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ABSTRACT

Government Education Expenditures, Pre-Primary Education and School Performance: A Cross-Country Analysis*

Using data from OECD's PISA, Eurostat and World Bank's WDI, we explore how child cognitive outcomes at the aggregate country level are related to macroeconomic conditions, specifically government education expenditures and early education experience. We find that both government expenditures in education and attendance to early child care are associated with better later school performance. We also consider different childcare characteristics such as duration and quality, which appear to have significant effects Our results may imply that policies encouraging childcare expansion should also take into account quality issues.

JEL Classification: I26

Keywords: early childcare and education, school performance, test scores

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1. Introduction

Education is crucial for building a nation's human capital, and the government's investments in education reflect its priority in promoting human capital development. In fact, many empirical studies have shown that education provides positive returns to society as more education leads to higher productivity (Hanusheck and Woessman, 2010).

Recent empirical analyses suggest that not only the level of government investment is important but also its timing. Specifically, governments investments in early education appears to have a stronger impact on later individuals' cognitive outcomes than investments in adolescence or during adults' years (Carneiro and Heckman, 2003). The comparison across countries confirms these results. In Northern European countries, where higher investments in early education are made, cognitive test scores are higher and inequality is lower, while in Southern European countries, where investments in early education are lower, children perform worse in school and the level of inequality is higher (OECD, 2013).

Besides the government expenditure also the individual attendance to early education is crucial for students' later performance. The literature on the impact of early education on later cognitive outcomes has grown remarkably in the last decades, both in the field of economics of education as well as in household and labor economics (Del Boca et al 2014, Del Boca et al 2017). The objective of our paper is to contribute to this literature with a macroeconomic approach, analysing the relationship between students' performance, governments' investments in education and early education experience at the aggregate country level. In order to do so we use OECD's PISA data, Eurostat and World Bank's World Development Indicators for 19 countries[1] for three waves 2003, 2012 and 2015.

Our study is novel for several reasons. First of all, it uses a macroeconomic framework to explore a question mostly analysed in micro setting: the returns of investments from cumulative past educational policies and early education aggregate attendance on later cognitive skills of one country's students. Second, we consider both the impact of government expenditures -not only contemporaneous but also occurred during students' early years- and early education attendance of the assessed students. We use the expenditure in education realized when the students were in pre-school age (0-6) and in the following

[1] Austria, Belgium, Denmark, Finland, France, Great Britain, Greece, Hungary, Ireland, Iceland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland

schooling experience period (when they were aged 7-15), and early education attendance when they were 3 to 6. To identify the parameters of interest, we exploit across countries as well as across time variation in the considered variables, and across subject variation in PISA assessments. Third, we consider not only the impact of attendance, but also the impact of its duration, quality as well as other characteristics of the child care system (coverage and costs). Our results show that both higher governments' expenditures in early education, and higher shares of children who received pre-primary education improve students' performance at age 15. We also find that duration and quality of early childcare students have attended play a significant role in their later performance.

The remaining of the paper is structured as follows. Section 2 provides a brief overview of the recent literature and its relation to our contribution. Section 3 describes the data and variables used in the empirical analysis. In Section 4, we describe trends in education expenditure, early education attendance and school performance. Section 5 shows the association between school performance and our main variables of interest. The econometric strategy and results are illustrated in Section 6 and 7. Section 8 concludes.

2. Literature

Recent studies have shown that government expenditures in education tend to increase the quality of education, and lead to better economic outcomes. Most of these studies have analysed the situation of developing countries which have attempted to stimulate the accumulation of human capital through public education expenditure (Jung and Thorbecke, 2001). Only more recently these links have been analysed in developed contexts (Grimaccia and Lima, 2013) reporting similar results.

However, besides governments expenditures' levels, also its composition is important. The economics literature of early intervention has demonstrated that early investments in education are more important than later investments. Carneiro and Heckman (2003) and Todd and Wolpin (2003) have modelled children's outcomes (cognitive and non-cognitive) as the output of a production function in which inputs are supplied by families as well as by institutions, and child outcomes are largely determined early in life. Children's skills are in fact most malleable at the youngest age, making early parental and public investments more significant for future life outcomes when children are young (Shonkoff and Phillips, 2000). Moreover, early education investments are less expensive than the ones made in adolescence

or in adulthood because they do not have to remedy damages already occurred. If institutions invest early enough, they can affect significantly later cognitive abilities. Early interventions can affect schooling results, promote workforce productivity and are estimated to have higher rates of return than later interventions, such as job training, rehabilitation programs, tuition subsidies (Cunha et al., 2006).

