.016)	(0.015)	(0.014)
Observations	365955	360056	362144
Adjusted R2	0.368	0.340	0.360
AIC	671266.195	684903.039	692816.340

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

Table A4

Additional outcome variables: Plans for higher education in grade 6, 8 and 10 by mother's education (2SLS results)

	Plans for higher education		
	Low educated mothers		
Sample	Grade 6	Grade 8	Grade 10
KG starting age	-0.022	-0.036***	-0.029*
	(0.012)	(0.010)	(0.011)
School starting age	0.123***	0.081***	0.048***
	(0.018)	(0.014)	(0.011)
Observations	177910	170297	160537
Adjusted R2	0.120	0.164	0.330
AIC	187678.785	176629.667	139071.859
	High educated mothers		
Sample	Grade 6	Grade 8	Grade 10
KG starting age	-0.011	-0.013	-0.006
	(0.010)	(0.007)	(0.007)
School starting age	0.042***	0.032**	0.005
	(0.012)	(0.011)	(0.010)
Observations	235411	226634	235045
Adjusted R2	0.172	0.187	0.366
AIC	239326.790	225701.397	193493.760

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

Table A5

Class grades as given by the teacher (2SLS, by mother's education)

	Grade 6							
	Low educated				High educated			
	Literacy	Grammar	Literature	Mathematics	Literacy	Grammar	Literature	Mathematics
KG starting age	-0.084*	-0.094**	-0.057	-0.111**	-0.001	-0.013	0.005	-0.001
	(0.036)	(0.031)	(0.031)	(0.039)	(0.023)	(0.015)	(0.016)	(0.023)
School starting age	0.318***	0.299***	0.302***	0.401***	0.135***	0.156***	0.117***	0.177***
	(0.044)	(0.040)	(0.040)	(0.041)	(0.025)	(0.027)	(0.023)	(0.027)
Observations	174407	174086	173871	184309	233339	232882	232693	264515
Adjusted R2	0.160	0.207	0.216	0.172	0.169	0.200	0.202	0.229
AIC	482382.662	455653.840	463347.718	505428.595	610522.858	559444.254	534458.075	689482.723
	Grade 8							
	Low educated				High educated			
	Literacy	Grammar	Literature	Mathematics	Literacy	Grammar	Literature	Mathematics
KG starting age	-0.051	-0.062*	-0.059*	-0.064*	0.001	-0.006	0.021	0.003
	(0.030)	(0.029)	(0.028)	(0.026)	(0.023)	(0.016)	(0.020)	(0.017)
School starting age	0.180***	0.225***	0.213***	0.179***	0.068**	0.073**	0.030	0.140***
	(0.035)	(0.036)	(0.035)	(0.034)	(0.024)	(0.023)	(0.020)	(0.023)
Observations	163768	163516	163400	174666	221301	220902	220936	276178
Adjusted R2	0.163	0.220	0.227	0.166	0.168	0.220	0.216	0.216
AIC	445937.668	422853.881	428506.540	466574.180	595868.136	534658.807	512801.224	757317.157
	Grade 10							
	Low educated				High educated			
	Literacy	Grammar	Literature	Mathematics	Literacy	Grammar	Literature	Mathematics
KG starting age	0.000	-0.043	-0.013	-0.058	0.017	-0.018	-0.026	0.021
	(0.034)	(0.031)	(0.033)	(0.030)	(0.020)	(0.019)	(0.021)	(0.019)
School starting age	0.005	0.067*	0.087**	0.012	-0.082**	0.043*	0.039	-0.029
	(0.033)	(0.029)	(0.031)	(0.029)	(0.030)	(0.021)	(0.024)	(0.030)
Observations	154020	153258	151984	163258	226430	225900	225567	275139
Adjusted R2	0.123	0.188	0.176	0.144	0.227	0.306	0.288	0.276
AIC	433700.124	398757.643	412393.671	435573.309	643467.764	564643.678	591144.549	763812.432

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

Table A6

School track choice in grade 10 by mother's education (2SLS results)

	Low educated mothers	
	Academic vs. Vocational	Academic vs. Vocational
KG starting age (KSA)	0.008	0.007
	(0.006)	(0.012)
School starting age (SSA)	0.016**	0.041***
	(0.006)	(0.010)
Observations	163258	163258
Adjusted R2	0.800	0.518
AIC	-90998.977	99977.102
	High educated mothers	
	Academic vs. Vocational	Academic vs. Vocational
KG starting age (KSA)	0.000	-0.000
	(0.004)	(0.004)
School starting age (SSA)	0.006	0.010
	(0.005)	(0.005)
Observations	275139	275139
Adjusted R2	0.874	0.485
AIC	-173190.580	-81217.636

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*
Results for the low and high educated mothers are presented in the upper and lower panel, respectively.

