CERGE-EI

Center for Economic Research and Graduate Education -

Economics Institute

A joint workplace of Charles University and the Economics Institute of the

Czech Academy of Sciences

Master thesis

2020 **Bc. Monika Neufussová**

CERGE-EI

Center for Economic Research and Graduate Education -

Economics Institute

A joint workplace of Charles University and the Economics Institute of the

Czech Academy of Sciences

Bc. Monika Neufussová

Pre-school Abilities: European Comparative Study

Master thesis

Prague 2020

Author: Bc. Monika Neufussová

Supervisor: Doc. Ing. Daniel Münich, Ph.D.

Academic year: 2019/2020

Bibliographic note

NEUFUSSOVÁ, Monika. *Pre-school Abilities: European Comparative Study.*[1] Prague 2020. 73 pages. Master thesis. Center for Economic Research and Graduate Education - Economics Institute, A joint workplace of Charles University and the Economics Institute of the Czech Academy of Sciences. Thesis supervisor: Doc. Ing. Daniel Münich, Ph.D.

Abstract

Pre-school education improves cognitive and non-cognitive skills of children, and the positive effects persist to adulthood. The literature provides rich evidence of beneficial effects of pre-school, some of them even causal. However, most studies come from the US, and the research lacks a comprehensive picture of European countries concerning pre-school education. I contribute to the research by providing a comparison of European countries regarding pre-school attendance, pre-school skills, and test scores in fourth grade. In Section 3, I focus on the Czech Republic. The results show that more educated mothers are more likely to send children to pre-school. In most countries, children with stronger pre-school skills achieve higher results on standardized tests in fourth grade, which supports the idea of the existence of the Matthew effect. In the Czech Republic, pre-school attendance may increase fourth-grade test scores by 0.3 SD. The most important pre-school skill is the ability to read, which is associated with an increase in fourth-grade math achievement of 0.2 SD. The results contribute to the literature on pre-school education in Europe; however, they should not be interpreted causally, as they are essentially a description of the pre-school context in Europe.

[1] *Parts of this thesis were used as course work in Labour Economics at CERGE-EI.*

Abstrakt

Předškolní vzdělávání zlepšuje kognitivní a nekognitivní schopnosti dětí a jeho efekt přetrvává až do dospělosti. Literatura poskytuje mnohé důkazy o prospěšných vlivech předškolního vzdělávání, některé z nich dokonce kauzální. Většina studií nicméně pochází z USA a výzkum tak postrádá ucelený obraz předškolního vzdělávání v evropských zemích. K tomuto výzkumu přispívám srovnáním evropských zemí v ohledech předškolní docházky, předškolních dovedností a dosažených výsledků ve čtvrté třídě. Dále se soustředím na Českou republiku. Výsledky ukazují, že vzdělanější matky mají větší pravděpodobnost dávat děti do školky. Ve většině zemí děti s lepšími předškolními dovednostmi dosahují lepších výsledků ve standardizovaných testech ve čtvrté třídě, což podporuje existenci Matoušova efektu. V České republice je docházka v předškolním zařízení spojována s nárůstem výsledků ve čtvrté třídě o 0.3 směrodatné odchylky. Nejdůležitější dovedností je schopnost číst, která zvyšuje výsledky v matematice o 0.2 směrodatné odchylky. Tyto výsledky přispívají k literatuře ohledně předškolního vzdělávání v Evropě, ale neměly by být interpretovány kauzálně, neboť tvoří spíše popis evropské předškolní situace.

Keywords

Pre-school Education, Cognitive Skills, European Comparison, Test Scores, Matthew Effect

Declaration of Authorship

I hereby proclaim that I wrote my master thesis on my own under the leadership of my supervisor and that the references include all resources and literature I have used.

I grant a permission to reproduce and to distribute copies of this thesis document in whole or in part.

Prague, July 23, 2020

Signature

Acknowledgement

I would like to express my gratitude to my supervisor Doc. Ing. Daniel Münich, Ph.D. for his guidance and helpful comments. I would also like to thank my family and especially Marek for his huge emotional support.

Project of Master Thesis

Author of the master thesis:	**Bc. Monika Neufussová**
Supervisor of the master thesis:	**Doc. Ing. Daniel Münich, Ph.D.**
Academic year:	**2019/2020**

Theme: Pre-school abilities: European Comparative Study

Research question and motivation:

Education is an important aspect for various economic outcomes (Hanushek & Woessmann, 2012). Therefore, it is important to understand the mechanisms that determine the returns to education, years of education, grades and many others. A large number of studies focus on the effects of primary schools and their characteristics, such as teacher quality (Hanushek, 2010; Rivkin, Hanushek & Kain, 2005), class size (Rivkin, Hanushek & Kain, 2005) and peer effects (Hanushek, Kain, Markman & Rivkin, 2003). Recently, however, it has been shown that even in pre-school age, children develop skills that are instrumental in further skills acquisition (cognitive skills, social preferences, risk behaviour...). These skills are then kept for later life and therefore analysing pre-school education can provide results also relevant for adults (List, Tungodden, Cappelen & Samek, 2016).

Usually, researchers focus on the effects of kindergartens, socio-economic status or mother's characteristics and they confirm that these have significant effects on school performance (Sammons et al., 2004; Magnuson, Meyers, Ruhm & Waldfogel, 2004). There are also several studies analysing overall school readiness, which includes not only abilities to read and compute, but also the emotional status of a child (Duncan et al., 2007). However, few studies have been conducted in the area of comparing pre-school abilities across countries and evaluating their associations and possible causal impacts on later school performance. There are two possible scenarios. Children with a lower level of pre-school abilities may "catch up" with those with a higher level of skills, thanks to the equalizing role of the educational sys-

tem. This direction will be hypothesized in the thesis. On the other hand, in some countries the gap between them may remain, or even increase.

Contribution

There is a wide range of studies focusing on the effects of pre-school education. To the best of my knowledge, there is no comparative study of the European countries concerning pre-school abilities and school readiness. I will contribute to this gap in the existing research by performing a comparative study of European countries and by analysing associations and a possible causal impact of pre-school abilities on math and science test scores in fourth grade.

Methodology

I will use the data from the Trends in International Mathematics and Science Study (TIMSS) from 2015. TIMSS is an international dataset containing information about fourth grade students, particularly their results in a math and science test, retroactively reported pre-school abilities and socio-economic background, among others.

Firstly, I will perform an observational comparative study of the European countries with particular interest in Central European countries. The aim of this study will be to explain heterogeneity in the school readiness of children and to determine which factors affect it. Secondly, I will focus on the Czech Republic and attempt to estimate the causal effect of pre-school abilities on the test score, using the proximity of kindergarten as an instrument. The aim of this part will be to determine whether children that have better abilities at early ages keep this advantage, or whether they equalize with the others. In addition, the test score from math can be divided into algebra, geometry and working with data parts, thus the effects on particular sections may be evaluated separately.

Outline

1. Introduction

2. Literature Review
3. Comparative Study
4. Identification Strategy and Causal Impact of Pre-school Abilities on the TIMSS test score
5. Discussion
6. Conclusion

References:

[1] Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., ...Japel, C. (2007). School readiness and later achievement.*Developmental Psychology, 43(6).* 1428-1446. Doi: 10.1037/0012-1649.43.6.1428.

[2] Hanushek, E. A. (2011). The economic value of higher teacher quality. *Economics of Education Review, 30(3).* 466-479.

[3] Hanushek, E. A., Kain, J. F., Markman, J. M. & Rivkin, S. G. (2003). Does peer ability affect student achievement? *Journal of Applied Econometrics, 18.* 527-544. Doi: 10.1002/jae.741.

[4] Hanushek, E. A., & Woessmann, L. (2012). Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation. *Journal of Economic Growth, 17.* 267-321. Doi: 10.1007/s10887-012-9081-x.

[5] Cappelen, A. W., List, J. A., Samek, A., & Tungodden, B. (2019). The effect of early childhood education on social preferences. *Journal of Political Economy 0.*

[6] Magnuson, K. A., Meyers, M. K., Ruhm, C. J. & Waldfogel, J. (2004). Inequality in preschool education and school readiness. *American Educational Research Journal, 41(1).* 115-157. Doi: 10.3102/00028312041001115.

[7] Rivkin, S. G., Hanushek, E. A. & Kain, J. F. (2005). Teachers, schools, and academic achievement. *Econometrica, 73(2).* 417-458.

[8] Sammons, P., Elliot, K., Sylva, K., Melhuish, E., Siraj-Blatchford, I. & Taggart, B. (2004). The impact of pre-school on young children's cognitive attainments at entry to reception. *British Educational Research Journal,*

30(5). Doi: 10.1080/01411920420002346 56.

In Prague on .....

Signature of the supervisor

Signature of the author

Contents

Introduction

Pre-school education helps to develop children's cognitive and non-cognitive skills of children and has persistent positive effects for later ages. The literature provides evidence that children who attend pre-school achieve higher results on primary school tests, have better literacy and numeracy skills, and are more emotionally prepared for primary school attendance. Moreover, the effect is strongest for children from lower socio-economic backgrounds. Several studies also focus on the length of pre-school education and conclude that it positively correlates with cognitive attainments.

Some studies even provide evidence of causal effects of institutional pre-school education on acquisition of cognitive skills (e.g. by randomly assigning children to institutional pre-school education). However, most studies use US data and are not applicable in Europe due to different legal settings. Also, there is no comprehensive picture summarizing European findings about pre-school education; what influences parental decisions to send children to pre-school, whether pre-school attendance improves all types of cognitive skills, and what the subsequent effects on primary school achievement are.

Furthermore, few studies analyse the Matthew effect, i.e. whether children who start in better positions (have stronger cognitive skills prior to entering primary school) achieve higher test scores in fourth grade. However, evidence concerning this phenomenon is mixed and insufficient. Also, many studies take parental education as the source of primal inequality.

I contribute to existing research by providing a comparative study of European countries concerning pre-school education, pre-school skills, and fourth-grade test achievement. I use the TIMSS 2015 data to illustrate interesting patterns in European pre-school education, and how it corresponds to the legal settings in individual countries. I also focus on the existence of the Matthew effect. In the analysis I use pre-school skills as the source of primal inequality, in contrast to existing studies that mostly use parental education. Nevertheless, I control for the relationship between parental education and

pre-school skills. Then, I focus on the Czech Republic and analyse pre-school education in more detail.

The thesis countributes to the literature on pre-school education. It provides a novel European comparison, which complements research from the US and from individual European countries. It could serve as a reference for other researchers who analyse pre-school education in Europe, because it contains a thorough summary of European data and includes several tabular and graphical illustrations of patterns in European pre-school education.

The results of the European comparison are best summarized graphically; however, they provide three main take-aways. First, attendance in pre-school education correlates highly with parental education and occupation. More educated parents are more likely to send their children to pre-schools. Also, parents with more prestigious careers are more likely to do so. Second, children who attend pre-school and have higher levels of pre-school skills achieve better on fourth grade standardized tests, which is evidence of the presence of the Matthew effect. Third, pre-school skills are often associated with pre-school attendance, but this does not hold for all skills and countries. Even though these are only descriptive correlation statistics, the results suggest that maybe the results of US studies about the beneficial effects of pre-school education on acquisition of cognitive skills cannot be generalised to the European environment. Moreover, it signals that pre-school quality matters, and pre-school attendance itself may not solely produce the desired effects.

Based on the interesting findings from European comparison, I build two models for the Czech Republic. The first focuses on the parental decision to send children to pre-school, while the second analyses the origins of heterogeneity in fourth grade test scores. The results show that maternal occupation is the most significant factor influencing the decision to send children to pre-school. Although the descriptive analysis shows that maternal education attainment is also important, in the regression, the occupation drives the full effect. Nevertheless, the magnitude of the effect is minor (around 3% increase in the probability of sending child to pre-school). The second

model shows that attending pre-school for more than 3 years is positively associated with a 0.3 SD increase in fourth-grade test scores. Reading, writing, and counting skills at pre-school ages also improve test scores in fourth grade. Interestingly, there is a heterogeneity of effects based on gender - boys are significantly more influenced by maternal education and pre-school attendance than girls. However, the results cannot be interpreted as causal, since there are some omitted variables (e.g. family status and number of siblings) which may bias the results. However, these were not available in the dataset.

The rest ot the thesis is organised as follows. Section 1 summarizes the relevant literature concerning the beneficial effects of pre-school education on cognitive skills acquisition. It also describes the legal differences across European countries as regards pre-school education. Section 2 explains the explanatory and outcome variables used and provides a European cross-country comparison based on these variables. Section 3 focuses on the Czech Republic and shows the results of the analyses. First, it provides descriptive statistics of Czech data, and second, it contains results of the models used. Section 4 discusses possible limitations of the analysis and suggests possible extensions for future research. The last section concludes.

1 Literature Review

Education sector is an important element in the economic development of a country. As Krueger (2002) points out, about 70 % of national income may be attributed to human capital. Higher levels of education also cause higher economic growth of a country (Hanushek and Woessmann, 2012) and crucially influence economic variables such as employment, wages, life expectancy, and criminality rate (e.g. Hanushek and Woessmann, 2012; Rindermann, 2007; Apps et al., 2013). In addition to economic outcomes, education affects cognitive and non-cognitive skills, social preferences, and the socio-emotional and mental development of young generations (e.g. Sammons et al., 2004; Apps et al., 2013; Magnuson et al., 2004). Cognitive skills are further decisive for earnings (Hanushek et al., 2015)

Recently, the period of life before primary school has received rising attention from researchers. Pre-school aged children develop skills that are instrumental in further skills acquisition. Because these skills impact later life, analysing the pre-school period can provide findings which are also relevant for adults (Cappelen et al., 2016; Behrman et al., 2014). Although this issue has been addressed mostly by psychologists, it is important for economics as well, because skills developed in early childhood influence economic outcomes, e.g. earnings, employment, occupational choices, and further accumulation of human capital (Hanushek et al., 2015). Existing empirical literature presents convincing evidence that attending formal (institutional) pre-school education can have significant effects on later test scores, acquisition of skills, development of social preferences, socialization, behavioral disorders and others (e.g. Magnuson et al., 2004; Sammons et al., 2004; Apps et al., 2013; Monnet, 2019).

At pre-school ages, children may be subjected to care-based settings or education-based settings, depending on their age. Care-based settings are focused on children younger than 3 years old; children are not directly educated there and the purpose of these institutions is providing care and socialization (e.g. nurseries). In education-based settings, which are at-

tended by children between 3 and 6 years of age, children are educated in addition to socializing (e.g. kindergartens). Henceforth, I use the term *pre-school education* to refer to education for children between 3 and 6 (although the specific ages differ across countries). Pre-school education can take both parental and formal (institutional) forms. Parental care means that children stay with their parents and are "educated" at home, while formal education implies that children are enrolled in an institutional setting.

According to the EACEA (2019), there are currently about 31 million children under six years of age (when primary school education usually begins) in the EU who are potential attenders of some pre-school program. However, only seven EU countries guarantee places in public institutions for children younger than 3, but older than 18 months (mostly Scandinavian countries), and about half of EU countries guarantee places for children 3 and up. A growing number of countries are making pre-school programs compulsory, at least one year. It is therefore essential to understand whether formal pre-school care is beneficial and to understand its effects.

The form of pre-school care and education is a crucial aspect in designing education policies for every country. Unfortunately, most existing studies are from the United States and therefore their generalisability is questionable due to cultural and legal differences. Further in this section, I review the most relevant literature concerning the effects of attending preschool and school readiness on latter school performance. Additionally, I summarize the most important legal differences concerning kindergarten attendance among European countries.

1.1 Pre-school Attendance and Cognitive Skills

Hungary is the only country in the European Union which has three compulsory years of pre-school education. Nevertheless, a growing number of countries have made at least one year of pre-school education compulsory (EACEA, 2019). It is therefore essential to know to what extent formal pre-school education is beneficial and to understand its impacts. In this section,

I summarize the literature concerning the effects of pre-school education, with particular focus on the development of cognitive skills.

First, as stated above, pre-school education does not necessarily mean attending an institution, since in many countries formal pre-school education is not compulsory (e.g., Ireland, Italy, and Slovakia) (EACEA, 2019). Pre-school education may thus be carried out by parents. This allows researchers to study the effects of attending pre-school, the duration of attendance, the quality of teachers and many other factors.

Several studies suggest that pre-school attendance has a strong positive impact on skills development. Duncan and Magnuson (2013) point out the issue of low enrollment rates in pre-school education in the US. Most US pre-school programs are private and costly, and so are available mainly to wealthier families. However, pre-school programs are especially beneficial for children from low income families, as demonstrated by the results of the Abecedarian program (Ramey and Campbell, 1984). The authors of the Abecedarian program randomly assigned children to full-time center-based care for five years, starting in the children's first year of life. The results show significantly positive effects of the program on IQ and on verbal and quantitative skills in later life. The advantages of treatment persist to adulthood - children who participated in Abecedarian program had higher IQs at age 21 and were more likely to attend university, compared to the control group (Ramey and Campbell, 1984).

Using German data, Anders et al. (2012) search for reasons of varying levels of childhood skillswhen children enter primary schools. Using a latent growth model, they conclude that pre-school education develops numeracy skills, although they cannot interpret these results causally, since they are lacking a control group not attending pre-school. The data from the United Kingdom show that, while about 30% of children are weak in performance when entering pre-school, many fewer remain weak when entering primary school. Sammons et al. (2004) perform a multilevel analyses, which provides evidence that attending kindergarten has strong positive effects on language

development, pre-reading skills, and early number concepts. The impacts on language development and early number concepts were the strongest (effect size = 0.44), suggesting that on average, children attending pre-school achieve 2.7 points higher in pre-reading and 2.0 points higher in early number concepts than children with no pre-school experience. In addition, Sammons et al. (2004) found that the length of attendance positively correlates with cognitive attainments (in pre-reading, language and early numeracy). This might be evidence that a single compulsory year of pre-school education is not enough. However, controlling for more variables yields no significant causal effects of the length of pre-school education on cognitive skills (Leak et al., 2012).

In addition, parents may also educate their children to prepare them for primary school. As Biedinger (2011) states, parental education and home environment influence children's cognitive skills. For example, various joint parent-child activities improve reading skills (Wood, 2002) and numeracy skills (Anders et al., 2012).