Recent empirical research has analysed the impact of early investments on later skills at the individual level. These analyses, conducted on US or European countries have reported positive effect of early education on several cognitive outcomes (IQ, language and motor skills, school readiness, achievement tests) and more beneficial effects for children from disadvantaged backgrounds. Elango et al. (2015) reviewed a large number of empirical studies evaluating the impact of early formal childcare on later children outcomes. They report results showing effects on IQ long after school entry. Evaluating a Spanish reform using PISA data for several years, Felfe et al. (2015) have focused on an early 1990s reform in Spain, which led to a sizeable expansion of publicly subsidized full-time childcare for 3-year olds. They find that growth in early education led to a sizable increase in reading and math test scores at age 15. In Denmark, Datta Gupta and Simonsen (2016) have shown that attendance to high quality early formal care at age 2 has a positive effect on grades in language at age 16. García et al. (2016) have analyzed early childhood programs conducted in North Carolina (starting at eight weeks of age) and show long lasting effects on IQ and other school outcomes.

As we mentioned above, we contribute to this literature with a macro perspective exploring how early education attendance and expenditures in education at different stages of life cycle affect school performance at 15 at the country level. This focus helps us to explore the length of the effect of early education (Vandell et al., 2010).

3. Data and definition of variables

In our empirical analysis, we use pooled aggregate data for the 19 analysed countries from three different sources: OECD's PISA, Eurostat and World Bank's World Development Indicators.

The **test outcomes** of students between ages 15 years 3 months and 16 years 2 months are obtained from the PISA database (years 2000, 2003, 2006, 2009, 2012 and 2015). Students who are in grade 7 or higher are assessed at the period approaching the end of the compulsory schooling, usually around March and April, from countries with enrolment that sees almost universal participation. The outcomes we consider are the country average unadjusted test scores in reading, mathematics, and science[2] and the country shares of low and high performing students in the same three domains. The latter capture information about the distribution of the student performance and allows for alternative definitions of the improvement or worsening of a country's results. To classify low- and high-performing students, assessment scores are divided by the PISA project into 6 proficiency levels that correspond to different levels of difficulty. Students are considered low performers if their scores are level 2 or below, which correspond to below 480 for reading, below 482.4 for mathematics, and below 484 for science. High performers are those who have at least level 5 or above, which correspond to at least 626 for reading, 607 for mathematics, and 633.3 for science[3].

In order to understand the impact of the government's commitment to economic growth through improving human capital, we analyse the relationship between the aggregate students' performance and previous life course investments in education of the country and early education experience**. The previous life course investments** in education are measured with the share of government education expenditures with respect to the country's GDP. These indicators are derived from OECD Eurostat and World Bank's World Development Indicators. The measures of government education investments refer to the years when the students in the cohort were 0-6 years old and when they were 7-15 years old. To illustrate, students evaluated in PISA 2003 are matched with the corresponding government education expenditures as a percentage of GDP referring to 1986-1994, when they were 0-6 years old to measure early investments, and to 1993-2003, when they were 7-15 years old, to measure intermediate investments.[4]

[2] Science scores are not available in 2012, we use the one in wave 2009 instead.

[3] Details of the proficiency levels and the description of each are detailed here (http://www.oecd.org/pisa/aboutpisa/PISA%20scales%20for%20pisa-based%20test%20for%20schools.pdf).

[4] An alternative to government education investments would have been represented by the use of data on social expenditures released by the OECD. We preferred not to do so, following De Henau (2007), since these data are not harmonized and comparable across countries. Moreover, for older children, a substantial share of the public supply of childcare is part of educational arrangements for children below age of compulsory school enrolment and thus falls under the responsibility of the ministry of education, and this support our choice about the use of government education expenditures

The early education experience of the students is measured with the share of PISA students who attended early child care (which corresponds to ISCED-0). This share is cohort-specific, i.e., corresponding to the assessment scores from PISA 2003 with cohort born between 1986-1988, early education experience refers to the years when the students were 3 to 6 years old (1989/1992 to 1991/1994). In our regression analyses in Section 5 we are forced to use only PISA waves 2003, 2012, and 2015 since they are those to which we can attach information about cohort specific early child care attendance. The table below summarizes these correspondences.