APPENDIX FOR REVIEW

Table AR.1.

Loss of data due to missing values

	Remaining sample size	Loss (%)	Loss (# obs.)
Total	2,019,277		
Missing birth date (missing EKSA or ESSA)	1,945,653	4%	73,624
Missing SSA or KSA	1,768,379	9%	177,274
Missing catchment area	1,533,336	13%	235,043
Missing weight	1,408,563	8%	124,773
Subtotal	**1,408,563**	**34%**	**610,714**
Out of range values of KSA or SSA	1,338,269	4.99%	70,294
Total	***1,338,269***	***39%***	***681,008***

Table AR.2.

Association of the instruments with missing observations

	(1) missing
Expected School Starting Age	-0.002
	(0.001)
Expected KG Starting Age	-0.002
	(0.001)
Observations	1945653
Adjusted R^2	0.282
AIC	1960442.657

Year and grade fixed effects are included. Standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table AR.3.

Math and reading scores in grade 6, 8 and 10 (2SLS results) – full table

	Math standardized test score			**Reading** standardized test score		
	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)	Grade 6 (4)	Grade 8 (5)	Grade 10 (6)
KG starting age	-0.058***	-0.024*	-0.019	-0.073***	-0.046***	-0.025*
	(0.014)	(0.012)	(0.013)	(0.014)	(0.013)	(0.012)
School starting age	0.279***	0.155***	0.019	0.299***	0.189***	0.056***
	(0.021)	(0.017)	(0.015)	(0.021)	(0.019)	(0.015)
Special Education Needs	-0.396***	-0.357***	-0.414***	-0.364***	-0.320***	-0.450***
	(0.029)	(0.033)	(0.036)	(0.030)	(0.036)	(0.037)
Female	-0.092***	-0.113***	-0.337***	0.242***	0.236***	0.107***
	(0.010)	(0.009)	(0.004)	(0.005)	(0.005)	(0.003)
Not entitled for cheap meal	0.112***	0.064***	-0.021*	0.088***	0.053***	0.007
	(0.007)	(0.008)	(0.009)	(0.007)	(0.007)	(0.008)
Entitled for cheap meal	0.075***	0.080***	0.065***	0.035***	0.056***	0.067***
	(0.006)	(0.005)	(0.008)	(0.005)	(0.006)	(0.008)
Not entitled for free meal	0.137***	0.156***	0.196***	0.103***	0.122***	0.131***
	(0.013)	(0.008)	(0.007)	(0.010)	(0.006)	(0.007)
Entitled for free meal	0.009	0.037***	0.087***	-0.026***	0.008	0.055***
	(0.009)	(0.008)	(0.010)	(0.007)	(0.007)	(0.010)
Student does not receive textbook for free in school	-0.105***	-0.093***	-0.091***	-0.088***	-0.078***	-0.087***
	(0.009)	*(0.010)*	*(0.009)*	*(0.010)*	*(0.009)*	*(0.010)*
Student receives textbook	-0.048***	-0.073***	-0.115***	-0.029**	-0.056***	-0.109***