Kindergarten attendance has a positive impact on cognitive skills in adolescent age, especially for the children from families with low socio-economic status (Apps et al., 2013). Using data from the questionnaires of Longitudinal Study of Young People in England, Apps et al. (2013) match users and non-users of pre-school based on variables such as *maternal education, marital status at birth, and month of birth of the child.* They find that institutional pre-school education positively affects language, math and science skills of girls (but not boys) at ages 11, 14 and 16 ($p=0.01$). The average treatment effect on the treated (the impact of pre-school on children who attended) is comparable to the average treatment effect on untreated (the hypothetical impact of pre-school on children not attending), ranging from 0.08 to 0.15. Overall, the effects on language skills are stronger than the effects on math. In general, the authors assume that the positive effects of pre-school are due to early exposure to literacy and numeracy, and also socialisation.

Very similar patterns were found in the US ECLS-K data on pre-school education by Magnuson et al. (2004), who also conclude that also children who attend a pre-kindergarten program perform better in both math and reading skills than children in parental care. They employ a large set of covariates, including family characteristics, home learning environments, and school environment, to overcome omitted variable bias from the OLS estimation. They conclude that children enrolled in some form of pre-school care setting the year before entering pre-school education develop better reading and math skills than those in parental care. Their estimated effect of attending a pre-school care setting on reading skills is 1.35 ($p=0.01$), which implies approximately one additional correct answer on a reading test, raising the child from the 50th to the 54th percentile. Importantly, they show that these positive effects tend to decrease as children age, and the differences among children eventually dissipate.

German data from the BiKS project also show that pre-school attendance positively influences numeracy skills. Anders et al. (2013) separate the effects of pre-school and primary school on numeracy skills, and then analyse how these interact. A growth model together with multivariate value-added regression provide evidence that while children's numeracy skills already differ at young ages due to family socio-economic background, pre-school and school experience can influence children's skills. However, the self-selection bias cannot be ruled out. In addition, Anders et al. (2013) highlight the importance of pre-school quality, which has an impact on the development of children's skills, as it causes faster development of children.

There are also various pre-school inputs that may significantly causally affect performance at the primary school level, such as class size, quality of teachers, and peer effects. As far as the class size is concerned, Funkhouser's (2009) results for US kindergartens correspond to the opinion of Hanushek (2002) regarding primary schools; that class-size reduction is inefficient, compared to higher teacher quality. Funkhouser (2009) finds the effects of class-size reduction in kindergarten to have almost no effect on children's academic

performance in the second grade. Anders et al. (2013) show that in Germany, class size is negatively correlated with numeracy skills, but children who attend larger pre-school classes tend to catch up faster. Another essential channel in pre-school education effects on primary school achievement may be the teacher-child relationship. Pianta et al. (1995) show on US data that children who have negative relationships with teachers tend to be less cooperative and have more behaviour problems at older ages, and vice versa, children who have a positive relationship with kindergarten teacher adapt better to primary school.

To sum up, pre-school education attendance seems to have strong positive effects on the acquisition of cognitive and non-cognitive skills, and also improves abilities, such as reading skills and basic number concepts. The channels are usually assumed to be early exposure to literacy and numeracy, along with early socialisation. There are various pre-school inputs that may strengthen or weaken this effect, most importantly the quality of the pre-school setting, but also class size, teaching methods, child-teacher relationship, and peer effects. This is not an extensive list, since analysing every influence would be beyond the scope of this paper. However, the section gives a comprehensive image of ways how pre-school education may affect later performance.

1.2 Pre-school Attendance and School Readiness

Pre-school education has been established as influencing children's cognitive skills, literacy, language skills, and understanding of basic math concepts. However, it does not influence only *cognitive* skills, but also non-cognitive (socio-emotional) skills, the so-called overall school readiness. The main difference between cognitive skills (including reading, writing, and numeracy skills) and school readiness is that the latter also includes the socio-emotional maturity of a child, self-control, and captures the degree to which she is prepared to learn (Lewit and Baker, 1995). While age is often the only condition for starting school, the children may not always be emotionally

mature enough to thrive in a school environment. Pre-school education can often boost school readiness, which may be then a potential channel for further benefits of pre-school education (children who attend pre-school often have higher levels of initial skills, and may also learn more quickly as they are more prepared for schooling).

Although innate temperament is also important for later development and performance, much social behaviour can be acquired during childhood (Shala, 2013). Therefore, children who attend pre-school can learn to control their emotions better and to become more socialized. Shala (2013) shows that the social and emotional status of a child is significantly correlated with later performance on primary school.

Even though Claessens et al. (2009) reveal positive effects of pre-school education on reading and math skills, they did not find any effects of socio-emotional skills during the kindergarten age on primary school performance. On the other hand, Cappelen et al. (2016) focused on the opposite effect – whether pre-school education can help to develop socio-emotional skills. They randomised children into parental and kindergarten programs, thus they do not have any self-selection problems that would bias their results. They demonstrate that early childhood education has a significant causal impact on social preferences when children reach primary school, since children attending kindergartens are more egalitarian compared to those in parental care. Similarly, Sammons et al. (2003) find a positive correlation between pre-school attendance and social development, i.e. ability to socialize, to concentrate, and to cooperate.

The results suggest that socio-emotional skills develop significantly at pre-school ages and attending a kindergarten has positive effects on development of these skills. Importantly, this effect is not homogeneous, but is stronger for children from lower socio-economic backgrounds. This has strong policy implications concerning provision, targeting and accessibility of pre-school education. Formal pre-school education is beneficial not only from the point of view of test scores and cognitive skills, but also from the point of view

of school readiness, including socio-emotional skills, socialization, and self-control. Moreover, school readiness might be controlled in more countries prior to primary school admission (in addition to age), since it positively influences performance (Shala, 2013).

1.3 The Matthew Effect

Children entering primary school have varying levels of cognitive and non-cognitive skills. The reasons they differ (within a country, even within a school) could be attributed to parental education (Biedinger, 2011), home learning environment (Anders et al., 2013), and school entry age (Angrist and Krueger, 1992). Primary education may then either reduce the gaps among children, or widen them. Therefore, it may happen that low-skilled children learn faster and "catch up" to the high-skilled, or vice versa, the inabilities cummulate, which increases the gap between children. The empirical evidence concerning this phenomenon is insufficient and mixed, thus more detailed research including comparisons of various countries is needed. In this section I review some studies from individual countries and highlight the contradictions among them.

The phenomenon of cumulative advantages (or disadvantages) is called the *Matthew effect*. The term was coined by Merton (1968) and describes a situation in which *"social advantages lead to further advantages - or disadvantages to further disadvantages - through time, creating widening gaps between those who have more and those who have less"* (Rigney, 2010). By the definition, the Matthew effect may help to explain growing inequalities. It occurs in many fields; economics ("the rich get richer, and the poor get poorer"), sociology, sports, biology, and education (Rigney, 2010). Social advantages described by the Matthew effect may be of various types, e.g. wealth, parental education, children's education and more.

Empirical research concerning the Matthew effect in education provides mixed evidence, since sometimes gaps between students narrow as children grow older. Naturally, the phenomenon of modifying differences among stu-

dents might be influenced by cultural or legal differences, and thus the results vary across countries or schools. Aunola et al. (2002) analyze reading skills of Finnish primary school children and find that the sample variance decreases as children age, since poor readers tend to improve more than good readers. Slightly different results for Finland are presented by Leppänen et al. (2004), who show that during pre-school, the gap between children tends to increase in size; however, in primary school children tend to equalize. Unfortunately, both of these studies use only Finnish data. The education system of Finland is very specific, and thus generalizability of these results is questionable. Claessens et al. (2009) show that in the US, reading skills before entering primary school are positively correlated with first grade achievement ($corr = 0.5$); however, their effect weakens in higher grades. These results suggest that the Matthew effect is not present.

On the other hand, some researchers do find evidence of the Matthew effect. Walberg and Tsai (1983) show that, in the US, young adults with better educated parents tend to be more educated. These days this principle is generally accepted worldwide, but the contribution of Walberg and Tsai (1983) is that the educational advantage is not linear but cumulative, which supports the presence of the Matthew effect. Coleman et al. (1966) also find evidence of the Matthew effect in the US, showing that students with higher scores in early grades also score much higher in the later grades, as the gap cummulates. Kerckhoff and Glennie (1999) focus on American high school students and show that the Matthew effect occurs even at this level of education.

Outside of the US, the Matthew effect has also been found in Europe. Luyten et al. (2003) find evidence supporting the existence of the Matthew effect in the Netherlands. They show that Dutch children with poorly educated parents also tend to be disadvantaged in learning. Pfost et al. (2012) focus on German students and conclude that reading skills of poor readers develop at slower rates than the reading skills of better readers, hence the Matthew effect is present. These results correspond to those of Walberg

and Tsai (1983) and Stanovich (1986), who explain that better readers read more, thus they become even better.

The evidence concerning the Matthew effect is evidently mixed; the studies come from very different countries and there is no consensus whether children tend to equalize, or whether their differences accumulate. Moreover, studies supporting the existence of the Matthew effect often take parental education as the source of the prior inequality, while there is a gap in the research concerning the cumulative advantages of pre-school skills, both cognitive and non-cognitive. The purpose of this thesis is to compare students from the point of view of their own abilities before primary school attendance. I compare various European countries regarding the differences in pre-school abilities and how they evolve, and thus find the evidence of the presence of the Matthew effect. The patterns in cross-country differences may replicate the cultural and legal settings of countries, thus in the next section I focus on legal differences among European coutries.

1.4 Legal Differences

The legal settings of pre-school education vary across countries. While primary school education is compulsory in all European countries, the length of compulsory pre-school education varies. Further, there are differences concerning the ages at which children start attending particular institutions, parents' involvement, and financing of pre-schools, among others. Since legal differences can significantly influence attendance in kindergartens, and therefore the identification strategies in potential research, it is crucial to understand these and take them into account. Therefore, in this section, I review the most relevant legal differences across European countries with a particular focus on explaining the Czech system. The information in this section comes from EACEA (2019) and TIMSS data documentation.

First, the transition age varies over European countries. In most cases, children transfer from pre-school care to pre-school education at the age of 3, and start attending primary school at the age of 6. However, there are

some exceptions. In Northern Ireland, compulsory education starts at the age of 4, and in England and Malta at the age of 5. In the Baltic countries, Finland, Sweden, Poland, Bulgaria, and Croatia, primary education starts at the age of 7. In this regard, the Czech Republic belongs to the majority; children are legally entitled to attend a pre-school at the age of 3 and start attending primary school at the age of 6 (with some exceptions - the TIMSS data show that only fewer than 1% of children start before they turn six, and 29% of children start at seven or later).

In 29 European countries, age is the only condition for primary school admission. In 15 of these, deferment is possible upon the request of parents (e.g. the Czech Republic, Poland, Scandinavian countries); but in the remaining 14 there is no possibility of deferment (e.g. Iceland, the UK, France, Spain). In the rest of the countries, children's cognitive skills, emotional and mental development are assessed prior to primary school admission (e.g. Germany, Austria, Slovakia, and Hungary).

Pre-school institutions may be organised either as unitary or separate. One third of European countries (Scandinavia, Baltic countries, Croatia, Slovenia...) have unitary settings, which means that the institutions are intended for the whole age range, primary school age being the upper limit. However, most European countries (including the Czech Republic) have separate settings, so children younger than 3 are separated from older children. This assures that child care and education are separated. In some European countries both systems coexist (e.g. Germany, Austria, Denmark, and the UK). In countries with unitary settings there is usually an obligatory pre-primary class, which is supposed to guarantee a smooth transition between pre-school and primary school. In separate settings, the whole second level is considered a preparation for primary school.

An alternative to centre-based care (or education) is home-based provision. This often takes the form of childminders who, in their homes, care for four to five children. Even though this service is typically for children younger than 3 years old, it can also include older children. In France, the

home-based child-care dominates the centre-based model. In the Czech Republic, the home-based alternative is allowed by law; however, it is very rare.

The activities offered in both settings are quite similar across countries and include reading literacy, learning to learn, numerical reasoning, language and communication skills, and support for emotional, personal and social development. However, in some countries, e.g. the UK, Poland, Spain, and Montenegro, parents can also be involved and participate in deciding about children's activities and/or budget allocations. In the Czech Republic, this is not possible.

Pre-school education for children older than 3 is usually financed publically or privately using public subsidies. Most often, private financing does not exist, or is of minor importance. On the other hand, the settings for children younger than 3 years are more often financed privately (e.g. in Slovakia, Cyprus, Malta, and the UK).

The countries also differ regarding the time that children spend weekly in institutional care or education. Based on this criterion, institutions can be divided into part-time (less than 20 hours per week), school-time (between 20 and 29 hours per week), and full-time (more than 30 hours per week). While the first two are primarily intended for education, the last category helps working parents, and there is usually no clear delineation between education, games, and relaxation. Figure 1 shows the number of hours, based on the type of guarantee (legal and compulsory). Most countries guarantee school-time hours; the Czech Republic usually offers full-time hours for legally entitled children.

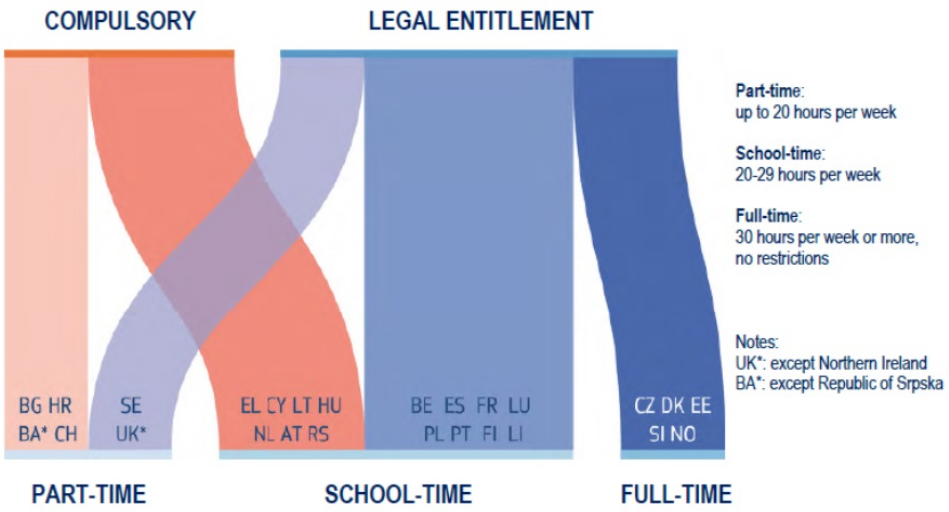

Figure 1: Weekly Hours by Type of Timeframe
Source: EACEA (2019)

2 European Comparison

I use the data from the international assessment Trends in International Mathematics and Science Study (TIMSS) of fourth graders from 2015. The TIMSS database provides data for more than 50 countries. I compare only European[2] countries, since the rest of the world may have very different legal pre-school settings and culture. The data contain information on students' achievement in math and science, and their personal and home backgrounds. The data constitute representative samples of schools and classes (two-stage random sample design) in participating countries through forms completed by teachers, students, and parents. The sample size in each country is approximately 150 schools and 4000 students.

In this section, I first discuss the response rates and possible sources of missing data. Then I introduce the crucial dependent and independent variables used later in the analysis and provide some basic summary statistics. I present a graphical cross-country comparison of pre-school attendance, pre-school skills, and test scores in fourth grade.

[2]These include Belgium (Flemish part), Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, England, Finland, France, Germany, Hungary, Ireland, Italy, Lithuania, Malta, the Netherlands, Northern Ireland, Norway, Poland, Portugal, the Russian Federation, Serbia, Slovakia, Slovenia, Spain and Sweden

2.1 Non-Response Rates

The dataset provides information about 25 European countries. However, England, the Netherlands, Northern Ireland and Slovenia need to be removed from the analysis due to too many missing observations (response rate less than 30 % or missing crucial information for analysis). The data I use contain information from questionnaires completed by students and their test scores, and from take-home questionnaires that were filled in by parents. In England, the take-home questionnaires for parents probably were not distributed, since there is no information from parents.

Generally, the source of non-response rates is unknown. Although parental education is a fundamental indicator of socio-economic background, whole rows of data are missing, therefore I cannot conclude that non-response correlates with parental education, occupation, or income. Missing rows suggest that the questionnaires were not returned by the students. Thus, the only sources of non-response that can be analysed are information from students' questionnaires, i.e. the gender of the student and her test scores. The analysis did not provide evidence of any significant correlation of non-response with gender or test scores in any country analysed. Girls do not submit questionnaires as often as boys, and it is not the case that well-performing students submit questionnaires with higher probabilitiy. In addition, the questions related to pre-school abilities were answered by parents. Due to the retrospective character of the questions, the answers may be less than fully reliable because parents may not remember clearly, or may desire to put their children into a better light. This may imply measurement error and a bias in my later models.

2.2 Outcome Variables

The key outcome variables are attendance at pre-school care and education settings (coded as *creche* and *kindergarten* for simplicity), the length of attendance, and, most importantly, the level of pre-school skills and fourth grade test scores. Table 8 in Appendix shows descriptive statistics of all

countries. Further in this section, I provide a cross-country comparison. These variables are later used as outcomes in OLS regressions, which seek to explain the heterogeneity in pre-school attendance, skills, and test performance in fourth grade.

Creche is a dummy variable indicating whether a student when a child attended pre-school care setting for children younger than 3. Figure 2 shows the attendance rates in the countries analysed. In Norway and Sweden the pre-school care attendance rate is over 80%, the highest of the European countries analysed. Finland does not conform to the pattern of high attendance rate in Scandinavian countries, since only 47.7% of children attend pre-school care institutions, slightly above the average of all countries analysed. In Belgium, 60.8% of children attend pre-school care. By contrast, Central Europe evinces very low attendance rates - only 4.6% in the Czech Republic, 8.41% in Poland and 8.2% in Slovakia.

Kindergarten is a dummy variable indicating whether a child attended pre-school education for children older than 3 years, irrespective the length. The European attendance rates are depicted in Figure 2. The attendance in pre-school education settings is in general much higher than in the case of pre-school care; the average in the analysed countries is 89.6%. The highest attendance rate, 99%, is in Hungary, which corresponds to the legal setting (in Hungary, three years of pre-school education are compulsory). Similarly high attendance rate is in Poland (99%). The rest of the countries range between 85-95%. Surprisingly low attendance in pre-school education is found in Sweden (78.4%), which together with Spain (76.7%) occupy the last positions. Although in some countries *kindergarten* attendance correlates with parental characteristics (particularly those of the mother), as shown in Table 3, often it is not correlated with anything - naturally, because it is compulsory by law (e.g. Hungary, Finland, and Norway).