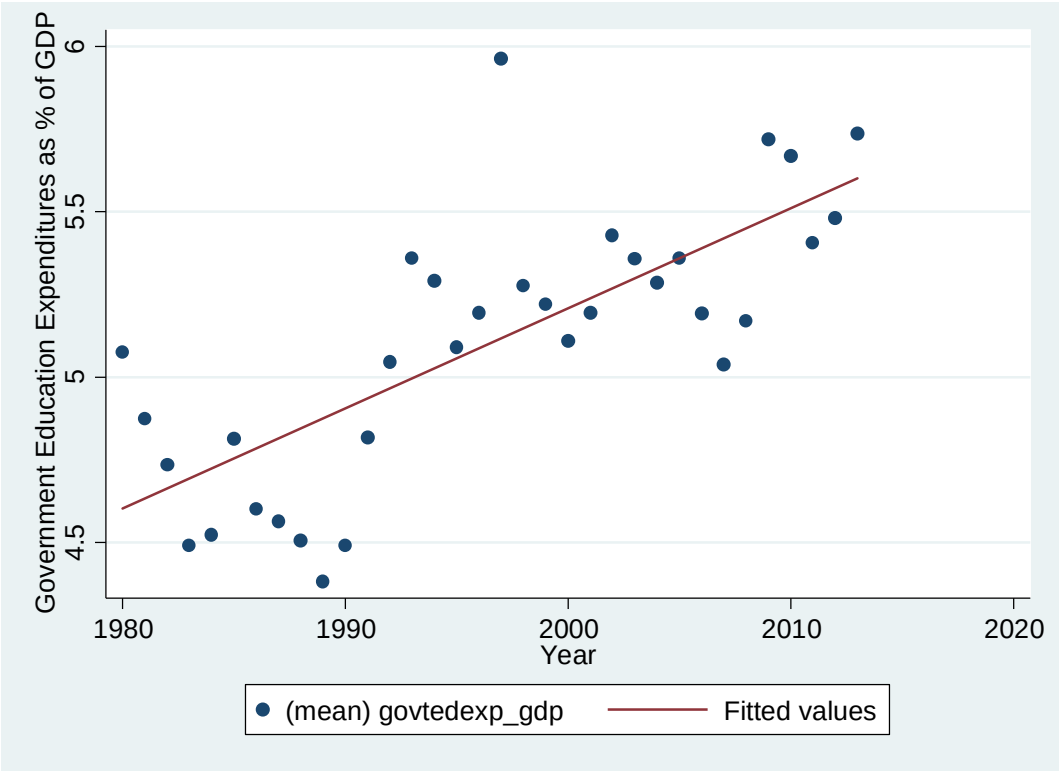
Table 1. Summary of data sources and matched periods

PISA test scores	Cohort's year of birth	Early investments (0-6 years old)	Intermediate investments (7-15 years old)
2003	1986	1986-1992	1993-2001
	1987	1987-1993	1994-2002
	1988	1988-1994	1995-2003
2012	1996	1996-2002	1997-2011
	1997	1997-2003	1998-2012
2015	1999	1999-2005	2000-2014
	2000	2000-2006	2001-2015
Source: PISA		Source: OECD	Source: OECD

4. Patterns in education expenditure, early education attendance, and school performance at age 15

Our main macroeconomic indicator is represented by public education expenditures, expressed as a share of GDP, which reflects the government's commitment to economic growth through improving human capital. Indeed, a workforce with higher education and skills drives the economy to be more productive. The yearly average of this variable over the sampled countries exhibits a positive trend (see Figure 1), indicating an increasing growth of government's priority in human capital investments.

Figure 1. Time trend of government education expenditure as a percentage of GDP, 1980-2015



Source: World Development Indicators.

The second indicator of interest is the early education experience of the 15 years old students assessed by PISA. In order to obtain aggregate measures of this important input in the child development process, we consider two country level variables: the share of government expenditure in education during the period when the sampled cohorts were in their early years (0-6 years old), and the aggregate attendance of pre-primary education from age 3 to 6.

Table 2 shows that on average (over the 19 countries) the share of government expenditure in education occurring in the first years of life of the different PISA cohort students is increasing, from 4.7 percent in 2003 to 5.5 percent in 2015.

Table 2. Government expenditures in education as percentage of GDP, Early years (students 0-6 years old) of PISA cohorts 2003, 2012, and 2015

Cohort Year	Government Education Expenditures as % of GDP	Std. Dev.
2003	4.737	1.006
2012	5.236	1.141
2015	5.460	1.100
Overall	5.140	1.120

Source: OECD Social Expenditure Database

The PISA 2003, 2012 and 2015 surveys include information on the percentage of sampled students who received early childcare or pre-primary level of education, which "is defined as the initial stage of organised instruction, designed primarily to introduce very young children to a school-type environment, that is, to provide a bridge between the home and a school-based atmosphere." (http://www.oecd.org/edu/1841854.pdf). Because of differences in each country's definitions of pre-primary or early childhood education, "comparability depends on each country's willingness to report data for this level according to a standard international definition, even if that definition diverges from the one that the country uses in compiling its own national statistics. Programs should be centre- or school-based (may come under the jurisdiction of a public or private school or other education service provider), designed to meet the educational and developmental needs of children of at least 3 years of age, and have staff that are adequately trained (i.e., qualified) to provide an educational programme for the children" (http://www.oecd.org/edu/1841854.pdf)

Table 3a. Percentage of students reporting that they had attended pre-primary education2003, 2012, and 2015

Year	No Pre-primary attendance	Pre-primary attendance <=1 year	Pre-primary attendance>1 year
2003	7.6	18.8	73.6
2012	4.6	17.4	78.0
2015	3.3	2.8	93.9
Overall	5.2	13.1	81.7

Table 3a shows the percentages of students reporting their attendance to pre-primary education. A comparison of the PISA cohorts 2003 and 2015 shows a significance increase in the share of students who received pre-primary education of more than 1 year, and corresponding decreases in the shares of students without or up to 1 year of pre-primary

education. Table 3b shows the distribution in 2003 and 2015 by country, with almost all students having received more than 1 year of year pre-primary education coming from countries such as Denmark, Finland, Hungary, Belgium, and Iceland.