	Math standardized test score			**Reading** standardized test score		
	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)	Grade 6 (4)	Grade 8 (5)	Grade 10 (6)
for free in school						
	(0.009)	(0.010)	(0.009)	(0.009)	(0.010)	(0.010)
Student lives in own family	0.132***	0.091***	0.050***	0.146***	0.112***	0.056***
	(0.021)	(0.016)	(0.012)	(0.019)	(0.016)	(0.012)
Number of siblings living in the same household: 0	0.006	0.002	0.062***	-0.016	-0.006	0.040***
	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)
Number of siblings living in the same household: 1	0.004	0.022*	0.072***	-0.061***	-0.040***	0.007
	(0.007)	(0.009)	(0.008)	(0.007)	(0.009)	(0.008)
Number of siblings living in the same household: 2 or more	-0.038***	-0.009	0.088***	-0.127***	-0.097***	-0.004
	(0.009)	(0.011)	(0.009)	(0.009)	(0.011)	(0.008)
Mother education: missing	-0.294***	-0.204***	-0.027*	-0.317***	-0.211***	-0.061***
	(0.022)	(0.016)	(0.013)	(0.023)	(0.014)	(0.011)
Mother education: elementary	-0.656***	-0.575***	-0.246***	-0.687***	-0.632***	-0.285***
	(0.014)	(0.017)	(0.019)	(0.013)	(0.016)	(0.016)
Mother education: vocational	-0.344***	-0.301***	-0.088***	-0.353***	-0.310***	-0.095***
	(0.010)	(0.011)	(0.008)	(0.008)	(0.010)	(0.007)
Mother education: high school	-0.145***	-0.117***	-0.016**	-0.160***	-0.127***	-0.023***
	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)
Father education: missing	0.016	0.029***	0.034***	0.021	0.032***	0.028***

	Math standardized test score			Reading standardized test score		
	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)	Grade 6 (4)	Grade 8 (5)	Grade 10 (6)
	(0.009)	(0.008)	(0.007)	(0.012)	(0.009)	(0.007)
Father's education: elementary	0.104***	0.089***	0.064***	0.112***	0.112***	0.077***
	(0.011)	(0.013)	(0.016)	(0.011)	(0.012)	(0.014)
Father's education: vocational	0.002	0.004	0.013**	-0.002	0.003	0.007
	(0.011)	(0.008)	(0.004)	(0.009)	(0.007)	(0.005)
Father's education: high school	0.091***	0.086***	0.041***	0.100***	0.093***	0.047***
	(0.014)	(0.010)	(0.005)	(0.013)	(0.010)	(0.005)
Father's education: university	0.180***	0.147***	0.058***	0.189***	0.149***	0.057***
	(0.008)	(0.010)	(0.007)	(0.009)	(0.012)	(0.007)
Mother's age: less than 30	-0.089***	-0.176***	-0.071*	-0.099***	-0.165***	-0.055
	(0.016)	(0.025)	(0.031)	(0.017)	(0.026)	(0.037)
Mother's age: 30-35	-0.117***	-0.085***	-0.035**	-0.117***	-0.079***	-0.034**
	(0.011)	(0.013)	(0.011)	(0.011)	(0.014)	(0.011)
Mother's age:35-40	-0.101***	-0.069***	-0.016	-0.106***	-0.068***	-0.016
	(0.011)	(0.012)	(0.008)	(0.011)	(0.012)	(0.008)
Mother's age: 40-45	-0.093***	-0.062***	-0.014	-0.094***	-0.059***	-0.019*
	(0.011)	(0.011)	(0.008)	(0.011)	(0.011)	(0.008)
Mother's age: 45 or more	-0.139***	-0.099***	-0.028***	-0.114***	-0.079***	-0.015
	(0.011)	(0.011)	(0.008)	(0.012)	(0.012)	(0.008)
Father's age: less than 30	-0.040*	-0.059**	0.047*	-0.052***	-0.019	0.010
	(0.016)	(0.021)	(0.023)	(0.015)	(0.020)	(0.026)