Length represents the total number of years a child spent in some form of pre-school, whether education- and/or care-based. Figure 3 depicts the chart of lengths of pre-school attendance. Usually, children spend 3 or 4 years in

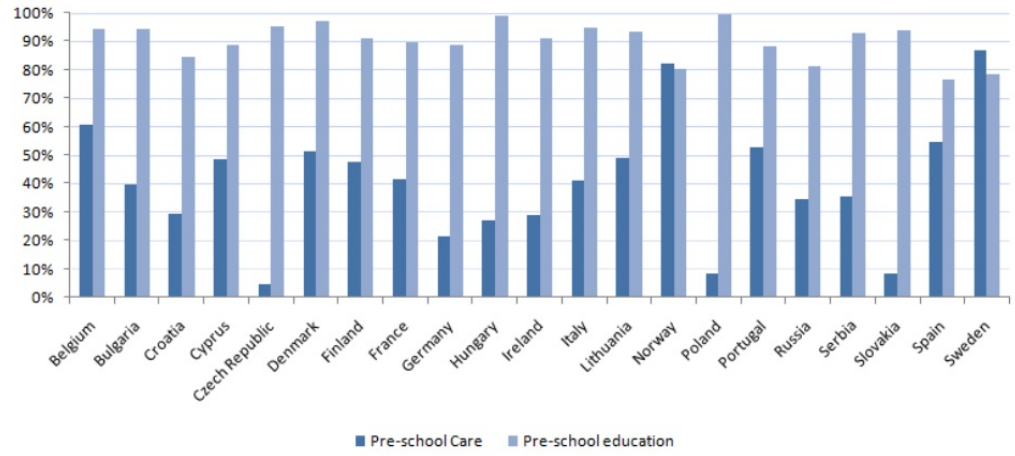

Figure 2: Attendance Rates of Pre-school Institutions

Source: Author's calculations based on TIMSS 2015 data

pre-school. Ireland is an exception in this regard; it is more common to attend pre-school for 1-2 years. The longest pre-school attendance is in Sweden, Norway, and Belgium, which corresponds to high attendance rates in pre-school care in these countries.

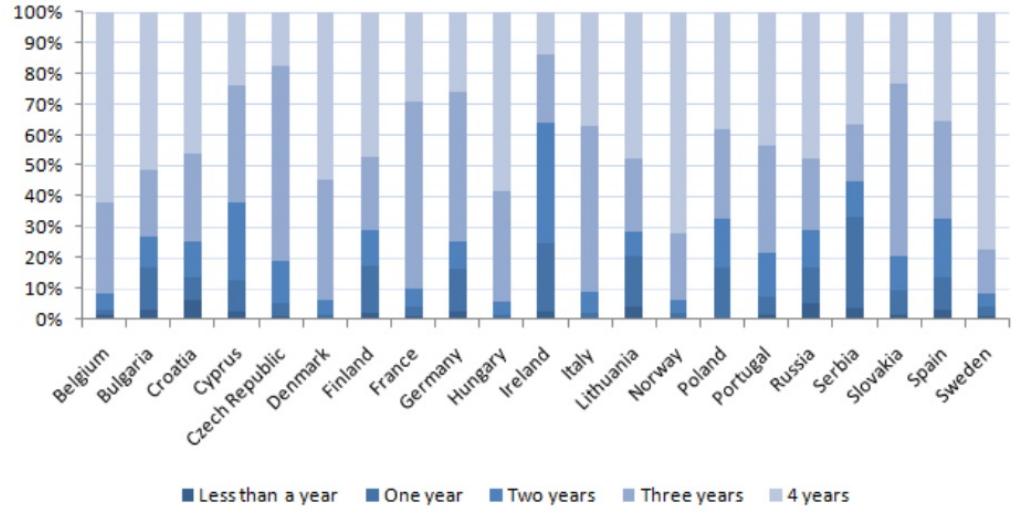

Figure 3: Length of Pre-school Attendance

Source: Author's calculations based on TIMSS 2015 data

School age is a variable indicating how old a child was when she started attending primary school. A cross-country comparison of average school entry ages is displayed in Figure 4. The average age of students entering

primary school education is 6.2 years, but as noted in the previous section, this varies across countries. In Bulgaria, Croatia, Hungary, Serbia, Finland, and Sweden, children are obliged to begin primary school education at the age of 7, which corresponds to the average entry school age from the data. In the Czech Republic, the average school entry age is 6 years and 4 months. The data show that although a majority of children begin primary school at the age of 6 (as given by law), a third begin at 7, suggesting quite a large share of deferment. On the other hand, in Spain, almost half of children begin primary school at the age of 5.

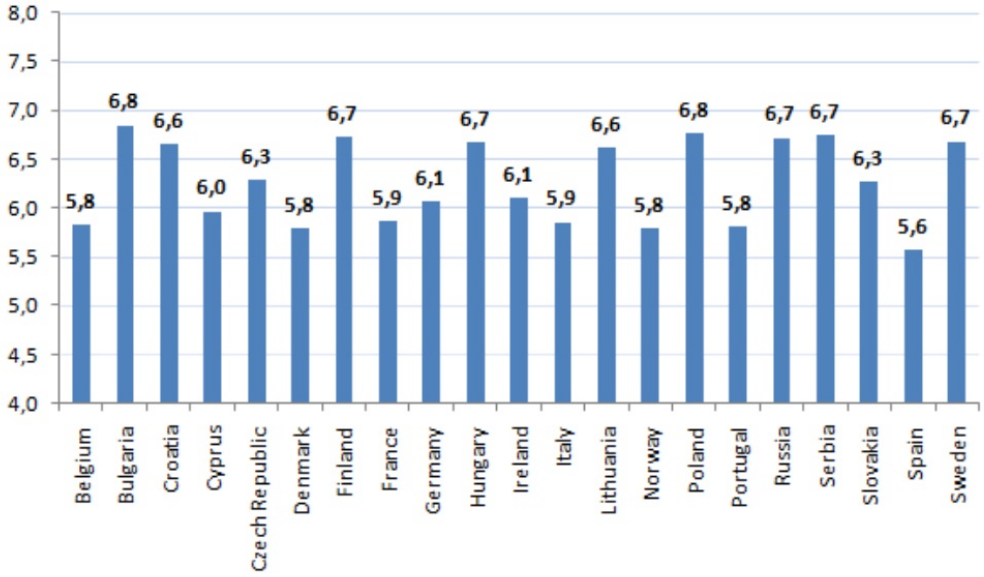

Figure 4: Entry School Age

Source: Author's calculations based on TIMSS 2015 data

Furthermore, the data contain retrospective information on children's pre-school abilities, i.e. how well they could read, write, and count before they began primary school. These may correlate with one another, and Figure 5 shows a Czech correlation matrix of pre-school skills. Literacy skills are originally measured on a four-degree scale, but for the purpose of the analysis, these are transformed into dummies. *Read_letters*, *read_words*, *read_sent* and *read_story* are dummies equal to one if a child can read letters, words, sentences, and stories, at least moderately well. Dummy variables for writing

skills are created analogously. Figure 6 shows differences in pre-school reading skills across countries in detail. The best performing country in reading skills is Ireland, where more than 90% of children can read words and 78% of children can read simple stories prior to entering primary school. Children in Croatia, Lithuania, and Spain also perform very strongly. In contrast, Hungarian children are among the worst performing in pre-school reading skills, despite their compulsory pre-school education. Nevertheless, interpretation of the results needs to be taken cautiously. For example, in Serbia 86% of children can read stories, but only 51% can read sentences, which seems contradictory. This is probably caused by the retrospective character of information, explained in Section 2.1. Hence, the dummy variables explained above are equal to one only if a child has the logically preceding skill, to prevent occurance of such errors (for example, intuitively a child cannot read stories if he cannot read sentences).

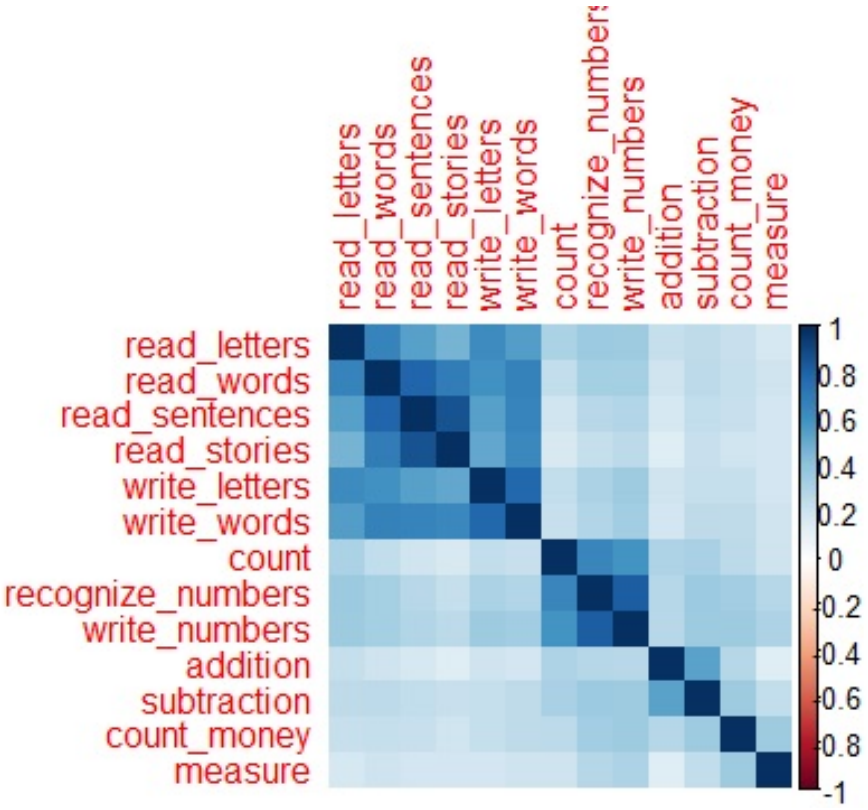

Figure 5: Czech Correlation of Pre-school Levels of Skills

Source:Author's calculations based on TIMSS 2015 data

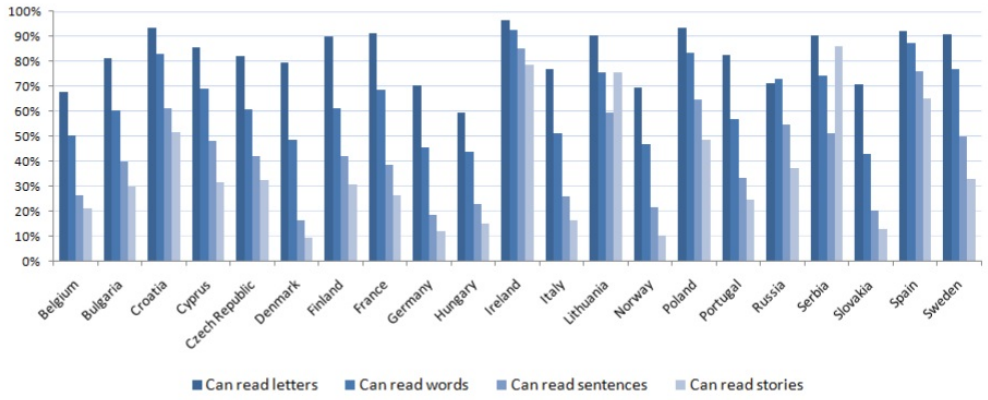

Figure 6: Reading Skills when Starting School
Source: Author's calculations based on TIMSS 2015 data

Ireland also stands out in writing skills, followed by Croatia and Spain (see Figure 7). In these countries, writing skills prior to primary school attendance reach or exceed 90% level. On the other hand, Hungary is again the lowest achieving with less than 45% of children able to write letters and words.

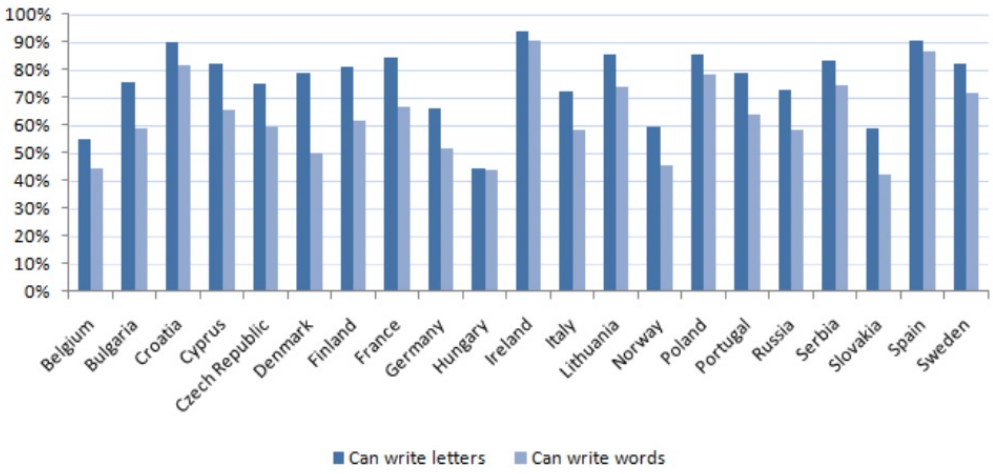

Figure 7: Writing Skills when Starting School
Source: Author's calculations based on TIMSS 2015 data

Numeracy skills are divided into two categories. First, basic number concepts include the abilities to recognize numbers, write numbers, and verbally count. These are measured on four-degree scale, but for the purpose of the analysis they are transformed into dummies equal to one if a child can

count/recognize numbers/write numbers at least up to 10. Low-performing children who can count only to 10 or less are depicted in Figure 8. The data show that writing numbers is the weakest ability of pre-school children, while the ability to count verbally is quite common. Irish children are well prepared for math at primary school level, with fewer than 20% of Irish pre-schoolers who cannot count higher than 10. On the contrary, more than half of children in the Czech Republic, Slovakia, Germany, Italy and Belgium cannot recognize and write numbers above 10. There is only negligible a number of children who cannot count at all prior to primary school - the exceptionally high percentage is 7.2% in Slovakia.

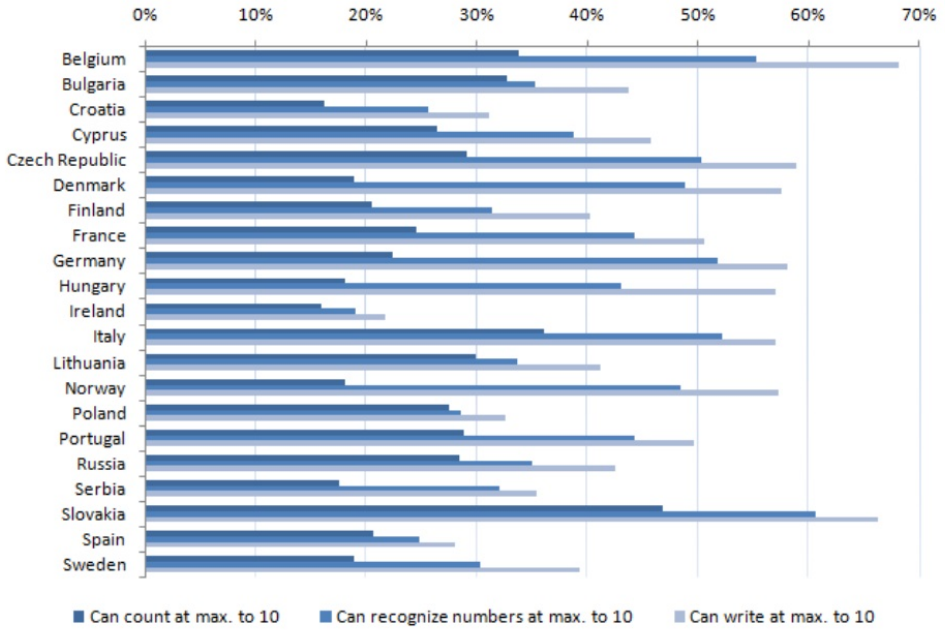

Figure 8: Numeracy Skills when Starting School
Source: Author's calculations based on TIMSS 2015 data

The second category includes counting skills, including simple addition and subtraction, the ability to count money and to measure length and height. These are coded as dummy variables equal to one if a child has the corresponding skill. The European comparison is graphed in Figure 9. Evidently, adding numbers is much easier than subtracting them, since addition skills in all countries exceed 60%, except for Italy, where only 43% of

children can add numbers prior to primary school. Italian children, together with the French, are the weakest in subtraction (around 30%, compared to the average of 62% in the rest of analysed countries). Apparently, money may be a good tool for acquiring numeracy, since on average 46% of children can count money prior to primary school. The most difficult concept for pre-school aged children is measuring length and height. In the best achieving countries - Russia, Sweden, Poland, Ireland, and Hungary, the share of children who can measure length and height does not exceed 28%.

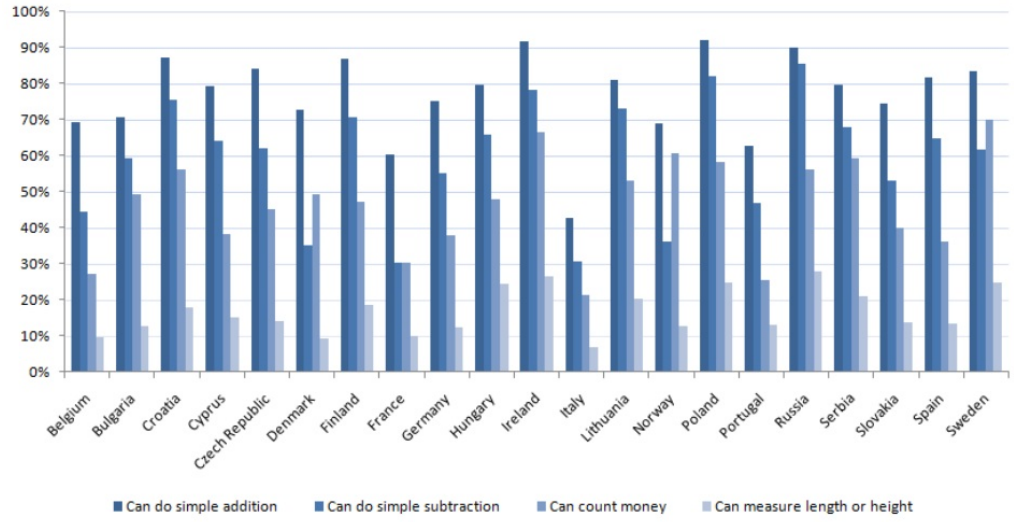

Figure 9: Counting Skills when Starting School
Source: Author's calculations based on TIMSS 2015 data

Table 1 shows the relationship between pre-school attedance and skills. Based on the literature, I expect pre-school education to be positively correlated with pre-school skills, and Table 1 shows that it is mostly the case. Children who attend pre-school education for three or more years are more likely to have cognitive skills prior to primary school entry. In Bulgaria, pre-school seems to have the largest association among the countries analysed. In Bulgaria only 25.1% of children who did not attend pre-school can read words, but 65.7% of children who attended pre-school for 3 years or longer can do so. Other countries also exhibit positive correlation between pre-school education and cognitive skills acquisition; however, the differences are not as striking. In all countries, pre-school attendance seems to corre-

late positively with the skill to recognize numbers. For example, in Slovakia, 54.4% of children who did not attend pre-school can recognize numbers, nevertheless, 86.4% of children who attended pre-school for 3 or more years can do so.