Table 3b. Percentage of students reporting that they had attended pre-primary education, by country, 2003 and 2015

	Pre-primary0		Pre-primary<=1		Pre-primary>1	
	2003	2015	2003	2015	2003	2015
Austria	4.3	1.3	15.5	0.6	80.2	98.1
Belgium	2.4	1.2	3.8	0.6	93.8	98.2
Denmark	2.3	0.6	32	0.3	65.7	99.1
Spain	5.4	1.0	10.2	3.0	84.4	96.0
Finland	7.9	1.7	25.3	1.2	66.8	97.1
France	1.6	0.8	4.5	2.7	93.9	96.4
Great Britain	6.0	1.6	26.0	3.5	68.0	94.9
Greece	5.4	2.1	32.7	1.1	62.0	96.8
Hungary	1.0	0.2	4.7	0.6	94.2	99.3
Ireland	27.7	7.1	39.8	2.8	32.5	90.1
Iceland	6.6	1.7	4.5	0.3	88.9	98.1
Italy	4.8	1.7	8.4	2.0	86.7	96.4
Luxembourg	11.9	2.6	8.7	2.4	79.3	94.9
Netherlands	2.9	-	3.1	-	93.9	-
Norway	7.6	5.9	14	0.5	78.3	93.6
Poland	3.9	17.4	51.7	0.5	44.4	82.1
Portugal	27.7	7.3	17.4	26.5	54.9	66.2
Sweden	11.8	3.7	28.6	0.7	59.5	95.6
Switzerland	3.1	1.3	30.2	0.9	66.7	97.7

Country heterogeneity certainly exists in terms of childcare quality provision. Several studies have dealt with the issue of evaluating the quality of childcare provisions. Behrman and Birdsall (1983) and Love et al. (2003) report that quality of available childcare influences children's developmental outcomes and should be taken into account when evaluating childcare policies.

Therefore, we incorporate childcare quality in our analysis, resorting to two distinct measures.

The first indicator we include proxies the quality of early childcare services with the cohort-specific average pupil-teacher ratio in pre-primary education, provided by WDI or the number of children for every carer in the context of pre-primary education. Experiencing a

low ratio, is believed to improve the students' future outcomes, through increased opportunities for individual interactions and care/educational instructions from staff. While most countries adopt a required maximum, the actual averages and ranges vary, especially when measured for services devoted to 0-3 years old children. We select as indicator of early childcare quality the average pupil-teacher ratio occurring when the students were 0-3 years old. On one hand, the ratio at 4-6 years old displays too little variability and on the other hand the recent literature emphasizes the importance of very early interventions. We believe that this ratio also conveys information on the country's educational system, with a low ratio signalling that care is viewed as a responsibility of the country's institutions.

The second measure of quality we consider is an index score developed by De Henau et al. (2007) that is broader, than the child/staff ratio. Indeed, country heterogeneity certainly exists not only in terms of childcare quality, but also of coverage and costs. In a detailed comparative study, De Henau et al. (2007) have constructed a ranking of child care (ages 0-5) which includes all three variables, namely child care coverage, child-staff ratio, and level of public expenditure spending. They applied a linear scaling technique, with relative weights for each criterion, which they argued is "a very relevant method to use when criteria do not have a consensual maximum (spending, child/staff ratios, flexibility of leave, etc.), and consequently for indicators that combine these two types of criteria".

Childcare coverage is a combination of three indicators, assumed to be equally and perfectly substitutable: (1) the coverage rate, which provides the proportion of available places in a public or publicly-funded childcare for children in a given age group, (2) the daily coverage, which refers to the opening hours of childcare arrangements, and (3) the sharing of cost between public and private or employer. The resulting childcare coverage indicator tells the proportion of children in a given age category with a free full-time place in public or publicly-provided child care facilities.