	Math standardized test score			**Reading** standardized test score		
	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)	Grade 6 (4)	Grade 8 (5)	Grade 10 (6)
Father's age: 30-35	-0.072***	-0.057***	-0.013	-0.069***	-0.047***	-0.004
	(0.010)	(0.012)	(0.016)	(0.011)	(0.011)	(0.017)
Father's age:35-40	-0.026**	-0.013	-0.025*	-0.035***	-0.019	-0.019
	(0.009)	(0.011)	(0.011)	(0.009)	(0.011)	(0.011)
Father's age: 40-45	-0.019*	-0.002	-0.014	-0.036***	-0.015	-0.025**
	(0.009)	(0.012)	(0.009)	(0.009)	(0.011)	(0.009)
Father's age: 45 or more	-0.045***	-0.022*	-0.024**	-0.053***	-0.031**	-0.035***
	(0.009)	(0.011)	(0.009)	(0.009)	(0.010)	(0.009)
No car in the household	0.149***	0.101***	0.060***	0.153***	0.114***	0.087***
	(0.008)	(0.012)	(0.009)	(0.008)	(0.011)	(0.010)
At least one car in the household	0.213***	0.169***	0.066***	0.197***	0.154***	0.056***
	(0.009)	(0.012)	(0.009)	(0.009)	(0.013)	(0.010)
No bathroom in the household	-0.216***	-0.249***	-0.165***	-0.218***	-0.246***	-0.178***
	(0.012)	(0.012)	(0.014)	(0.013)	(0.013)	(0.013)
At least one bathroom in the household	-0.121***	-0.141***	-0.068***	-0.127***	-0.138***	-0.070***
	(0.011)	(0.010)	(0.012)	(0.011)	(0.011)	(0.012)
Less than 150 books in the household	-0.033*	-0.075***	-0.078***	-0.032	-0.063***	-0.063***
	(0.015)	(0.017)	(0.011)	(0.020)	(0.018)	(0.013)
At least 150 books in the household	0.165***	0.149***	0.077***	0.190***	0.193***	0.112***
	(0.016)	(0.018)	(0.011)	(0.020)	(0.020)	(0.013)

	Math standardized test score			**Reading** standardized test score		
	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)	Grade 6 (4)	Grade 8 (5)	Grade 10 (6)
No internet connection in student's home	-0.313***	-0.285***	-0.189***	-0.298***	-0.294***	-0.202***
	(0.013)	(0.016)	(0.013)	(0.013)	(0.017)	(0.015)
Internet connection in student's home	-0.177***	-0.143***	-0.116***	-0.148***	-0.126***	-0.111***
	(0.012)	(0.015)	(0.012)	(0.012)	(0.015)	(0.014)
Student has no own desk	0.011	0.008	0.038***	-0.001	-0.026**	0.015
	(0.009)	(0.010)	(0.009)	(0.009)	(0.010)	(0.009)
Student has own desk	0.075***	0.069***	0.045***	0.076***	0.054***	0.022**
	(0.008)	(0.008)	(0.007)	(0.008)	(0.008)	(0.007)
Mother is non-employed	0.064***	0.058***	0.067***	0.077***	0.075***	0.097***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.009)	(0.008)
Mother is employed	0.059***	0.059***	0.062***	0.066***	0.064***	0.083***
	(0.008)	(0.008)	(0.007)	(0.008)	(0.009)	(0.007)
Father is non-employed	0.016*	0.004	0.027***	0.011	0.009	0.033***
	(0.007)	(0.009)	(0.008)	(0.007)	(0.007)	(0.007)
Father is employed	0.067***	0.054***	0.031***	0.077***	0.061***	0.044***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.009)	(0.007)
Family helps with homework less than once in a week	0.030*	0.018	0.016	0.056**	0.031*	0.028**
	(0.014)	(0.012)	(0.010)	(0.018)	(0.014)	(0.011)
Family helps with homework at least once in a week	-0.216***	-0.199***	-0.152***	-0.185***	-0.180***	-0.114***

	Math standardized test score			**Reading** standardized test score		
	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)	Grade 6 (4)	Grade 8 (5)	Grade 10 (6)
	(0.011)	(0.012)	(0.011)	(0.015)	(0.015)	(0.011)
2010	0.081***	0.038***	0.052***	0.093***	0.053***	0.062***
	(0.009)	(0.011)	(0.012)	(0.007)	(0.009)	(0.010)
2011	0.069***	0.052***	0.057***	0.076***	0.057***	0.054***
	(0.009)	(0.011)	(0.010)	(0.008)	(0.008)	(0.005)
2012	0.052***	0.053***	0.028***	0.056***	0.060***	0.026***
	(0.010)	(0.009)	(0.008)	(0.008)	(0.007)	(0.006)
2013	0.025**	0.034***	0.009	0.032***	0.036***	0.007
	(0.009)	(0.007)	(0.005)	(0.009)	(0.006)	(0.005)
2014	0.009	0.013	0.001	0.020**	0.019*	0.002
	(0.009)	(0.011)	(0.008)	(0.007)	(0.008)	(0.006)
Observations	448898	450898	438440	448898	450898	438440
Adjusted R^2	0.299	0.315	0.474	0.323	0.338	0.491
AIC	1091516.814	1085375.649	950054.422	1070668.130	1064921.378	931554.078

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. School fixed effects are included.*
Reference categories for dummy variables: Male; Entitled for cheap meal: missing; Entitled for free meal: missing; Student receives textbook for free in school: missing; Number of siblings living in the same household: missing; Mother education: university; Mother's age: missing; Father's age: missing; Number of cars in the household: missing; Number of bathrooms in the household: missing; Number of books in the household: missing; Internet availability in the household: missing; Student has own desk at home: missing; Mother's employment status missing; Father's employment status missing; Family helps with homework: missing.