However, in some European countries pre-school attendance does not correlate with the probability of having cognitive skills prior to primary school. In Belgium, the pattern seems to be reversed for most skills. In the Czech Republic, pre-school attendance is negatively correlated with reading skills (however, around 95% of Czech children attended pre-school education, so the comparison between those who attended and those who did not needs to be taken cautiously). Rarely, pre-school education is related to counting money and measuring skills.

	Read_letters			Read_words			Read_sent			Read_story			Write_letters			Write_words			Count_num			Read_num			Write_num			Addition			Subtraction			Count_money			Measure		
	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2
Belgium	75.7	67.9	65.4	60.7	51.7	44.1	48.5	33.6	22.1	36.9	25.8	16.3	70.9	58.6	51.8	57.3	44.4	37.2	93.7	92.5	96.8	90.3	89.5	92.3	84.0	82.0	79.6	68.9	67.0	68.2	48.5	47.1	42.7	41.7	35.1	24.6	22.8	16.5	7.7
Bulgaria	39.5	67.2	87.6	25.1	45.0	65.7	16.2	27.6	43.2	13.7	20.5	32.0	39.9	61.0	81.6	28.2	43.6	64.0	69.8	89.7	95.4	66.0	88.6	94.7	54.0	79.6	91.8	42.6	63.1	74.4	31.3	50.6	63.4	41.9	51.3	48.2	7.6	12.5	12.7
Croatia	89.2	93.3	94.3	72.9	80.0	81.3	53.2	61.6	62.0	44.4	51.7	50.1	85.3	90.4	90.4	75.8	83.1	80.4	96.4	97.8	98.6	95.2	97.0	97.8	94.5	93.9	96.5	83.4	87.6	87.3	72.9	75.2	75.9	58.3	56.4	55.2	19.9	16.0	17.4
Cyprus	81.9	81.5	87.8	69.4	64.3	68.4	51.0	44.7	46.8	33.8	30.1	29.6	76.6	79.4	83.3	61.7	61.2	65.4	92.0	92.8	94.1	90.2	92.0	93.0	86.6	89.0	91.1	73.3	73.2	78.5	61.7	58.2	63.4	40.7	37.7	35.2	18.7	15.4	13.4
Czech Republic	78.6	83.0	81.2	66.6	64.1	58.3	53.6	47.3	38.8	42.3	36.1	30.0	74.4	76.5	73.9	69.6	60.8	56.7	94.6	98.1	98.4	88.1	93.7	94.7	83.9	88.6	89.6	79.8	83.5	84.0	60.1	63.7	61.6	54.2	47.7	43.7	19.0	17.6	13.2
Denmark	71.4	81.5	78.5	40.5	52.7	46.6	19.0	23.4	15.1	14.3	11.4	8.4	71.4	76.1	78.3	45.2	50.0	48.4	88.1	95.1	97.6	83.3	89.1	92.8	83.3	88.0	89.5	59.5	70.1	71.0	40.5	33.7	34.1	35.7	50.5	47.8	11.9	12.5	8.6
Finland	84.5	90.6	89.2	61.2	60.5	60.2	48.3	42.2	40.8	39.7	31.2	29.8	82.8	81.8	80.2	68.1	63.5	59.2	90.5	95.2	94.9	94.0	95.6	95.7	92.2	93.8	93.7	84.5	87.8	85.0	74.1	75.7	67.5	50.9	48.2	45.8	25.0	19.9	17.6
France	86.8	86.8	90.4	65.3	64.3	66.7	36.8	38.8	36.8	30.6	27.2	23.5	76.4	79.8	83.7	60.4	61.2	64.6	92.4	93.3	94.0	84.0	86.0	89.1	84.7	83.7	86.6	56.9	57.0	58.8	26.4	28.4	29.3	31.9	36.2	28.7	11.1	12.1	9.1
Germany	68.7	69.4	69.1	41.6	43.4	41.3	24.0	18.7	16.1	16.7	12.0	9.5	62.7	66.5	65.0	41.2	51.1	47.3	95.7	98.6	98.3	88.0	91.1	94.2	87.1	89.9	89.4	72.5	72.8	75.8	51.5	51.3	56.4	35.6	34.3	39.0	16.3	8.5	12.9
Hungary	51.9	62.5	58.0	33.3	42.5	39.6	25.9	24.5	21.3	18.5	17.6	13.3	37.0	47.5	43.1	25.9	37.9	34.8	81.5	97.3	99.0	74.1	85.8	92.6	59.3	77.4	79.8	66.6	77.4	79.3	48.1	67.4	65.4	51.9	52.5	47.3	29.6	31.8	23.9
Ireland	88.0	95.7	97.9	77.8	91.3	94.6	64.8	83.5	88.7	59.2	76.3	82.1	82.0	92.7	96.2	72.9	88.8	92.9	91.9	93.9	93.3	89.4	92.9	92.8	84.9	91.9	92.3	77.8	90.5	93.6	65.1	75.9	82.6	58.1	65.5	67.6	22.5	25.1	28.6
Italy	68.4	75.4	76.4	44.3	52.7	48.8	27.8	27.8	24.1	24.1	16.8	14.1	67.1	77.2	71.6	49.4	61.7	55.5	97.5	94.3	95.5	89.9	89.2	90.4	81.0	86.2	85.8	48.1	42.8	41.7	43.0	32.9	29.7	31.6	26.9	20.3	17.7	8.7	6.2
Lithuania	80.5	84.6	92.0	64.0	66.8	77.8	50.7	53.1	60.1	43.6	43.7	49.9	79.9	80.2	87.0	63.7	67.8	74.4	92.4	95.4	97.2	90.9	94.8	97.0	87.0	91.4	93.9	72.8	78.0	81.7	62.9	71.7	73.7	54.1	55.2	51.3	22.4	22.5	18.8
Norway	69.0	69.9	68.5	51.7	48.5	44.1	34.5	28.2	20.1	10.3	15.5	9.6	62.1	56.3	58.9	41.4	43.7	42.7	89.7	95.1	98.3	79.3	92.2	94.6	79.3	89.3	90.2	72.4	65.0	68.4	58.6	43.7	34.9	51.7	56.3	60.3	13.8	11.7	12.6
Poland	80.0	90.6	93.7	66.7	79.7	83.0	40.0	62.7	64.5	33.3	47.7	47.0	80.0	85.5	84.9	70.0	77.8	76.3	100	96.5	97.2	93.3	96.3	96.3	96.7	95.3	94.1	93.3	91.0	91.0	76.7	82.9	80.6	40.0	61.8	56.0	20.0	29.4	22.5
Portugal	75.2	79.9	81.6	52.2	53.6	54.0	31.7	34.2	30.3	25.7	24.1	21.0	73.9	77.7	77.7	62.2	61.7	59.9	89.1	95.7	96.8	80.0	88.8	92.9	81.7	87.7	90.6	57.0	59.8	61.9	42.2	44.1	46.6	37.8	26.2	23.4	18.3	13.9	11.8
Russia	80.2	90.5	91.2	60.3	73.7	74.7	43.1	54.2	56.3	29.5	35.7	38.5	63.9	76.4	73.2	46.8	59.8	58.4	91.4	95.7	95.6	90.7	95.9	95.6	85.6	93.2	92.7	80.8	88.5	91.1	76.1	83.2	87.4	54.6	54.0	55.9	21.9	25.9	30.1
Serbia	83.2	88.0	91.2	56.0	69.6	76.4	38.1	47.1	53.0	36.2	43.8	50.2	73.9	82.0	84.1	56.3	69.9	74.7	92.5	97.3	97.1	84.3	90.8	93.2	85.1	92.7	94.4	72.8	75.3	81.8	58.2	64.2	70.6	54.9	60.7	57.1	22.8	21.4	19.9
Slovakia	48.2	69.4	70.7	29.9	42.4	40.7	18.9	21.0	18.4	13.3	13.0	11.1	41.7	59.7	57.8	29.0	40.4	38.7	68.6	90.8	93.4	54.4	83.0	86.4	53.6	80.6	82.5	54.7	71.9	75.5	41.1	52.9	53.1	53.0	42.8	37.2	18.0	14.6	12.8
Spain	84.1	89.3	94.1	75.8	80.9	88.5	64.2	68.0	78.9	53.7	57.3	66.7	82.9	87.6	93.0	75.8	81.5	87.6	93.8	94.8	95.2	91.1	93.1	94.4	88.9	91.5	93.3	76.1	75.4	82.6	64.6	58.1	65.2	38.8	35.9	33.9	16.6	12.6	12.5
Sweden	73.5	84.1	90.5	58.2	70.5	76.0	44.9	47.4	48.7	39.8	31.1	30.9	74.5	78.9	81.7	61.2	66.9	69.5	87.8	94.4	95.9	86.7	93.6	95.2	87.8	92.4	92.5	71.4	74.9	83.3	62.2	58.2	61.0	69.4	66.9	69.0	31.6	28.3	23.9

Table 1: Pre-school Skills Relation to Pre-school Attendance

Shares of Children (in Percents) Who Have Particular Skill Based on the Length of Pre-school Attendance

Source: Author's calculations based on TIMSS 2015 data

The fourth grade standardized test scores are measured as plausible values (PVs) [3]. for overall performance in math and science, and also for particular cognitive and content domains. The content domains in math include number, data display, and geometric shapes and measures, and the content domains in science are life science, physical science and earth science. In both math and science, the cognitive domains include knowing, applying, and reasoning. Table 2 reports the international benchmarks that indicate students' achievements on an international scale.

Figures 10 and 11 show boxplots of PVs in math and science[4]. Generally, the data do not indicate that European children are stronger in either of the subjects. In most countries, science achievement is somewhat better. However, the differences between math and science achievements are quite large in Croatia, Finland, Slovakia, and Sweden, in which the difference between share of students passing high benchmark in science and math exceeds 13 percentage points. However, in some countries students perform better in math, such as in Belgium, Cyprus, and Ireland. In Croatia, the share of children who achieve above the high benchmark in science is 43%, while the same share in math is only 25.3%. Russian children achieve exceptionally high scores in both math and science, and are also strongest in all domains.

Russian children achieve the highest overall scores in math, followed by children in Norway and Ireland. Over 20% of Russian children achieve above the advanced benchmark and another 40% above the high benchmark, while only 1.69% fall below the low benchmark. In Norway and Ireland there are also more than 50% of students who achieve above the high international benchmark. On the other hand, France and Slovakia are among the worst

[3]Each student receives only a subset of test questions, and his overall performance is estimated based on his score on this subset. To reflect the uncertainty of measurement, this estimation provides five plausible values, and each gives an unbiased estimate of the student's achievement. According to the TIMSS 2015 User Guide to the data, *"the plausible values for any given scale are the best available measures of student achievement (...), and should be used as the outcome measure in any study of student achievement"*. More details on plausible values can be found in Methods and Procedures in TIMSS (2015) .

[4]I use the first plausible value for the graph and analysis. Nevertheless, if I used another one, the results would be identical

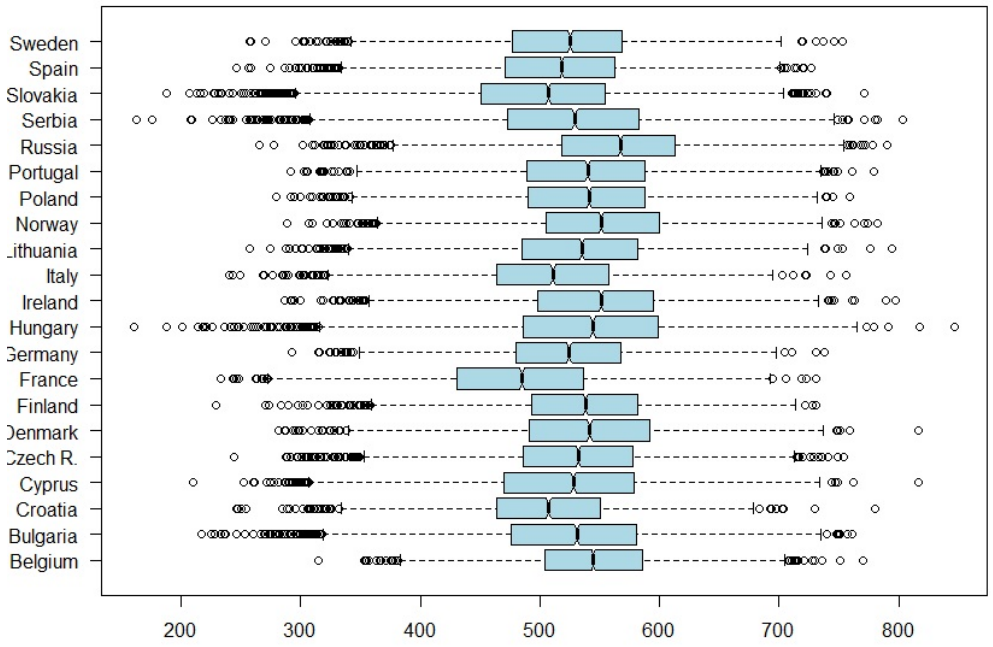

Figure 10: Math Test Scores

Boxplot of math test scores. The blue area is the interquartile range (IQR), and the whiskers (dashed line) show 1.5 the IQR above and below the IQR.

Source: Author's calculations based on TIMSS 2015 data

achieving countries in math. In France, 14% of students score below the low benchmark, and fewer than 3% are above the advanced, while in Slovakia these shares are 11.5% and 4.1%, respectively.

French children also achieve low scores in science; more than 14% of children fall bellow the low international benchmark. The same holds for Cyprus. Similarly to math, the highest achieving country in science is Russia, followed by Finland and Hungary.

An analysis of particular domains shows that usually the skills are quite equally distributed across domains; however, in some countries there are significant differences. In Bulgaria and Finland, the test scores are very evenly distributed, but for example in Belgium, Croatia and Denmark, children perform significantly better in geometry than in other math domains. German

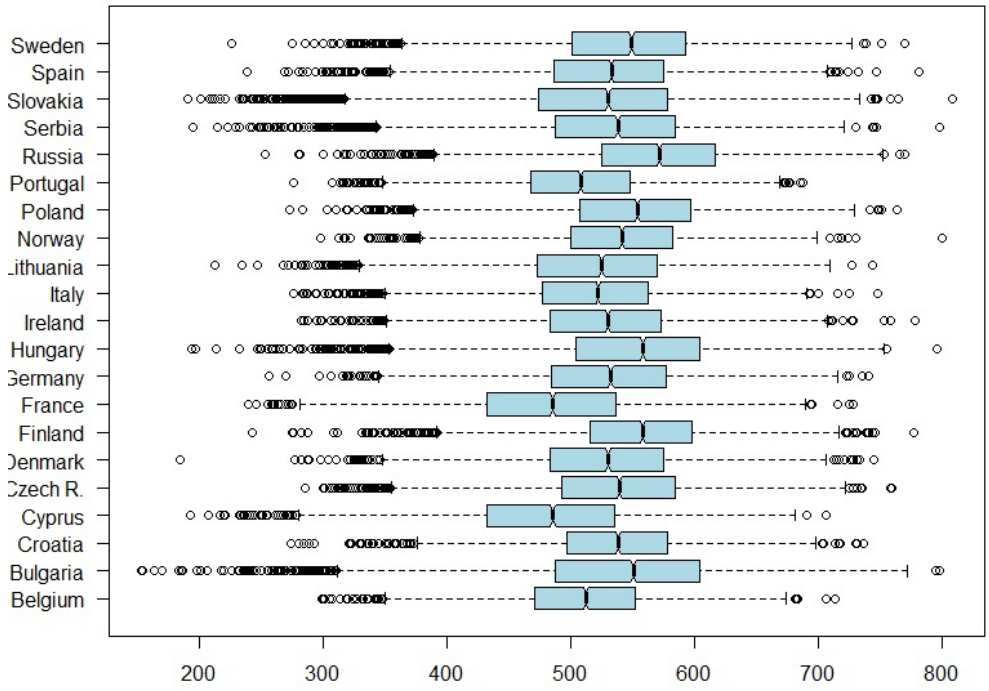

Figure 11: Science Test Scores

Boxplot of science test scores. The blue area is the interquartile range (IQR), and the whiskers (dashed line) show 1.5 the IQR above and below the IQR.

Source: Author's calculations based on TIMSS 2015 data

children perform significantly better in data displaying and reasoning than in other math domains. Norwegian students are particularly strong in geometry and data displaying, but weak in physical sciences. Swedish students are relatively weak in math knowledge, but strong in reasoning, compared to other domains. Table 12 in Appendix shows summary statistics of plausible values in particular domains.

2.3 Explanatory Variables

The independent variables used to explain the variations in the outcome variables are gender, parental education and job, and household income. Figure 13 shows a Czech correlation matrix of these independent variables. These

Scale Score	International Benchmark
625	Advanced International Benchmark
550	High International Benchmark
475	Intermediate International Benchmark
400	Low International Benchmark

Table 2: TIMSS 2015 International Benchmarks of Mathematics and Science Achievement
Source: Martin et al. (2017)

are used to explain heterogeneity in pre-school attendance. Table 3 shows the shares of parents placing their children to pre-school (for various lengths of time) based on parental education and jobs. The explanatory variables are used to model two regressions: to explain pre-school attendance, and to explain heterogeneity in test scores. Additionally, pre-school attendance also serves as an explanatory variable to explain test scores heterogeneity.

Father education, *mother education*, *father job* and *mother job*. There are three levels of education attainment for each mother and father, captured as dummies. These represent having no or only primary education (henceforth sometimes called "low education"), secondary education, and tertiary education. In addition, there are four dummies representing job variables for each parent. *Job_m_0* is a dummy equal to 1 if a mother never worked for pay. The remaining job dummies divide parents into three groups based on their occupations: group 1 are manual workers (builders, farmers, machine operators), group 2 are "halfway" (clerks, vendors, service workers), and group 3 are professionals (scientists, teachers, doctors). For both education and job, the first dummy (primary education and never worked) is used as a base in the models.