Child-staff ratio is similar as the discussion above, i.e., the number of children that every carer is responsible for. Public intervention or involvement is captured by government spending on education of "all current and capital expenditures by central, regional or local government, oriented directly towards institutions providing education (schools and other educational establishments)". This variable gives comparable measurement of spending per child in a public or private education programme, and is indicative of elements such as

quality of care, staff earnings, capital investments in the sector, etc. The resulting final index for age group 0-5, defined Childcare score, is displayed in Table 2.A.4. Countries displaying high values of this score include Denmark, Sweden, France, Finland, and Belgium, and consistently display high values of all the index sub-components. Unfortunately, this Child care score is available only at a single point in time, in year 2002, and we cannot derive cohort specific measures as we do for the pupil teacher ratio. For this reason, in our main econometric analysis we will rely on the pupil teacher ratio, and use the Childcare score to perform a robustness check exercise.

Our outcome variable is the school performance at age 15. Unadjusted score for the 19 countries averages at 497.86 points, with 19% low performers, and 9.5% high performers, as displayed in Table 4a.

The table also reveals a slight worsening of average results in 2015 compared to previous years, with lower average score, higher shares of low performers and lower share of high preforming students.

Table 4a. Average assessment scores and shares of low and high performers in PISA, 2003, 2012 and 2015

	Score	Low	High
2003	499.400	18.609	10.011
2012	499.158	18.423	9.591
2015	494.907	20.220	8.850
Overall	497.855	19.069	9.489

Country specific time averages contained in Table 4b indicate that the best performing ones in terms of average scores are Switzerland, Ireland, and Netherlands, while Finland, Netherlands, Belgium, and Switzerland appear as the countries with the highest shares of high performing students

Table 4b. Average assessment scores and shares of low and high performers in PISA, by country

Country	Score	Low	High
Austria	498.556	19.433	9.745
Belgium	509.222	18.178	13.73
Denmark	501.000	15.878	8.367
Finland	534.000	9.344	16.067
France	498.667	20.267	10.678
Great Britain	503.000	18.186	10.886
Greece	462.556	29.756	3.845
Hungary	484.333	22.867	6.700
Ireland	511.111	13.489	10.056
Iceland	488.333	21.289	7.978
Italy	482.445	23.500	6.644
Luxembourg	486.333	23.611	8.356
Netherlands	522.000	12.883	14.717
Norway	498.111	18.756	9.489
Poland	506.445	15.300	10.011
Portugal	485.889	21.956	6.611
Spain	488.556	19.778	5.978
Sweden	495.445	19.978	9.578
Switzerland	512.445	15.611	12.911

5. Observed association between students' performance and early child education experience

In this section we inspect correlational patterns between our variables of interest, whose description is provided in Table 5. Table 6 shows the share of students with up to 1 year of pre-primary education is positively related to average scores and are negatively related to share of low performers. Higher government education expenditures are associated with better students' performance, as expected.

Table 5. Definition of variables

Variable names	Variable descriptions
Outcome variables	
Score	Average unadjusted scores
Low	Share of low performers
High	Share of high performers
Explanatory variables	
Pre-primary0	Share of students with no pre-primary education when students where 3-6 years old
Pre-primary<=1	Share of students who received up to 1 year of pre-primary education when students where 3-6 years old
Pre-primary>1	Share of students who received more than 1 year of pre-primary education when students where 3-6 years old
Govtexp0-6	Government education expenditures as % of GDP when students were 0-6 years old
Govtexp7-15	Government education expenditures as percentage of GDP when the students were 7-15 years old
GDP0-6	GDP in 2005 USD when the students were 0-6 years old
GDP7-15	GDP in 2005 USD when the students were 7-15 years old
Pupil-teacher ratio	Pupil-teacher ratio in pre-primary and early childhood education when students where 0-3 years old
Childcare score	De Henau composite index measured in 2002

Table 6. Correlations between performance measure, early education experience, government education expenditure

	Score	Low	High
Pre-primary<=1	0.1889*	-0.2453*	0.0928
Pre-primary>1	-0.1461	0.2180*	-0.0438
Govtexp0-6	0.4530*	-0.4502*	0.3151*
Govtexp7-15	0.3469*	-0.3978*	0.1963*

* significant at 5% level

Tables 7a and 7b display the averages of our variables of interest, as well as mean comparison tests according to the two indicators for child care quality described in Section 4. We dichotomize the quality indicator defining an average of pupil-teacher ratio less than 15 as “low,” which splits the observations in two groups of similar size, and includes Belgium, Denmark, Finland, Greece, Hungary, Iceland, Italy, Norway, Poland, Sweden. Countries displaying values for the Score index lower than 47.5.are defined as Low Score, while those

scoring above are defined as High Score. Three interesting patterns emerge: (i) higher quality in pre-primary education is associated with better future performance for both quality indicators (see the top panel of both tables), despite the difference in mean performance across high/low quality is statistically significant only for the second quality indicator (childcare score index); (ii) attendance of early education services is positively associated with quality (see the central part of both tables); (iii) government education expenditures are positively associated with childcare quality (see the bottom part of both tables).