Table AR.4

Robustness check: with imputed values for excluded sample

	Math standardized test score			**Reading** standardized test score		
	Grade 6	Grade 8	Grade 6	Grade 8	Grade 6	Grade 8
	(1)	(2)	(1)	(2)	(1)	(2)
KG starting age (KSA)	-0.038**	-0.007	-0.008	-0.059***	-0.031*	-0.015
	(0.013)	(0.012)	(0.013)	(0.013)	(0.012)	(0.012)
School starting age (SSA)	0.261***	0.139***	0.011	0.287***	0.179***	0.052***
	(0.020)	(0.016)	(0.014)	(0.019)	(0.018)	(0.016)
Observations	462382	467319	453928	462382	467319	453928
Adjusted R^2	0.301	0.316	0.474	0.325	0.339	0.491
AIC	1123624.238	1124701.524	983768.251	1102184.221	1103462.440	965084.532

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

To avoid endogeneity issues resulting from measurement errors or unobserved heterogeneity, we remove in the baseline model individuals who reported to have started kindergarten before age 2 and 7 months. This corresponds to about 5% of the full population. This table tests whether the results are robust for excluding these observations, using the original kindergarten starting ages.

Table AR.5

Robustness check: with imputed values for excluded sample

	Math standardized test score			**Reading** standardized test score		
	Grade 6	Grade 8	Grade 10	Grade 6	Grade 8	Grade 10
	(1)	(2)	(3)	(1)	(2)	(3)
KG starting age, imputed (KSA-I)	-0.040**	-0.008	-0.008	-0.062***	-0.032*	-0.016
	(0.014)	(0.012)	(0.013)	(0.014)	(0.013)	(0.013)
School starting age (SSA)	0.262***	0.140***	0.011	0.289***	0.180***	0.052***
	(0.020)	(0.016)	(0.014)	(0.019)	(0.018)	(0.015)
Observations	462382	467319	453928	462382	467319	453928
Adjusted R^2	0.301	0.316	0.474	0.325	0.339	0.491
AIC	1123652.921	1124703.440	983767.396	1102276.814	1103492.452	965091.240

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

To avoid endogeneity issues resulting from measurement errors or unobserved heterogeneity, we remove in the baseline models individuals who reported to have started kindergarten before age 2 and 7 months. This corresponds to about 5% of the full population. This table tests whether the results are robust for excluding these observations, using imputed kindergarten starting dates based on individual characteristics.

Table AR.6

Robustness check: without the special needs students

	Math standardized test score			**Reading** standardized test score		
	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)	Grade 6 (1)	Grade 8 (2)	Grade 10 (3)
KG starting age (KSA)	-0.058***	-0.025*	-0.019	-0.073***	-0.046***	-0.026*
	(0.014)	(0.012)	(0.013)	(0.014)	(0.013)	(0.012)
School starting age (SSA)	0.278***	0.154***	0.020	0.299***	0.189***	0.056***
	(0.020)	(0.017)	(0.015)	(0.021)	(0.018)	(0.015)
Observations	448108	450228	437972	448108	450228	437972
Adjusted R^2	0.299	0.315	0.474	0.323	0.338	0.491
AIC	1089507.767	1083588.787	948904.104	1068598.815	1063036.418	930327.752

*Note: Significance: *** 1%; ** 5%; * 10%. The robust standard errors clustered on the kindergarten catchment area level are in parentheses. The reading test scores are annually standardized to mean 0 and standard deviation 1. We include a rich set of individual and family characteristics, year and school fixed effects.*

Table AR.6 shows the results of a sample without special needs students. The results suggest that our baseline results are very robust for dropping special needs students.