In addition, three dummy variables *Preschool_0*, *Preschool_1* and *Preschool_2* are created based on the *length* of pre-school attendance. These serve as explanatory variables in regressions which explain heterogeneity in skills and fourth grade performance. *Preschool_0* is a base, which is equal to one if a child did not attend pre-school, or attended it for less than a year. *Preschool_1* signals attending pre-school for one or two years, and

Preschool_2 means attending pre-school for three or more years. Table 11 in Appendix provides a comparison of children attending pre-school for different periods. It shows that pre-school attendance significantly positively correlates with performance of children in fourth grade. For example, the median plausible value of Czech children who could read letters prior to primary school and did not attend pre-school is 496.8, while it is 522.1 for children who attended pre-school for one or two years and 543.5 for children who attended pre-school for 3 and more years.

Further, gender is a dummy equal to one for girls. Appendix Table 8 shows that gender composition in all countries analysed is balanced. Lastly, information about approximate number of books at home and possession of digital devices is used as a proxy for family income.

Table 3 shows what percentage of parents put their child into pre-school based on parental education and occupation. The table reveals that pre-school attendance correlates with the education of both mother and father. Parents with only primary or lower education are least likely to send a child to pre-school. The more education parents have, the more likely they are to place a child to pre-school[5]. For example, the probability that a low educated Czech mother does not place her child to pre-school is 17.6%, while it is only 3.7% and 1.7% for the mothers with secondary and tertiary education, respectively. Norwegian data indicate a 27.3% probability a child with low educated mother does not attend pre-school, but only 2.6% of mothers with secondary education do not send the child to pre-school. So, the probability that a Norwegian child with a low educated mother does not attend pre-school is more than twice as great as in the case of a child with low educated Czech mother. This pattern in data is depicted in Figure 12.[6]
A similar pattern holds for children attending pre-school for 3-4 years. The higher the education of parents, the higher probability that they place their child to pre-school for longer period. Among the low educated Czech moth-

[5]This phenomenon occurs in all countries except Finland and Poland. In these countries; however, there are virtually no mothers with only primary level of education (0.4% and 3.4%, respectively)

[6]Croatia, Russia, and Slovakia were excluded from the graph for graphical reasons (outliers).

ers, 41.2% send their child to a pre-school for three years or longer, but 77.4% and 85.2% of mothers with secondary and tertiary education, respectively, send their child to pre-school for three years or more. Parental occupation demonstrates similar trends. Parents with more prestigeous occupations (i.e. with higher educational requirements on the jobs) more often send their children to pre-school for longer time periods. For instance, the probability that a Czech mother who has never worked for pay sends her child to pre-school for more than three years is 31.3%, but it is almost three times more for mothers with a professional career.

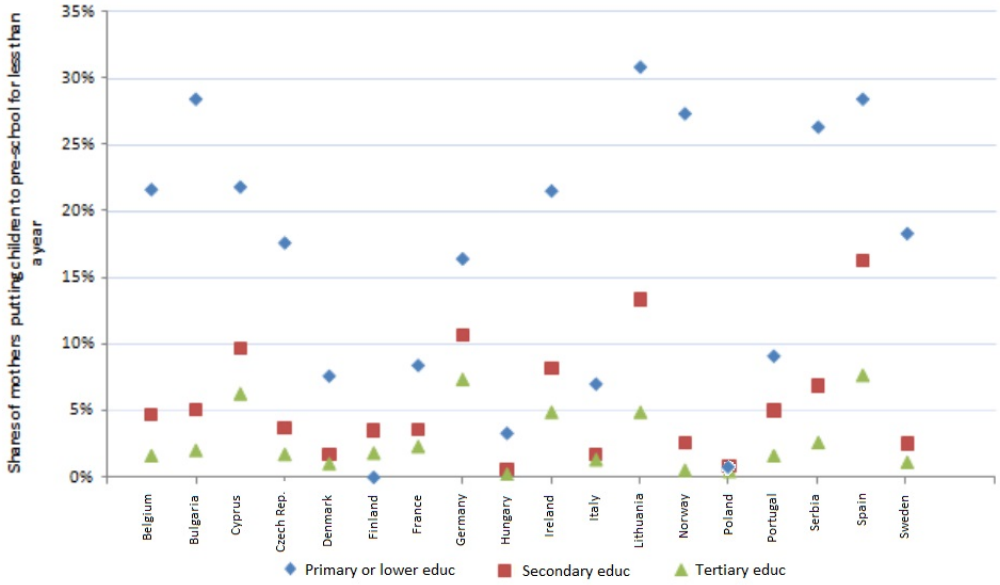

Figure 12: Pre-school Attendance for Less Than a Year by Mother's Education
Source: Author's calculations based on TIMSS 2015 data

2.4 The Matthew Effect in European Countries

The Matthew effect in education is a phenomenon in which students who start in better positions achieve better results, and the differences between students' skills increase. Table 4 compares students who did and who did not have reading, writing, and counting skills prior to entering primary school. The median plausible values from a math test provide evidence that in most cases, children who could read, write, and/or count, achieve significantly higher test scores in fourth grade. For example, Czech children who could

count (verbally) prior to school entry achieve 44 points higher on the math test than children who could not. Hungarian children who could count achieve 132 more points, which is about one third more, than children who did not have counting skills.

However, not only math skills are relevant for math test scores. The results show that even reading skills are important, presumably because the ability to read improves ability to understand the test questions at fourth grade. In several countries, for example, in Finland, France and Lithuania, reading skills make more difference than counting skills. In France, pre-school ability to recognize letters of the alphabet increases math test score in fourth grade by 55 points, while ability to count increases it by only 28.

The results support the idea of the Matthew effect, since children who had stronger pre-school skills achieve higher scores than children who had not. This is true for most of the countries analysed. However, in some countries there are no differences between the two groups of students. For example in Germany, children who could read prior to entering primary school achieve equal results as those who could not. In some cases, the results even show a negative effect of pre-school skills, i.e. that children with better skills have worse performance in fourth grade tests. Although the magnitude of difference is not large (max. -18 points in Belgium), it suggests the absence of the Matthew effect in these countries.

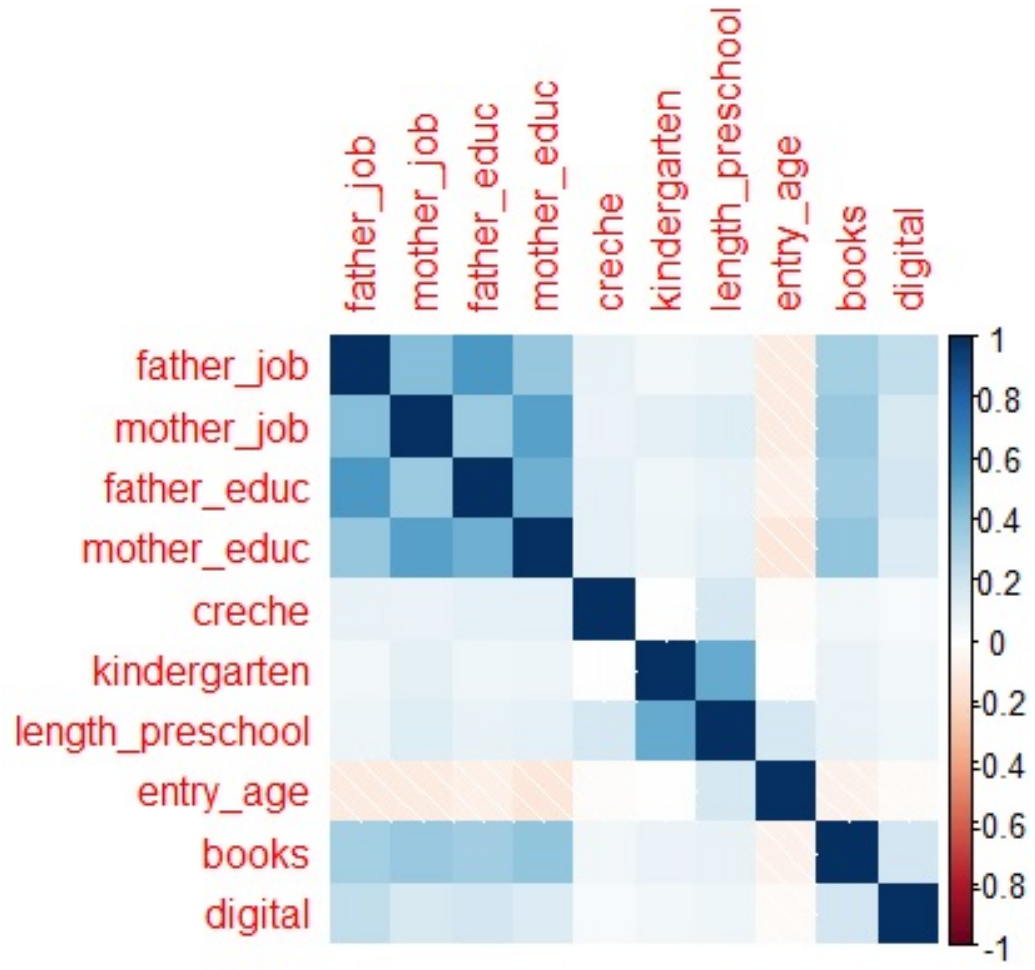

Figure 13: Czech Correlation Matrix of Independent Variables and Pre-school Institutions Attendance

Source: Author's calculations based on TIMSS 2015 data

	Preschool_0													Preschool_1												Preschool_2											
	Mother Educ			Father Educ			Mother Job				Father Job				Mother Educ			Father Educ			Mother Job				Father Job				Mother Educ			Father Educ			Mother Job				Father Job			
	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary	Never worked	Manual	Halfway	Professional	Never worked	Manual	Halfway	Professional	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary	Never worked	Manual	Halfway	Professional	Never worked	Manual	Halfway	Professional	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary	Never worked	Manual	Halfway	Professional	Never worked	Manual	Halfway	Professional
Belgium	21.6	4.7	1.6	15.5	4.6	1.8	20.5	7.7	2.8	0.6	26.7	5.8	2.4	1.0	15.0	7.1	5.1	12.3	6.6	5.9	8.7	9.5	5.8	4.3	33.3	8.0	5.5	4.9	63.4	88.2	93.3	72.1	88.9	92.3	70.9	82.8	91.4	95.2	40.0	86.2	92.1	94.1
Bulgaria	28.4	5.1	2.0	28.7	5.6	1.9	24.0	11.3	3.2	1.5	27.0	8.7	4.5	1.8	50.1	23.3	12.5	45.7	21.9	13.0	42.8	32.0	17.6	10.8	38.5	26.0	19.0	11.7	21.5	71.6	85.5	25.6	72.6	85.2	33.2	56.7	79.2	87.6	34.4	65.2	76.5	86.5
Croatia	77.3	24.0	6.3	76.2	22.1	9.0	54.7	31.8	16.6	6.6	57.1	27.5	15.2	9.3	13.6	19.0	10.7	9.5	18.8	10.0	24.5	23.9	15.1	11.2	23.8	20.8	14.3	10.9	9.1	57.0	83.0	14.3	59.1	80.9	20.8	44.2	68.3	82.2	19.0	51.7	70.6	79.8
Cyprus	21.8	9.7	6.3	17.1	9.2	5.3	16.4	11.3	6.9	3.0	22.2	10.7	7.0	3.9	48.5	40.2	25.7	40.3	38.9	26.0	44.5	45.3	31.9	24.3	27.8	39.4	33.9	26.3	29.7	50.1	68.0	42.6	51.9	68.7	39.1	43.3	61.1	72.8	50.0	49.9	59.1	69.8
Czech Rep.	17.6	3.7	1.7	11.8	3.7	1.8	29.2	4.8	2.6	1.4	28.0	4.0	2.7	2.1	41.2	18.9	13.1	23.5	18.7	13.5	39.6	19.4	16.8	12.8	20.0	18.7	17.7	14.5	41.2	77.4	85.2	64.7	77.6	84.7	31.3	75.8	80.6	85.8	52.0	77.3	79.6	83.4
Denmark	7.6	1.7	1.0	2.0	1.4	1.2	20.0	2.1	1.2	0.7	0.0	3.5	1.6	0.4	6.1	7.0	5.2	9.2	5.6	5.1	10.0	6.8	6.0	4.1	26.1	8.1	5.6	4.8	86.4	91.3	93.8	88.8	93.0	93.7	70.0	91.1	92.7	95.2	73.9	88.4	92.9	94.9
Finland	0.0	3.5	1.8	4.3	2.4	2.4	4.4	4.5	2.2	1.7	0.0	2.8	2.6	1.9	50.0	32.0	23.3	26.1	29.8	24.0	46.7	38.0	27.0	22.5	21.1	32.1	26.6	23.5	50.0	64.5	74.9	69.6	67.8	73.5	48.9	57.5	70.8	75.8	78.9	65.1	70.9	74.6
France	8.4	3.6	2.3	7.1	3.6	2.0	4.9	3.9	2.6	1.7	3.6	3.7	3.0	1.9	10.7	9.7	6.7	8.7	9.2	6.9	11.5	11.0	8.7	5.9	14.3	8.6	9.2	6.2	80.9	86.7	91.0	84.2	87.2	91.1	83.5	85.1	88.7	92.4	82.1	87.7	87.8	91.9
Germany	16.4	10.7	7.4	16.7	9.9	8.5	15.6	12.0	10.1	4.5	28.6	10.9	9.5	7.2	23.3	23.5	16.7	28.2	23.0	18.0	33.3	23.1	22.1	15.8	14.3	22.7	23.7	15.2	60.4	65.8	75.8	55.1	67.1	73.4	51.1	64.8	67.8	79.7	57.1	66.4	66.8	77.6
Hungary	3.3	0.6	0.2	3.2	0.7	0.2	1.9	0.8	0.6	0.2	7.1	0.9	0.4	0.0	21.7	6.1	3.5	21.0	5.8	3.7	17.8	7.4	4.5	3.3	14.3	6.3	4.8	3.3	75.0	93.3	96.3	75.8	93.6	96.1	80.4	91.8	94.9	96.4	78.6	92.8	94.8	96.7
Ireland	21.5	8.2	4.9	18.5	7.1	4.9	20.3	8.1	6.0	3.5	28.6	8.0	6.9	3.9	54.7	65.6	55.3	58.5	62.5	55.8	54.4	64.0	59.8	55.4	42.9	62.4	59.7	55.2	23.8	26.2	39.8	23.0	30.4	39.3	25.3	28.0	34.3	41.1	28.6	29.6	33.4	40.9
Italy	7.0	1.7	1.3	5.6	1.6	2.0	4.5	2.1	1.1	0.5	11.1	2.4	1.6	1.0	31.4	7.9	5.8	13.7	7.9	7.4	12.0	9.8	5.6	5.7	14.8	9.1	6.7	6.1	61.6	90.4	92.9	80.6	90.5	90.6	83.4	88.0	93.3	93.8	74.1	88.6	91.6	92.9
Lithuania	30.8	13.4	4.9	14.0	11.4	5.6	21.6	13.3	7.0	4.0	11.9	9.9	7.2	4.5	28.2	29.8	17.6	40.4	25.6	19.2	36.9	31.8	19.0	15.8	25.4	26.6	17.2	17.3	41.0	56.8	77.5	45.6	63.1	75.1	41.4	54.9	74.1	80.2	62.7	63.4	75.7	78.3
Norway	27.3	2.6	0.5	9.5	2.3	0.7	15.4	5.0	2.1	0.4	18.2	2.0	2.5	0.4	9.1	8.7	3.8	14.3	6.5	4.4	30.8	14.9	5.0	3.4	9.1	8.1	5.8	3.6	63.6	88.7	95.7	76.2	91.2	94.9	53.8	80.2	92.9	96.2	72.7	90.0	91.6	95.9
Poland	0.6	0.8	0.4	1.1	0.7	0.3	2.0	0.7	0.7	0.4	0.0	0.9	0.4	0.6	71.8	42.4	15.2	67.3	37.2	16.1	68.4	53.0	27.8	16.9	50.0	43.4	23.7	18.2	27.6	56.8	84.4	31.5	62.0	83.6	29.6	46.3	71.5	82.7	50.0	55.7	76.0	81.2
Portugal	9.1	5.0	1.6	7.5	4.5	2.1	20.5	5.6	3.4	1.9	24.1	5.0	3.9	2.1	27.2	21.2	10.3	25.5	19.8	9.4	23.2	26.1	17.8	10.6	22.4	24.0	17.2	9.7	63.6	73.9	88.1	67.1	75.6	88.5	56.3	68.2	78.8	87.5	53.4	70.9	78.8	88.2
Russia	64.5	26.8	15.2	44.4	24.0	15.3	51.4	24.0	21.3	14.8	43.6	24.3	18.2	14.3	16.1	18.4	20.9	25.0	18.2	22.3	14.3	20.2	20.0	20.2	17.9	18.4	20.4	22.1	19.4	54.8	63.9	30.6	57.8	62.5	34.3	55.8	58.7	65.0	38.5	57.3	61.4	63.6
Serbia	26.3	6.9	2.6	30.8	6.8	3.7	12.1	9.5	5.5	3.5	10.0	8.1	5.0	3.0	59.2	43.5	23.5	50.0	42.8	26.0	68.3	52.9	35.3	24.8	67.0	48.1	34.2	24.6	14.5	49.6	73.8	19.2	50.5	70.4	19.6	37.6	59.2	71.7	23.0	43.7	60.8	72.4
Slovakia	60.6	6.9	1.2	53.6	6.9	1.3	35.5	7.1	1.6	1.4	39.3	6.2	3.0	1.2	18.2	21.5	10.0	26.8	20.8	9.3	40.2	30.9	13.8	10.5	36.4	23.8	14.0	11.1	21.2	71.6	88.7	19.6	72.3	89.4	24.2	62.0	84.6	88.1	24.3	70.0	83.1	87.7
Spain	28.4	16.3	7.7	24.1	13.8	8.1	28.4	19.5	11.4	6.6	19.0	17.2	11.6	7.4	27.5	30.6	21.5	29.8	28.5	22.8	17.8	31.5	29.2	19.1	31.0	28.3	28.5	21.6	44.1	53.2	70.8	46.1	57.7	69.1	53.8	49.0	59.4	74.3	50.0	54.5	60.0	71.0
Sweden	18.3	2.5	1.1	19.5	2.1	1.3	17.6	8.7	1.8	0.7	16.7	4.1	1.2	0.7	25.4	8.3	4.8	13.0	7.1	4.7	19.6	10.7	7.4	4.2	20.0	8.3	6.6	4.7	56.3	89.2	94.0	67.5	90.8	94.0	62.7	80.6	90.8	95.1	63.3	87.7	92.2	94.6

Table 3: Shares of Parents (in Percents) Sending Children to Pre-school Based on Parental Education and Occupation

The numbers show what percentages of parents with given characteristic do (not) send children to pre-school.