These patterns suggest that our regression analysis will have to account for quality in order to isolate the partial effect of attendance of early education services and early investments on students' future performance.

Table 7a. Mean comparison test, by pupil-teacher ratio in pre-primary when cohorts were 0-3 years old

	Low pupil-teacher ratio n=60		High pupil-teacher ratio n=67		
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Diff
Scores	494.617	17.961	493.015	16.040	1.602
Low	19.687	5.803	20.549	5.178	-0.863
High	8.613	3.599	8.691	3.630	-0.078
Pre-primary<=1	9.435	13.211	17.896	14.176	-8.461***
Pre-primary>1	87.225	13.508	74.694	18.523	12.531***
Govtexp0-6	5.013	1.026	4.133	0.998	0.881***
Govtexp7-15	5.725	1.364	4.619	0.885	1.106***

Table 7b. Mean comparison test by child care score index

	High Childcare score index n=45		Low Childcare score index n=121		
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Diff
Scores	507.667	17.374	494.207	17.236	13.460***
Low	16.729	4.828	19.940	5.480	-3.211***
High	11.684	4.726	8.673	3.949	3.012***
Pre-primary<=1	12.400	12.559	13.358	14.200	-0.958
Pre-primary>1	84.260	14.524	80.749	17.286	3.511
Govtexp0-6	5.171	0.527	4.385	1.068	0.785***
Govtexp7-15	6.105	1.223	4.821	0.978	1.284***

Note: From the list of ten countries with low pupil-teacher ratio, five of which are the countries with high child care score indices, namely Denmark, Sweden, France, Finland, and Belgium.

6. Estimation Strategy

In this section we investigate through econometric analysis whether past government expenditures in education and early education services attendance, two variables that can be chosen by policy makers, make a significant contribution to the future cognitive achievement of one's country 15 years old students. As mentioned before, the novelty of our approach consists in matching the country level school performance measure to these policy variables realized in the past, during the life course of the assessed students. More precisely, we relate aggregate school assessment at 15 years to the expenditure in education realized when the students were in pre-school age (0-6) and in the following schooling experience period (when they were aged 7-15), while Pre-Primary attendance refers to the period in which they were 3 to 6. To identify the parameters of interest we exploit across countries as well as across time variation in the considered variables, as well as across subject variation in PISA assessments. In doing so, our analysis will be the first to quantify the returns of investments from past educational policies and early education aggregate attendance on future cognitive skills of one country's students.

Our main estimation results are obtained with the model:

$$Test_{ijt} = \beta_0 + \beta_1 Childcare_{t-2} + \beta_2 Low\_PTR_{it-2} + \beta_3 Educ_{it-1} +$$
$$+\beta_4 Educ_{it-2} + \beta_5 GDP_{it-1} + \beta_6 GDP_{it-2} + \delta_j + \theta_t + \varepsilon_{ijt}$$

Where $Test_{ijt}$ is the PISA assessment measure (average score, share of low performers and share of high performers) for country i on subject j reported at wave or time t; δ_j are subject fixed effects; θ_t are PISA waves fixed effects. $Childcare$ is a vector containing the share of pupils who received up to 1 year of pre-primary education, and the share of those who received more than 1 year of pre-primary education (Pre-primary<=1, Pre-primary>1). Both shares refer to the period *t-2*, when the assessed students were in pre-school age. *Low_PTR* is a dummy capturing low quality according to the pupil-teacher ratio described in Sections 4 and 5, measured when assessed students where 0-3,[5] $Educ$ is the government spending on education as a percentage of GDP, measured at period *t-2*, when the assessed students were 0-6 years old (Govtexp0-6), and at *t-1*, when they were 7-15 years old (Govtexp7-15). GDP is the gross domestic product in 2005 US dollars measured in the same two past periods. Our coefficients of interest are the partial effects β_1 through β_4, where the latter two are to be interpreted as partial effects of the percentage of GDP devoted by the country to education for a given GDP level.

7. Estimation Results

Table 8 displays the OLS results when the model above is estimated on the sample we obtain pooling the 19 country/ 3 subjects/ 3waves (2003, 2012, 2015) observations. The pooled sample does not contain 171 observations (19 x 3 x 3), due to missing observations on reading and math scores of Great Britain in 2003 and all three scores of Netherlands in 2015. The resulting pooled dataset therefore consists of 166 observations.