Source: Author's calculations based on TIMSS 2015 data

	Read_letters			Read_words			Read_sent			Read_story			Write_letters			Write_words			Count			Read_num			Write_num			Addition			Subtraction			Count_money			Measure		
	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff	Can	Cannot	Diff
Belgium	550	545	**5**	547	548	**-1**	534	552	**-18**	535	550	**-15**	547	548	**-1**	544	550	**-6**	548	529	**19**	549	533	**16**	549	545	**4**	555	532	**23**	556	542	**14**	550	547	**3**	539	549	**-10**
	(61)	(58)	(-)	(61)	(58)	(-)	(63)	(58)	(-)	(62)	(59)	(-)	(61)	(58)	(-)	(61)	(59)	(-)	(59)	(62)	(-)	(60)	(57)	(-)	(60)	(59)	(-)	(59)	(58)	(-)	(61)	(58)	(-)	(63)	(58)	(-)	(63)	(59)	(-)
Bulgaria	541	493	**48**	546	511	**35**	553	519	**34**	555	524	**31**	541	507	**34**	544	516	**28**	535	467	**68**	536	471	**65**	536	498	**38**	542	511	**31**	543	517	**26**	539	527	**12**	544	531	**13**
	(75)	(94)	(-)	(73)	(87)	(-)	(73)	(83)	(-)	(74)	(82)	(-)	(75)	(92)	(-)	(74)	(87)	(-)	(79)	(100)	(-)	(78)	(100)	(-)	(77)	(100)	(-)	(77)	(87)	(-)	(76)	(86)	(-)	(80)	(83)	(-)	(80)	(82)	(-)
Croatia	510	466	**44**	515	479	**36**	519	491	**28**	521	497	**24**	510	485	**25**	512	488	**24**	508	465	**43**	508	464	**44**	508	483	**25**	513	470	**43**	516	482	**34**	518	498	**20**	529	503	**26**
	(65)	(69)	(-)	(64)	(67)	(-)	(64)	(65)	(-)	(64)	(65)	(-)	(65)	(69)	(-)	(64)	(69)	(-)	(66)	(85)	(-)	(65)	(77)	(-)	(66)	(73)	(-)	(64)	(64)	(-)	(64)	(64)	(-)	(67)	(63)	(-)	(69)	(64)	(-)
Cyprus	537	496	**41**	539	511	**28**	538	523	**15**	543	525	**18**	536	510	**26**	538	518	**20**	532	514	**18**	532	515	**17**	532	516	**16**	538	503	**35**	541	512	**29**	541	525	**16**	542	529	**13**
	(77)	(83)	(-)	(77)	(81)	(-)	(77)	(80)	(-)	(77)	(79)	(-)	(78)	(83)	(-)	(78)	(80)	(-)	(79)	(86)	(-)	(79)	(83)	(-)	(79)	(82)	(-)	(77)	(79)	(-)	(77)	(80)	(-)	(80)	(78)	(-)	(82)	(79)	(-)
Czech Rep.	539	512	**27**	542	521	**21**	541	530	**11**	542	531	**11**	537	526	**11**	539	528	**11**	534	490	**44**	536	506	**30**	536	521	**15**	539	507	**32**	544	520	**24**	542	528	**14**	554	531	**23**
	(69)	(72)	(-)	(67)	(71)	(-)	(68)	(71)	(-)	(67)	(71)	(-)	(70)	(69)	(-)	(70)	(69)	(-)	(70)	(70)	(-)	(69)	(72)	(-)	(69)	(73)	(-)	(68)	(72)	(-)	(69)	(69)	(-)	(70)	(70)	(-)	(70)	(69)	(-)
Denmark	549	523	26	556	535	21	551	542	9	545	544	1	549	525	24	551	537	14	545	486	59	546	520	26	546	526	20	554	521	33	563	534	29	555	534	21	556	543	13
	(73)	(73)	(-)	(72)	(73)	(-)	(76)	(73)	(-)	(76)	(74)	(-)	(73)	(75)	(-)	(73)	(74)	(-)	(74)	(64)	(-)	(74)	(76)	(-)	(73)	(79)	(-)	(73)	(71)	(-)	(71)	(73)	(-)	(73)	(74)	(-)	(74)	(74)	(-)
Finland	547	489	**58**	557	514	**43**	568	520	**48**	573	527	**46**	549	502	**47**	554	517	**37**	543	494	**49**	542	511	**31**	543	511	**32**	547	497	**50**	553	511	**42**	557	526	**31**	572	534	**38**
	(63)	(67)	(-)	(61)	(65)	(-)	(60)	(64)	(-)	(61)	(64)	(-)	(63)	(67)	(-)	(62)	(66)	(-)	(66)	(71)	(-)	(66)	(67)	(-)	(66)	(71)	(-)	(64)	(67)	(-)	(63)	(66)	(-)	(63)	(66)	(-)	(64)	(65)	(-)
France	495	440	**55**	499	469	**30**	497	487	**10**	494	490	**4**	496	461	**35**	498	473	**25**	491	463	**28**	493	460	**33**	492	474	**16**	503	471	**32**	506	483	**23**	500	487	**13**	484	491	**-7**
	(74)	(74)	(-)	(74)	(75)	(-)	(75)	(76)	(-)	(76)	(75)	(-)	(74)	(76)	(-)	(74)	(77)	(-)	(75)	(77)	(-)	(75)	(77)	(-)	(75)	(80)	(-)	(75)	(73)	(-)	(79)	(73)	(-)	(77)	(75)	(-)	(86)	(74)	(-)
Germany	537	536	**1**	539	535	**4**	536	537	**-1**	535	537	**-2**	536	538	**-2**	536	537	**-1**	537	499	**38**	537	523	**14**	537	537	**0**	544	515	**29**	547	524	**23**	545	532	**13**	558	534	**24**
	(65)	(62)	(-)	(64)	(64)	(-)	(65)	(64)	(-)	(66)	(64)	(-)	(65)	(62)	(-)	(65)	(63)	(-)	(64)	(59)	(-)	(64)	(60)	(-)	(65)	(59)	(-)	(63)	(63)	(-)	(63)	(63)	(-)	(65)	(63)	(-)	(62)	(64)	(-)
Hungary	551	538	**13**	559	537	**22**	563	541	**22**	557	544	**13**	547	544	**3**	549	544	**5**	545	413	**132**	547	517	**30**	546	541	**5**	556	499	**57**	561	514	**47**	552	539	**13**	553	544	**9**
	(86)	(87)	(-)	(88)	(85)	(-)	(94)	(84)	(-)	(98)	(84)	(-)	(89)	(84)	(-)	(90)	(84)	(-)	(86)	(107)	(-)	(85)	(99)	(-)	(86)	(90)	(-)	(81)	(90)	(-)	(82)	(86)	(-)	(89)	(84)	(-)	(89)	(85)	(-)
Ireland	556	480	**76**	558	498	**60**	561	507	**54**	564	515	**49**	557	505	**52**	559	509	**50**	554	566	**-12**	554	559	**-5**	554	553	**1**	559	494	**65**	561	525	**36**	564	531	**33**	573	548	**25**
	(70)	(75)	(-)	(69)	(77)	(-)	(68)	(73)	(-)	(68)	(72)	(-)	(70)	(75)	(-)	(69)	(74)	(-)	(72)	(73)	(-)	(71)	(80)	(-)	(71)	(78)	(-)	(69)	(71)	(-)	(69)	(72)	(-)	(69)	(71)	(-)	(70)	(71)	(-)
Italy	519	497	**22**	525	501	**24**	529	508	**21**	533	510	**23**	518	504	**14**	519	507	**12**	515	478	**37**	516	482	**34**	517	496	**21**	529	501	**28**	529	507	**22**	518	512	**6**	519	513	**6**
	(69)	(70)	(-)	(69)	(69)	(-)	(71)	(69)	(-)	(71)	(69)	(-)	(70)	(69)	(-)	(70)	(69)	(-)	(70)	(64)	(-)	(69)	(68)	(-)	(70)	(66)	(-)	(70)	(68)	(-)	(72)	(68)	(-)	(74)	(69)	(-)	(81)	(69)	(-)
Lithuania	545	469	**76**	552	493	**59**	558	511	**47**	560	518	**42**	545	500	**45**	549	509	**40**	540	484	**56**	541	474	**67**	542	504	**38**	546	506	**40**	548	511	**37**	547	530	**17**	556	534	**22**
	(69)	(74)	(-)	(68)	(72)	(-)	(67)	(71)	(-)	(68)	(71)	(-)	(70)	(76)	(-)	(69)	(74)	(-)	(72)	(81)	(-)	(72)	(74)	(-)	(72)	(77)	(-)	(70)	(74)	(-)	(70)	(74)	(-)	(73)	(71)	(-)	(76)	(72)	(-)
Norway	575	544	**31**	584	554	**30**	592	560	**32**	601	563	**38**	577	550	**27**	581	556	**25**	568	545	**23**	569	524	**45**	569	531	**38**	578	535	**43**	589	552	**47**	577	551	**26**	596	564	**32**
	(68)	(69)	(-)	(69)	(68)	(-)	(71)	(68)	(-)	(71)	(68)	(-)	(68)	(69)	(-)	(69)	(68)	(-)	(69)	(85)	(-)	(69)	(74)	(-)	(68)	(74)	(-)	(66)	(69)	(-)	(66)	(67)	(-)	(67)	(71)	(-)	(71)	(68)	(-)
Poland	545	496	**49**	549	507	**42**	554	520	**34**	556	530	**26**	545	523	**22**	547	526	**21**	542	523	**19**	543	528	**15**	543	529	**14**	545	514	**31**	546	522	**24**	548	532	**16**	556	537	**19**
	(71)	(77)	(-)	(69)	(76)	(-)	(68)	(75)	(-)	(68)	(74)	(-)	(71)	(76)	(-)	(70)	(76)	(-)	(72)	(83)	(-)	(72)	(81)	(-)	(72)	(73)	(-)	(71)	(78)	(-)	(72)	(72)	(-)	(71)	(73)	(-)	(72)	(72)	(-)
Portugal	546	518	**28**	547	533	**14**	544	540	**4**	546	540	**6**	545	524	**21**	545	535	**10**	542	504	**38**	543	508	**35**	543	512	**31**	553	518	**35**	556	528	**28**	554	536	**18**	544	541	**3**
	(69)	(76)	(-)	(70)	(72)	(-)	(70)	(72)	(-)	(70)	(71)	(-)	(70)	(73)	(-)	(70)	(73)	(-)	(71)	(78)	(-)	(71)	(72)	(-)	(70)	(76)	(-)	(71)	(68)	(-)	(71)	(69)	(-)	(71)	(71)	(-)	(73)	(71)	(-)
Russia	572	522	**5**	577	533	**44**	585	546	**39**	591	555	**36**	573	549	**24**	578	554	**24**	568	545	**23**	569	536	**33**	569	550	**19**	572	521	**51**	573	530	**43**	572	561	**11**	579	563	**16**
	(69)	(78)	(-)	(67)	(75)	(-)	(65)	(73)	(-)	(64)	(72)	(-)	(69)	(76)	(-)	(68)	(73)	(-)	(71)	(85)	(-)	(71)	(83)	(-)	(71)	(80)	(-)	(70)	(76)	(-)	(69)	(76)	(-)	(71)	(73)	(-)	(71)	(71)	(-)
Serbia	535	481	**54**	542	497	**45**	549	514	**35**	550	515	**35**	536	508	**28**	540	507	**33**	531	498	**33**	534	489	**45**	533	494	**39**	541	491	**50**	544	501	**43**	537	522	**15**	543	528	**15**
	(82)	(92)	(-)	(79)	(89)	(-)	(80)	(85)	(-)	(79)	(85)	(-)	(83)	(88)	(-)	(81)	(88)	(-)	(84)	(107)	(-)	(83)	(92)	(-)	(82)	(104)	(-)	(81)	(86)	(-)	(80)	(85)	(-)	(85)	(83)	(-)	(91)	(83)	(-)
Slovakia	514	492	**22**	520	500	**20**	520	507	**13**	520	508	**12**	513	502	**11**	513	507	**6**	511	452	**59**	514	471	**43**	513	487	**26**	518	477	**41**	521	495	**26**	509	508	**1**	524	507	**17**
	(76)	(84)	(-)	(78)	(79)	(-)	(85)	(78)	(-)	(88)	(78)	(-)	(77)	(82)	(-)	(78)	(80)	(-)	(77)	(96)	(-)	(75)	(91)	(-)	(76)	(91)	(-)	(76)	(81)	(-)	(79)	(78)	(-)	(85)	(76)	(-)	(89)	(78)	(-)
Spain	525	466	**59**	528	477	**51**	532	487	**45**	536	496	**40**	526	475	**51**	528	486	**42**	522	508	**14**	522	489	**33**	522	492	**30**	528	493	**35**	528	507	**21**	532	515	**17**	527	520	**7**
	(65)	(64)	(-)	(64)	(66)	(-)	(63)	(67)	(-)	(63)	(66)	(-)	(65)	(68)	(-)	(64)	(69)	(-)	(67)	(82)	(-)	(66)	(81)	(-)	(66)	(77)	(-)	(66)	(66)	(-)	(66)	(67)	(-)	(66)	(67)	(-)	(72)	(66)	(-)
Sweden	534	496	**38**	540	502	**38**	546	515	**31**	550	521	**29**	536	506	**30**	538	511	**27**	531	517	**14**	531	528	**3**	531	520	**11**	538	493	**45**	544	507	**37**	539	513	**26**	546	526	**20**
	(66)	(62)	(-)	(65)	(64)	(-)	(65)	(64)	(-)	(67)	(64)	(-)	(66)	(61)	(-)	(65)	(64)	(-)	(66)	(77)	(-)	(66)	(78)	(-)	(65)	(72)	(-)	(64)	(63)	(-)	(64)	(64)	(-)	(65)	(66)	(-)	(68)	(65)	(-)

Table 4: Median Test Scores in Fourth Grade Math Test Based on Pre-school Skills. Standard Deviations in Parantheses

Source: Author's calculations based on TIMSS 2015 data

3 The Czech Republic

The skills and attendance rates of children in pre-school vary across countries. Each European country has it's own legal setting reflected in the data. In many countries, pre-school attendance correlates strongly with maternal education attainment levels. The summary statistics of countries analysed also provide evidence that pre-school attendance is often linked to higher pre-school skills. In some countries, the Matthew effect seems to be present, since children with better pre-school skills achieve better test scores in fourth grade. Test scores in fourth grade are also improved by pre-school attendance. In previous sections I documented very heterogeneous institutional arrangements and patterns across European countries. Clearly, better understanding requires more detailed empirical analysis at the level of individual countries. Therefore, in this section, I focus on the Czech Republic and look closely at what influences pre-school attendance and test scores in fourth grade. First, I provide basic statistics of the variables, and put them into the European context. Then, I build two related models. The first model describes the parental decision to send their child to institutional pre-school. The second estimates the impact of pre-school attendance together with pre-school skills on test scores in fourth grade. Both models together provide a more comprehensive picture of the role of pre-school education in the Czech Republic.

3.1 Descriptive Statistics

In the Czech Republic, the transition age between pre-school care and education is three years. Pre-school education is not compulsory for children; however, in 2017 the last year of pre-school education (before beginning primary school) was made compulsory. This legal change does not affect my analysis, since the data contain retrospective information of fourth-graders in 2015, who attended pre-school around 2008-2010. Czech children begin primary school at the age of 6, but there is a possibility of deferment in the case of insufficient readiness for school. In this subsection, I describe Czech

data and analyse relevant patterns in Czech pre-school education.

Pre-school care settings are very rare in the Czech Republic, only 4.6% of children attended such an institution. This incidence is among the lowest in the coutries analysed, alongside two other Central European countries - Slovakia and Poland. In contrast, the pre-school education attendance rate in the Czech Republic, 95%, is among the highest in all countries analysed. Most children who attend pre-school education do so for three years (63.1%). 17.8% of children attend pre-school for four years, and since the attendance rate of pre-school care is low, this suggests that children defer primary school and stay in pre-school education even at the age of six. This is in line with the data concerning school entry age; the mean is 6.3, since one third of children begin primary school at the age of seven, as illustrated in Figure 14. The children who begin primary school later have significantly less educated parents who work in less intellectual jobs ($p < 0.001$). The shares of children who begin primary school before they turn six and of those who have two or more years of deferment are negligible.