According to our estimates a higher share of the student population who received up to one year of pre-primary education implies better school outcomes for all the three considered performance measures (resulting in higher average score, lower share of low performing students, higher share of high performing students). To be more precise, one additional percentage point (p.p.) in this share significantly increases the average score of 0.51 units - equivalent to 3.08 standard deviation- , and the share of high performers 0.13 units - equivalent to 0.670 standard deviation. Despite having the expected sign, the partial effect on

[5] Experimenting with the dichotomized version of the pupil teacher ratio led us to reject a linear specification in this quality index.

the share of low performers turns out not to be statistically significant. On the contrary, one additional p.p.in attendance for more than one year does not have a significant effect on any of the considered outcomes. These results indicate a non-linear hump-shaped pattern with respect to the duration of enrolment to pre-primary education, with a positive effect only when the proportion of children receiving some (up to one year) pre-school inputs increases, and the proportion of children not receiving any pre-primary education concomitantly decreases. Increasing the proportion of children receiving more than one year, and concomitantly decreasing the proportion not receiving childcare, instead, does not lead to significant improvements in the aggregate future school performance.

These patterns seem to suggest that the crucial input affecting the development of cognitive skills in one country is the attendance of one year of pre-primary, which is most likely to correspond to the last year of pre-primary education, whose curriculum is typically devoted to primary school readiness. These results are coherent with previous literature. Loeb et al (2002) reported that the strongest cognitive benefits of early childcare attendance were enjoyed by children who attended one year of early childcare, while an additional year did not provide larger benefits.

Coming to the effect of past government expenditure in education, it can be noticed how the relevant period, influencing future school outcomes, corresponds to the childhood, preschool age of the assessed students, a result which is in line with the importance of early investments in child cognitive development recognized in many individual level analyses by Heckman and his co-authors. This effect is found to be sizable: one p.p. increase in the share of education expenditure occurring when the student was aged 0-6 leads to (i) an increase of about 9.5 units in the assessment score; (ii) a decrease of about 2.5 p.p. in the share of students with poor performance and (iii) an increase of 1.7 p.p. in the share of students with good performance, i.e. it affects both the average performance and the performance distribution.

Concerning the role of quality, it can be noticed from the same table that a low pupil-teacher ratio in pre-primary when the students were 0-3 years old significantly decreases –ceteris paribus- the share of low-performing students in PISA, while the partial effects on the other two outcome measures have the expected sign, but are not statistically significant. This

suggest that a more direct pupil-teacher relationship benefits the more disadvantaged students, i.e. those in the bottom part of the cognitive outcomes distribution.

In Table 9 we check the robustness of the previous results to the inclusion of the alternative indicator for child care quality presented in Section 4, despite this is not cohort specific. The results on the partial effects of the share of children attending pre-primary education and on government expenditure during early childcare are quite similar both in magnitude and significance to those of Table 8. The effect of quality is qualitatively similar to the one obtained before, but stronger. Countries with high childcare score indices are found more likely to have higher assessment scores, lower shares of low-performing students, and higher shares of high-performing students, and the effect is statistically significant on all the three considered outcomes.

Table 8. OLS results on the pooled sample, with cohort specific pupil-teacher ratio

	Score	Low	High
Pre-primary<=1	0.513**	-0.107	0.134**
	(0.239)	(0.072)	(0.052)
Pre-primary>1	0.038	0.040	0.064
	(0.206)	(0.062)	(0.045)
Govtexp0-6	9.540***	-2.460***	1.722***
	(1.713)	(0.518)	(0.373)
Govtexp7-15	-1.205	-0.058	-0.396
	(1.514)	(0.457)	(0.330)
Low_pupil-teacher ratio	3.927	-2.080**	0.025
	(3.174)	(0.959)	(0.691)
Constant	435.681***	31.759***	-6.480
	(19.255)	(5.818)	(4.194)
Observations	127	127	127
R-squared	0.499	0.563	0.475

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10
Controls include GDP in constant 2005USD averaged when students were 0-6 years old and when students were 7-15 years old, subject and year fixed effects.

Table 9 OLS results for the 19 countries, with Child care index measured in 2002

	Score	Low	High
Pre-primary<=1	0.619**	-0.148*	0.143**
	(0.273)	(0.078)	(0.062)
Pre-primary>1	0.202	-0.017	0.084
	(0.232)	(0.067)	(0.053)
Govtexp0-6	10.111***	-2.570***	1.921***
	(1.841)	(0.529)	(0.419)
Govtexp7-15	-3.174*	0.158	-1.071***
	(1.650)	(0.474)	(0.375)
High child care score	12.513***	-2.458***	3.171***
	(3.115)	(0.895)	(0.708)
Constant	437.634***	33.405***	-4.396
	(22.345)	(6.419)	(5.081)
Observations	166	166	166
R-squared	0.387	0.441	0.448

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10
Controls include GDP in constant 2005USD averaged when students were 0-6 years old and when students were 7-15 years old, subject and wave fixed effects.

8. Conclusions

This research aims to explore how child cognitive skills at age 15 at the macroeconomic level are affected by government education expenditures and by aggregate early experience in childcare. We use data from OECD's PISA and Eurostat and World Bank's WDI, looking at 19 European countries. Because individual outcomes are results of cumulative inputs, we use a multivariate analysis to investigate how past government expenditures and early investments can affect the test assessment measures.