Pre-school education attendance significantly correlates with parental characteristics; children who attend pre-school education have more educated parents with more professional jobs. This is illustrated in Figure 3. The more professional the type of job a mother performs, the higher the probability that a child attends pre-school education. For mother who never worked for pay there is 29.2% probability of not sending her child to pre-school, while this probability decreases to less than 5% for mothers with manual occupation. The decreasing pattern persists also to professional occupations. Presumably, mothers with more prestigious occupations prefer to pursue their careers and do not prefer to stay home with their children for too long. However, the length of pre-school attendance is also correlated with paternal education and occupation. The more educated the father is, the longer the pre-school attendance of a child. There are two possible explanations for this phenomenon - either educated parents are more aware of the importance of pre-school, and/or they have demanding jobs that prevent

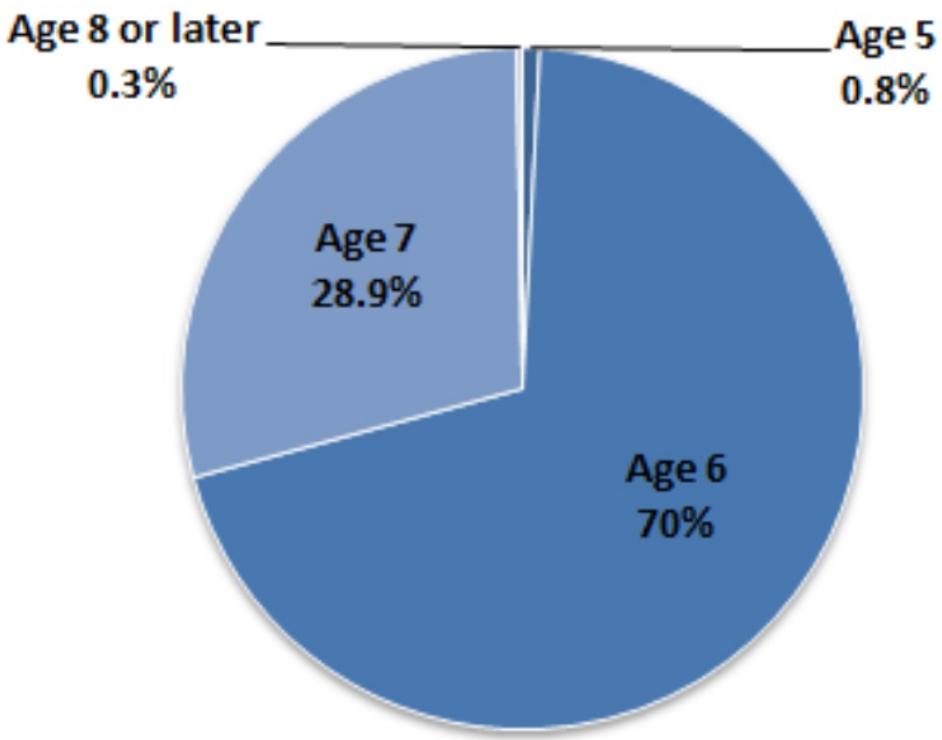

Figure 14: Czech School Entry Age
Source: Author's calculations based on TIMSS 2015 data

them from staying home with their child.

Tables 9 and 10 in Appendix show that regarding the level of pre-school skills, the Czech Republic is average in relation to the countries analysed. 82% of Czech children can recognize letters of the alphabet prior to primary school attendance. In pre-school writing skills, Czech children are slightly below the European average. On the other hand, they are significantly better in counting skills, since 84.1% of children can do simple addition and 62.2% can do simple subtraction, compared to the averages of countries analysed 76.9% and 59.2%, respectively. Nevertheless, in writing and recognizing numbers Czech children are significantly below the European average.

Czech fourth grade test scores in math and science are depicted in Figure 15[7]. In math, Czech students perform significantly below the European

[7]First plausible value was used in this graph. The rest of the PVs would generate similar graph.

average; however, in science they perform slightly above the average (this is depicted in Figures 10 and 11). The distributions of scores in math and science are very similar. Only fewer than 4% of children perform below the low international benchmark. Most children, approximately 40%, achieve the intermediate benchmark. However, significantly more students achieve above the advanced benchmark in science than in math, although the difference is just 1 percentage point. The analyses of particular domains show that Czech children perform above the high benchmark most often in reasoning in math (50.2%) and in science knowledge (50.4%). On the other hand, the lowest achievement is in data displaying in math and in earth science. Almost 7% of students in each of these domains perform below the low international benchmark.

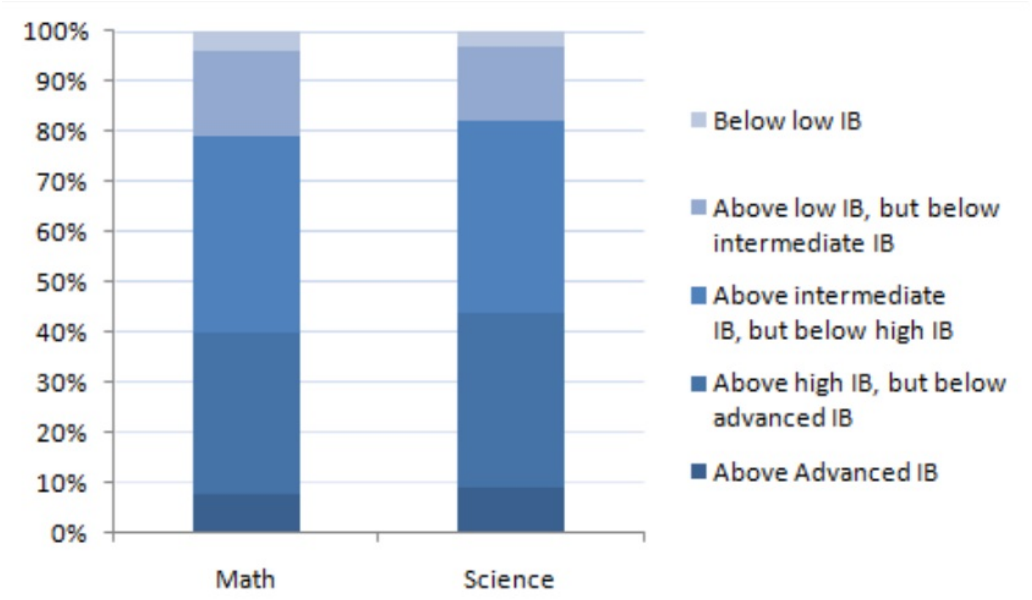

Figure 15: Czech Test Scores in Math and Science
Source: Author's calculations based on TIMSS 2015 data
Note: "IB" stands for international benchmark

3.2 Models

The comparison of European data provides three crucial informative contributions to this thesis. First, pre-school attendance seems to correlate highly

with parental education and occupation, as depicted in Table 3. Second, attending pre-school may improve cognitive skills prior to primary school entry. Third, these skills together with pre-school attendance and parental background are further determinants of test scores at primary school. I analyse these take-aways more deeply for the Czech Republic in the following subsections.

3.2.1 Determinants of Pre-school Attendance

In this subsection, I seek to decompose the contribution of individual factors to the decision of parents to send their child into pre-school, while controlling for each other. The descriptive statistics from previous section together with Table 3 suggest that pre-school attendance and its length is strongly correlated with parental education and occupation. The lower the education of parents, the higher the probability that they do not place their child into pre-school, and vice versa. There is a higher probability that more educated parents send their child to pre-school for three or more years. Education is partly correlated with occupation, and jointly they are natural candidates for the explanatory variables in Model 1. Additionally, the model also controls for family economic and socio-cultural situation, which is proxied by *Digital* and *Books*. The model analyses the magnitude of the effects of parental characteristics on pre-school attendance, represented by the variables *kindergarten* and *creche* on the left hand side. I remind the reader that these are dummy variables equal to one if a child attended pre-school education or care, respectively. With respect to the binary nature of dependent variables, I use the linear probability model.

$$\begin{aligned} Y = {} & \beta_0 + \beta_1 Educ\_m\_1 + \beta_2 Educ\_m\_2 + \beta_3 Educ\_f\_1 + \beta_4 Educ\_f\_2 + \\ & + \beta_5 Job\_m\_1 + \beta_6 Job\_m\_2 + \beta_7 Job\_m\_3 + \beta_8 Job\_f\_1 + \beta_9 Job\_f\_2 + \\ & + \beta_{10} Job\_f\_3 + \beta_{11} Books + \beta_{12} Digital + \epsilon \end{aligned} \tag{1}$$

The results of Model 1 summarized in Table 5 provide evidence that a

mother's job has a decent effect on pre-school attendance of a child. Specifically, when a mother has a clerical type of job, it increases the probability that her child attends pre-school by 3.3%, compared to a mother who never worked for pay. The probability increases by additional 0.5 percentage points if the mother has a professional career. Neither maternal education nor paternal characteristics have significant effects.[8] Although in Table 3 it seemed that parental education is an important aspect in pre-school attendance, the regression shows that the occupation takes all the effect. Possibly, the decision of parents to send a child to pre-school is influenced by pre-school availability (proximity). Then, naturally, the parental education would be irrelevant. Books, as a proxy for income, also increase the probability of pre-school attendance, although the magnitude of the effect is small. Having additional ten books at home increases the probability by 1.1%. Nevertheless, the model corresponds to the descriptive statistics that pre-school education is very common in the Czech Republic. The intercept suggests that even a child with low educated parents who never worked for pay has more than 80% probability to attend pre-school education.

Model 1 was also run for girls and boys separately. The results in columns 3 and 4 in Table 5 show that there are no significant gender differences in pre-school attendance. As expected, the parental decision about sending a child into pre-school does not depend on the gender of child. Although it seems that girls are more likely to attend pre-school, and there are slightly higher effects of the mother's job on girls, the size of the difference is negligible[9]. On the other hand, the attendance of pre-school care setting is not explained by any of the explanatory variables, not even by the constant, so it seems that the attendance is completely random. However, only fewer than 5% of children in the Czech Republic attend creche. This is because the availability of creche institutions is very low in the Czech Republic.

[8] I also used a different specification of the model with *Preschool_0*, *Preschool_1*, and *Preschool_2* on the left hand side. It provides comparative results as Table 5.

[9] Equation 1 was run also with *gender* on the right hand side. It has zero effect on pre-school attendance

	Dependent variable:			
			Kindergarten	
	Kindergarten	Creche	Girls	Boys
Educ_m_1	−0.058	−0.015	−0.093	−0.020
	(0.043)	(0.045)	(0.057)	(0.066)
Educ_m_2	−0.063	0.015	−0.113	−0.012
	(0.044)	(0.045)	(0.057)	(0.067)
Educ_f_1	0.069	−0.048	0.067	0.077
	(0.059)	(0.047)	(0.049)	(0.089)
Educ_f_2	0.079	−0.025	0.079	0.085
	(0.059)	(0.047)	(0.050)	(0.089)
Job_m_1	0.019	−0.006	0.011	0.027*
	(0.012)	(0.009)	(0.013)	(0.016)
Job_m_2	0.033***	0.0002	0.038***	0.029**
	(0.010)	(0.008)	(0.011)	(0.013)
Job_m_3	0.038***	0.009	0.044***	0.033**
	(0.010)	(0.012)	(0.013)	(0.013)
Job_f_1	−0.001	−0.005	−0.027	0.025
	(0.012)	(0.011)	(0.014)	(0.019)
Job_f_2	−0.010	0.007	−0.029	0.010
	(0.012)	(0.012)	(0.015)	(0.019)
Job_f_3	−0.013	0.008	−0.033*	0.008
	(0.012)	(0.013)	(0.015)	(0.019)
Books	0.011***	−0.0004	0.013***	0.009**
	(0.003)	(0.003)	(0.003)	(0.004)
Digital	0.005*	−0.002	0.005*	0.006
	(0.003)	(0.004)	(0.004)	(0.003)
Constant	0.886***	0.099	0.939***	0.826***
	(0.049)	(0.064)	(0.049)	(0.104)
Observations	4,653	4,662	2,310	2,343
R^2	0.017	0.015	0.022	0.019
Adjusted R^2	0.014	0.013	0.017	0.014
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 5: Pre-school Attendance Influences (Results of Model 1)

Source: Author's calculations based on TIMSS 2015 data

3.2.2 4^{th} Grade Test Scores

As the European comparison suggests, test scores in fourth grade are correlated with pre-school attendance and skills. This subsection seeks to explain heterogeneity in test scores by regressing them on the level of pre-school skills and pre-school attendance. In addition, the regression also controls for the socio-economic status of a family (parental education and occupation, and proxies for income), and for gender of students, as there may be significant gender differences in test performances. Equation 2 specifies the form of the regression.

However, as Figure 5 illustrates, there are high correlations among pre-school skills, and these are "clustered" into three groups; reading, writing, and counting. Since the correlations often exceed 60%, the skills cannot be used in the regression all at once, for multicollinearity reasons [10]. Hence, the skills are combined into the variables *read*, *write*, *count*, and *math*, each of them representing one "cluster". The variables $count\_money$ and *measure* are kept in their original form, as they do not correlate with any other skill variables.

$$\begin{aligned} PV = {} & \beta_0 + \beta_1 Educ\_m\_1 + \beta_2 Educ\_m\_2 + \beta_3 Educ\_f\_1 + \beta_4 Educ\_f\_2 + \\ & + \beta_5 Job\_m\_1 + \beta_6 Job\_m\_2 + \beta_7 Job\_m\_3 + \beta_8 Job\_f\_1 + \beta_9 Job\_f\_2 + \\ & + \beta_{10} Job\_f\_3 + \beta_{11} Books + \beta_{12} Digital + \beta_{13} Preschool\_1 + \beta_{14} Preschool\_2 + \\ & + \beta_{15} Read + \beta_{16} Write + \beta_{17} Count + \beta_{18} Math + \beta_{19} Count\_money + \\ & + \beta_{20} Measure + \beta_{21} Gender + \epsilon \end{aligned} \tag{2}$$

The results of Regression 2 are summarized in Table 6, and provide significant evidence that children with higher levels of pre-school skills achieve higher in fourth grade, supporting the hypothesis of the Matthew effect. A boy with no pre-school experience and no skills, with low educated parents who have never worked for pay, would achieve around 400 points on math and 431 points on science test. Both of these scores would categorise him

[10] Also, when one reading variable is regressed on the others, the R^2 of such regression is around 0.6

into the lowest group based on the International Benchmark.

All reading, math, and measure skills improve math test score. Students who could read at least words prior to primary school achieve 0.24 standard deviations (16.8 points) better than students who could not. This suggests that reading skills are even more important than math skills, since ability to add and subtract numbers prior to primary school increases the test score in fourth grade by only 0.19 SD (13.2 points). The same pattern holds for science tests; however, the magnitude of the effect is not as large as in the case of math. Presumably, reading skills are important for the ability to understand the tasks on tests. Also, students who could measure length and height prior to primary school achieve 0.17 SD (11 points) higher on math and 0.09 SD (6 points) higher on science test than students who could not.

In addition, parental characteristics also influence test scores in fourth grade. Children with mothers who have secondary education achieve 0.70 SD (50 points) more on math and 0.66 SD (46 points) more on science test compared to students with low educated mothers. Parental occupation also plays an important role; a child with both parents employed in a professional type of job achieves an additional 0.41 SD (28 points) in math and 0.74 SD (32 points) in science than a child with parents who have never worked for pay or who work manually.

The more books the household possesses, the higher the test score of a child. Having 11-25 books at home improves test score by approximately 10 points, corresponding to 0.13 SD, compared to having 0-10 books. Nevertheless, digital devices have no significant effects on math score, and even a slightly negative on science score.

Pre-school attendance has a positive effect on test achievement. Although attending pre-school for less than three years has no effect on test score, attending pre-school for three and more years adds 22 points in math and 13 points in science test, suggesting improvement by 0.31 and 0.19 SD, respectively. Lastly, girls are significantly worse at both math and science. In both subjects, girls achieve around 0.12 SD lower, which is around 8

points less than boys with the same characteristics.

Regression 2 was also run for girls and boys separately to detect heterogeneous effects for genders (of course without gender as an explanatory variable). The results reported in Table 7 show that there indeed are gender differences in test scores influences. While for boys maternal education is significant and improves their test scores by approximately 0.8 standard deviations (tertiary compared to low education), for girls it is irrelevant. On the other hand, the mother's occupation influences both girls and boys by approximately the same magnitude. Children of mothers with a professional type of job have 0.15 - 0.2 SD higher test scores than those of mothers who have never worked for pay or who work manually. Both girls and boys are influenced by paternal occupation; however, boys much more. Fathers with a professional job improve their sons' test scores in math by 0.3 SD (21.5 points), while their daughters' test scores improve by only 0.19 SD (13 points).

Boys are significantly more affected by pre-school attendance than girls. While attending pre-school for three and more years increases math test scores of boys by 0.39 SD (compared to attending for less than three years), girls improve by only 0.25 SD.

The bottom of Table 7 depicts that the effects of pre-school skills are virtually the same for both genders. All reading, math, and measure skills improve test scores in fourth grade, by the same magnitude for girls and boys. Again, for both genders reading is the most important skill for achieving high scores in math, since it improves test scores by more than 0.22 SD (15 points). Apparently, the ability to read prior to primary school transfers to better understanding the math tasks in fourth grade, leading to better test scores. The other possibility is also that students who can read prior to primary school are faster readers at the age of 9, and thus have more time to think about the tasks. On the other hand, for science test math skills are the most important. Children who could add and subtract numbers prior to primary school achieve around 0.19 SD more than children who could not.

	Dependent variable:	
	Math Test Score	Science Test Score
Educ_m_1	0.369	0.415**
	(0.239)	(0.212)
Educ_m_2	0.699***	0.656***
	(0.241)	(0.214)
Educ_f_1	−0.113	−0.072
	(0.197)	(0.165)
Educ_f_2	0.149	0.120
	(0.199)	(0.169)
Job_m_1	0.003	0.013
	(0.049)	(0.051)
Job_m_2	0.146***	0.154***
	(0.040)	(0.042)
Job_m_3	0.161***	0.192***
	(0.046)	(0.048)
Job_f_1	0.021	0.062
	(0.056)	(0.059)
Job_f_2	0.147***	0.159***
	(0.057)	(0.059)
Job_f_3	0.244***	0.276***
	(0.057)	(0.061)
Books	0.131***	0.171***
	(0.012)	(0.012)
Digital	0.027*	−0.033**
	(0.015)	(0.016)
Preschool_1	0.127	0.061
	(0.087)	(0.088)
Preschool_2	0.312***	0.187**
	(0.082)	(0.083)
Read	0.238***	0.116***
	(0.031)	(0.033)
Write	0.026	0.035
	(0.035)	(0.036)
Count	0.199	0.031
	(0.124)	(0.121)
Math	0.188***	0.186***
	(0.028)	(0.029)
Count_money	0.051*	0.027
	(0.029)	(0.029)
Measure	0.168***	0.087**
	(0.039)	(0.040)
Gender	−0.109***	−0.128***
	(0.026)	(0.026)
Constant	−1.840***	−1.510***
	(0.261)	(0.259)
Observations	4,557	4,557
R^2	0.254	0.206
Adjusted R^2	0.250	0.203
Note:	*p<0.1; **p<0.05; ***p<0.01. Standard Errors Clustered at School Level.	

Table 6: Fourth Grade Test Scores (Results of Model 2)
The results are in form of standardized coefficients, i.e. they represent standard deviation changes. Source: Author's calculations based on TIMSS 2015 data

The constant reveals an interesting fact. With all explanatory dummy variables equal to zero (i.e. low educated parents who have never worked for pay, and no pre-school skills), girls achieve more points than boys in both math and science. Although in math the difference is not as significant, in science it is 0.23 SD, translating into 17 points. But from Table 6 it follows that in total, girls achieve lower than boys. These two results seem contradictory at first sight; however, the larger effect of maternal education and pre-school on boys may offer an explanation. While a mother with secondary education increases her son's test score by 0.89 SD (46 points) in science, a daughter is not influenced at all. As a result, the boy performs at a higher level than a girl with the same characteristics.