Overall, we find that higher shares of children who received pre-primary education improve later outcomes. The effect is driven by the share of children having attended up to one year of pre-primary education, most likely the last year before starting primary school, showing a non-linear pattern of the effect of duration of pre-primary education.. Besides duration of childcare experience we also analyse quality and other childcare's characteristics (coverage and costs) which are found to exert a positive impact on aggregate assessments.

Our results have potential policy implications. First of all, the positive link between macroeconomic conditions and students' cognitive performance should advise policies aimed to prioritise and stabilise expenditures in education. Moreover, as we have shown in the empirical analysis, early education and its quality have significant positive impacts on child outcomes which implies that governments should focus on educational investments in early years. Our results confirm the large literature indicating the importance of early investments in child care and provide a potential economic justification for public intervention not only in early childcare availability but also in its quality.

APPENDIX

Table A1. Average pupil-teacher ratio in pre-primary when cohorts were 0-3 years old

	Average pupil-teacher ratio in pre-primary
Austria	17.799
Belgium	14.576
Denmark	8.531
Finland	12.057
France	19.526
Great Britain	24.416
Greece	15.932
Hungary	11.333
Iceland	3.943
Ireland	26.399
Italy	13.394
Luxembourg	16.530
Netherlands	17.220
Norway	5.298
Poland	13.912
Portugal	18.071
Spain	21.902
Sweden	15.026

Table A2. Country classifications according to De Henau et al 2007 child care index

Classification	Countries	Range of final scores
High	Denmark, Sweden, France, Finland, Belgium	47.5 to 89.3
Others	Italy, Austria, Luxembourg, Netherlands, Great Britain Portugal, Ireland, Spain, Greece	0.8 to 36.4
Non-classified	Norway, Switzerland, Hungary, Iceland, Poland	NA

Table 2.A.4 Final scores of the childcare index for the EU-15 member states for three age categories

Final score for childcare (age group 0-2)		Final score for childcare (age group 3-5)		Final score for childcare (age group 0-5)	
Denmark	100.0	Sweden	83.4	Denmark	89.3
Sweden	72.1	Denmark	78.6	Sweden	77.7
France	59.4	France	61.4	France	60.4
Finland	49.4	Italy	56.3	Finland	51.2
Belgium	39.2	Belgium	55.8	Belgium	47.5
Ireland	22.5	Finland	53.1	Italy	36.4
Austria	22.0	Luxembourg	43.3	Austria	29.6
Portugal	20.1	Austria	37.2	Luxembourg	28.4
UK	19.2	Netherlands	34.2	GE	23.9

Italy	16.5	GE	31.9	Netherlands	23.3
GE	15.8	UK	23.7	UK	21.4
Luxembourg	13.4	Spain	21.6	Portugal	20.1
Netherlands	12.3	Portugal	20.1	Ireland	13.7
Spain	2.2	Ireland	4.9	Spain	11.9
EL	1.1	EL	0.5	EL	0.8

Key: Concerning the final score for children aged 3-5 (col. 2), France's score is explained as follows: on a scale from zero (worst performer on all variables) to 100 (best performer), France is located at 61 on average for all underlying
De Henau et al. (2007). Page 58

The Child Care Index by De Hanau 2007

The child care index is computed by the following formulas with applied weights:

$$ICC_i^{0-2} = \left(scaled[FTFECov_i^{0-2}]\right) \bullet \frac{3}{4} + \left(scaled\left[\frac{1}{child/staff_i^{0-2}} / \frac{1}{child/staff_{DK}^{0-2}} \right] \right) \bullet \frac{1}{4}$$

$$ICC_i^{3-5} = \left(scaled[FTFECov_i^{3-5}]\right) \bullet \frac{3}{5} + \left(scaled\left[\frac{1}{child/staff_i^{3-5}} / \frac{1}{child/staff_{DK}^{3-5}} \right] \right) \bullet \frac{1}{5} + \left(scaled\left[spending_i^{3-5}\right]\right) \bullet \frac{1}{5}$$

Where ICC_i^{0-2} and ICC_i^{3-5} are the child care indices of country *i* at ages 0-2 and 3-5, respectively, $FTFECov_i^{0-2}$ and $FTFECov_i^{3-5}$ are the degree for full time free coverage, $child/staff_i^{0-2}$ and $child/staff_i^{3-5}$ are the child-staff ratios, expressed with respect to that of Denmark, and $spending_i^{3-5}$ is the public expenditure level.

The resulting ranking shows that the Northern countries and France provide the "best" child care both in terms of quality, availability and affordability for young children, while the Southern European countries (except Italy) provide the worst.

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