	Dependent variable:			
	PV_MAT		PV_SCI	
	Girls	Boys	Girls	Boys
Educ_m_1	0.115	0.599**	0.158	0.663**
	(0.427)	(0.280)	(0.338)	(0.293)
Educ_m_2	0.534	0.841***	0.417	0.885***
	(0.429)	(0.285)	(0.340)	(0.297)
Educ_f_1	0.045	−0.265	−0.057	−0.048
	(0.327)	(0.253)	(0.264)	(0.221)
Educ_f_2	0.245	0.060	0.083	0.206
	(0.331)	(0.258)	(0.268)	(0.227)
Job_m_1	−0.012	0.018	−0.040	0.064
	(0.067)	(0.073)	(0.073)	(0.073)
Job_m_2	0.168***	0.125**	0.175***	0.134**
	(0.055)	(0.058)	(0.060)	(0.060)
Job_m_3	0.150**	0.169**	0.200***	0.181**
	(0.063)	(0.068)	(0.067)	(0.071)
Job_f_1	−0.009	0.059	0.050	0.078
	(0.076)	(0.083)	(0.083)	(0.084)
Job_f_2	0.134*	0.170**	0.182**	0.141*
	(0.077)	(0.084)	(0.084)	(0.085)
Job_f_3	0.186**	0.306***	0.254***	0.298***
	(0.078)	(0.086)	(0.085)	(0.088)
Books	0.148***	0.114***	0.180***	0.162***
	(0.017)	(0.017)	(0.018)	(0.018)
Digital	0.023	0.034	−0.049**	−0.017
	(0.021)	(0.022)	(0.022)	(0.023)
Preschool_1	0.083	0.195	0.033	0.089
	(0.093)	(0.163)	(0.107)	(0.153)
Preschool_2	0.253***	0.393**	0.166*	0.209
	(0.085)	(0.159)	(0.099)	(0.148)
Read	0.224***	0.253***	0.096**	0.142***
	(0.044)	(0.045)	(0.046)	(0.047)
Write	0.113**	−0.052	0.123**	−0.042
	(0.050)	(0.049)	(0.052)	(0.051)
Count	0.230	0.177	0.112	−0.069
	(0.146)	(0.238)	(0.137)	(0.237)
Math	0.193***	0.180***	0.184***	0.184***
	(0.038)	(0.042)	(0.040)	(0.044)
Count_money	0.010	0.094**	0.005	0.052
	(0.039)	(0.042)	(0.041)	(0.043)
Measure	0.155***	0.167***	0.107*	0.062
	(0.058)	(0.052)	(0.059)	(0.054)
Constant	−1.901***	−1.931***	−1.479***	−1.704***
	(0.393)	(0.381)	(0.356)	(0.409)
Observations	2,265	2,292	2,265	2,292
R^2	0.267	0.243	0.209	0.202
Adjusted R^2	0.260	0.237	0.202	0.195
Note:	*p<0.1; **p<0.05; ***p<0.01. Standard Errors Clustered at School Level.			

Table 7: Fourth Grade Test Scores by Gender
The results are in form of standardized coefficients, i.e. they represent standard deviation changes. Source: Author's calculations based on TIMSS 2015 data

4 Discussion

This thesis provides a European comparison concerning pre-school education. It shows that both institutional setups and participation patterns differ significantly across countries, and concludes with three important take-aways. First, pre-school attendance strongly correlates with maternal education and occupation. Low educated mothers have much higher probability of not sending children to pre-school than mothers with secondary or tertiary education. Second, pre-school attendance is in most cases important for cognitive skills acquisition, but not always. Lastly, cognitive skills acquired before primary school correlate highly with test scores in fourth grade, supporting the notion of the Matthew effect. Analysing these take-aways in more detail for the Czech Republic reveals that although the vast majority of children in the Czech Republic attend pre-school education, the probability of attendance still increases in relation to the mother's job. The effect of parental education is not significant in regressions, which may be driven by the fact that variance in pre-school attendance is given by supply, not demand. Children who have some pre-school skills (can read, write, or count prior to primary school) achieve better test scores in fourth grade than children without such skills, in both math and science. Attending pre-school education also has positive impact on fourth-grade test scores, but only when children attend for three years or more. Consequently, one compulsory year of pre-school education may not be enough.

However, there are several limitations of the current study. Firstly, there may be a recall bias and systematic non-response, which may possibly cause biases of unknown directions in the estimates. Second, the data do not contain detailed information about family background, such as the number of siblings and their age. This could play a significant role in pre-school attendance. If the mother has two children, the second born soon after the first, she may decide not to send the older one to pre-school, since she would be on maternity leave with the younger one anyway. Thus, pre-school attendance of the older child would be influenced by the birth of a younger

sibling. In addition, the data do not provide information about the family status of parents; whether they live together or are separated. That could also significantly influence a parental decision about sending a child to pre-school. Presumably, when parents are separated, the mother has to work and cannot stay on maternity leave for too long. Hence, a child of a single mother has a higher probability of attending pre-school, and doing so for a long period.

In addition to family status and number of siblings, parental activities may be another omitted variable causing biasedness and inconsistency of results. It is beyond the scope of this thesis to include parental activities in the regressions and to build a model that would analyse how these educative activities contribute to skills acquisition. Nevertheless, the TIMSS data contain this information. It covers 16 educative activities that parents may perform with children aged two to five (e.g. singing counting rhymes, reading books, telling stories). Hence, one future extension to the thesis could be to include parental activities and analyse their effects.

Another possible extension to the project could be to use detailed information from test scores, since these provide test scores for particular domains separately. Using that information might explain the development of skills in geometry, data display, and others. For example, the results of such an extension could specify the gender differences in test scores, as they might indicate the domains in which girls are weaker than boys.

Finally, the results of both the European comparison and Czech analysis highlight the importance of pre-school education on cognitive skills development, and the persistent benefits of pre-school education on performance in the fourth grade. However, it is important to realise that pre-school attendance alone cannot affect the development of skills and improve test scores. The quality of pre-school education is a crucial aspect that needs to be taken into consideration. This is illustrated by the case of Hungary, where there are three compulsory years of pre-school education; however, Hungarian children have quite low levels of pre-school skills compared to

other Europeans.

To sum up, the analyses performed in this thesis shed light on pre-school education in Europe, with a particular focus on the Czech Republic. Nevertheless, to provide precise and causal estimates, a more detailed dataset and richer models would be necessary. The data should contain information about family background of children and the models might be designed more properly, possibly to reflect causal effects. For example, the distance to travel to the pre-school building (or simply it's presence in a village) might play a role in the parental decision making process, as to whether to send a child to pre-school. However, this type of data is not available.

Conclusion

Pre-school education is an important factor for the development of children. Existing studies provide evidence that already in pre-school age children may develop persistent cognitive and non-cognitive skills, and that attending an institutional pre-school setting may improve language and math skills. Although some studies proceed from experiments and thus provide solid causal effects, most studies come from the US and thus are inapplicable to the European environment due to different legal and cultural settings.

I contribute to the research about pre-school education by comparing European countries. I use the TIMSS 2015 data from fourth graders and show how pre-school attendance, pre-school skills, and test scores in fourth grade vary across countries. Furthermore, I focus on the Czech Republic and build two follow-up models explaining (a) what influences the pre-school attendance and (b) the impact of pre-school attendance and skills on academic performance in fourth grade.

The first part of the thesis is a thorough review of European data, and could serve as a reference for other researchers, as it summarizes and illustrates interesting patterns in data. The second part contributes to the literature concerning pre-school education, and highlights the importance of cognitive skills acquisition already at pre-school age, as these persist at least to primary school age. Nevertheless, the topic is very complex and a more detailed dataset and analyses are needed to provide comprehensive conclusions.

References

Anders, Y., C. Grosse, H. G. Rossbach, S. Ebert, and S. Weinert (2013). Preschool and Primary School Influences on the Development of Children's Early Numeracy Skills Between the Ages of 3 and 7 years in Germany. *School Effectiveness and School Improvement 24*(2), 195–211.

Anders, Y., H. G. Rossbach, S. Weinert, S. Ebert, S. Kuger, S. Lehrl, and J. von Maurice (2012). Home and Preschool Learning Environments and Their Relations to the Development of Early Numeracy Skills. *Early Childhood Research Quarterly 27*, 231–244.

Angrist, J. D. and A. B. Krueger (1992). The Effect of Age at School Entry on Educational Attainment: An Application of Instrumental Variables with Moments from Two Samples. *Journal of the American Statistical Association 87*(418), 328–336.

Apps, P., S. Mendolia, and I. Walker (2013). The Impact of Pre-school on Adolescents' Outcomes: Evidence from a Recent English Cohort. *Economics of Education Review 37*, 183–199.

Aunola, K., E. Leskinen, T. Onatsu-Arvilommi, and J. Nurmi (2002). Three Methods for Studying Developmental Change: a Case of Reading Skills and Self-Concept. *British Journal of Educational Psychology 72*, 343–364.

Behrman, J. R., J. Hoddinott, J. A. Maluccio, E. Soler-Hampejsek, E. L. Behrman, R. Martorell, M. Ramirez-Zea, and A. D. Stein (2014). What Determines Adult Cognitive Skills? Influences of Pre-school, School, and Post-school Experiences in Guatemala. *Latin American Economic Review 23*(4).

Biedinger, N. (2011). The Influence of Education and Home Environment on the Cognitive Outcomes of Preschool Children in Germany. *Child Development Research 2011*.

Cappelen, A. W., J. A. List, A. Samek, and B. Tungodden (2016). The

Effect of Early Education on Social Preferences. *NBER Working Paper 22898*.

Claessens, A., G. Duncan, and M. Engel (2009). Kindergarten Skills and Fifth-Grade Achievement: Evidence from the ECLS-K. *Economics of Education Review 28*, 415–427.

Coleman, J. S., E. Q. Campbell, C. J. Hobson, J. McPartland, F. D. Weinfeld, and R. L. York (1966). Equality of Educational Opportunity. Technical report, U.S. Government Printing Office.

Duncan, G. J. and K. Magnuson (2013). Investing in Preschool Programs. *Journal of Economic Perspectives 27*(2), 109–132.

EACEA (2019). Key Data on Early Childhood Education and Care in Europe - 2019 Edition. Eurydice report, Luxembourg: Publications office of the European Union.

Foy, P. (2017). TIMSS 2015 User Guide for the International Database. Technical report, TIMSS & PIRLS International Study Center. Lynch School of Education, Boston College.

Funkhouser, E. (2009). The Effect of Kindergarten Classroom Size Reduction on Second Grade Student Achievement: Evidence from California. *Economics of Education Review 28*, 403–414.

Hanushek, E. A. (2002). *The Class Size Debate*, Chapter Evidence, politics, and the class size debate, pp. 37–66. Washington D.C., Economic Policy Institute.

Hanushek, E. A., G. Schwerdt, S. Wiederhold, and L. Woessmann (2015). Returns to Skills Around the World: Evidence from PIAAC. *European Economic Review 73*, 103–130.

Hanushek, E. A. and L. Woessmann (2012). Do Better Schools Lead to More Growth? Cognitive Skills, Economic Outcomes, and Causation. *Journal of economic growth 17*, 267–321.

Kerckhoff, A. C. and E. Glennie (1999). The Matthew Effect in American Education. *Research in sociology of education and socialization 12*(1), 35–66.

Krueger, A. B. (2002). *The Class Size Debate*, Chapter Understanding the magnitude and effect of class size on student achievement, pp. 7–35. Washington D.C., Economic Policy Institute.

Leak, J., G. Duncan, W. Li, K. Magnuson, H. Schindler, and H. Yoshikawa (2012). Is Timing Everything? How Early Childhood Education Program Cognitive and Achievement Impacts Vary by Starting Age, Program Duration and Time since the End of Program. *Unpublished*.

Leppänen, U., P. Niemi, K. Aunola, and J. Nurmi (2004). Development of Reading Skills Among Preschool and Primary School Pupils. *Reading Research Quarterly 39*(1), 72–93.

Lewit, E. M. and L. S. Baker (1995). School Readiness. *The future of children 5*(2), 128–139.

Luyten, H., L. Cremers-van Wees, and R. Bosker (2003). The Matthew Effect in Dutch Primary Education: Differences Between Schools, Cohorts and Pupils. *Research Papers in Education 18*(2), 167–195.

Magnuson, K. A., M. K. Meyers, C. J. Ruhm, and J. Waldfogel (2004). Inequality in Preschool Education and School Readiness. *American Educational Research Journal 41*(1), 115–157.

Martin, M. O., I. V. S. Mullis, and M. Hooper (2017). Methods and Procedures in TIMSS 2015. Technical report, TIMSS & PIRLS International Study Center. Lynch School of Education, Boston College.

Merton, R. K. (1968). The Matthew Effect in Science. *Science 175*, 56–63.

Monnet, J. (2019). The Effect of Preschool Participation on Intellectual and Behavioral Disorder Diagnoses: Evidence from Surveys on Children's Health. *Economics of Education Review 68*, 136–147.

Pfost, M., T. Dörfler, and C. Artelt (2012). Reading Competence Development of Poor Readers in a German Elementary School Sample: an Empirical Examination of the Matthew Effect Model. *Journal of Research in Reading 35*(4), 411–426.

Pianta, R. C., M. Steinberg, and K. B. Rollins (1995). The First Two Years of School: Teacher-Child Relationships and Deflections in Children's Classroom Adjustment. *Development and Psychopathology 7*(2), 295–312.

Ramey, C. T. and F. A. Campbell (1984). Preventive Education for High-Risk Children: Cognitive Consequences of the Carolina Abecedarian Project. *American Journal of Mental Deficiency 88*(5), 515–523.

Rigney, D. (2010). *The Matthew Effect: How Advantage Begets Further Advantage*. Columbia University Press.

Rindermann, H. (2007). The g-factor of International Cognitive Ability Comparisons: the Homogeneity of Results in PISA, TIMSS, PIRLS and IQ-tests Across Nations. *European Journal of Personality 21*, 667–706.

Sammons, P., K. Elliot, K. Sylva, E. Melhuish, I. Siraj-Blatchfor, and B. Taggart (2004). The Impact of Pre-school on Young Children's Cognitive Attainments at Entry to Reception. *British Educational Research Journal 30*(5), 691–705.

Sammons, P., K. Sylva, E. Melhuish, I. Siraj-Blatchford, B. Taggart, and K. Elliot (2003). The Effective Provision of Pre-school Education (EPPE) Project: Technical Paper 8b - Measuring the Impact of Pre-school on Children's Social/Behavioral Development Over the Pre-school Period. Technical report, University of London, Institute of Education, Department for education and skills.

Shala, M. (2013). The Impact of Preschool Social-Emotional Development on Academic Success of Elementary School Students. *Psychology 4*(11), 787–791.

Stanovich, K. (1986). Matthew Effects in Reading: Some Consequences of Individual Differences in the Acquisition of Literacy. *Reading Research Quarterly 21*, 360–407.

Walberg, H. J. and S. L. Tsai (1983). Matthew Effects in Education. *American Educational Research Journal 20*(3), 359–373.

Wood, C. (2002). Parent-Child Pre-school Activities Can Affect the Development of Literacy Skills. *Journal of Research in Reading 25*(3), 241–258.

List of Tables

List of Figures

Appendix

	n	Response Rate	Share of Girls	Creche	Kindergarten	Mean School Entry Age
Belgium	5404	91.7%	50.56%	60.78%	94.35%	5.83
Bulgaria	4228	98.3%	49.22%	39.83%	94.4%	6.85
Croatia	3985	97.9%	48.61%	29.23%	84.36%	6.65
Cyprus	4125	91.5%	49.21%	48.53%	88.77%	5.97
Czech Republic	5202	96.2%	49.65%	4.58%	95.04%	6.29
Denmark	3710	87.9%	49.41%	51.29%	97.30%	5.79
Finland	5015	94.0%	48.59%	47.71%	91.13%	6.72
France	4873	86.7%	49.09%	41.61%	89.68%	5.86
Germany	3948	62.0%	47.24%	21.28%	88.60%	6.06
Hungary	5036	96.0%	49.76%	27.21%	99.05%	6.67
Ireland	4344	93.1%	47.42%	29.01%	91.00%	6.11
Italy	4373	93.1%	48.50%	40.90%	94.62%	5.85
Lithuania	4529	85.6%	49.72%	49.19%	93.19%	6.62
Norway	4329	42.2%	49.57%	82.07%	92.76%	5.79
Poland	4747	97.5%	50.26%	4.95%	80.43%	6.76
Portugal	4693	97.4%	48.88%	52.90%	82.08%	5.82
Russia	4921	98.0%	49.64%	34.64%	88.06%	6.72
Serbia	4036	97.5%	48.79%	35.42%	81.41%	6.75
Slovakia	5773	96.5%	48.57%	8.22%	92.73%	6.26
Spain	7764	64.0%	48.88%	54.73%	85.52%	5.57
Sweden	4142	88.4%	49.59%	86.97%	76.68%	6.68

Table 8: Descriptive Statistics of All Countries

Source: Author's calculations based on TIMSS 2015 data

	Can read letters	Can read words	Can read sentences	Can read stories	Can write letters	Can write words
Belgium	67.66%	50.40%	26.52%	21.03%	54.68%	44.60%
Bulgaria	81.24%	60.18%	39.65%	30.04%	75.39%	58.71%
Croatia	93.38%	82.88%	61.17%	51.54%	89.68%	81.48%
Cyprus	85.71%	68.91%	48.10%	31.56%	82.07%	65.43%
Czech Republic	82.00%	60.88%	41.82%	32.47%	74.87%	59.25%
Denmark	79.26%	48.73%	16.17%	9.35%	78.70%	49.81%
Finland	89.76%	61.08%	41.88%	30.79%	80.99%	61.56%
France	91.14%	68.60%	38.52%	26.27%	84.11%	66.36%
Germany	70.30%	45.39%	18.33%	11.94%	66.06%	51.73%
Hungary	59.33%	43.62%	22.95%	14.93%	44.32%	43.67%
Ireland	96.31%	92.41%	84.95%	78.63%	93.65%	90.28%
Italy	76.65%	51.30%	25.71%	16.13%	72.37%	58.19%
Lithuania	90.20%	75.69%	59.50%	75.69%	58.67%	73.81%
Norway	69.38%	46.75%	21.43%	10.22%	59.43%	45.43%
Poland	93.21%	83.25%	64.87%	48.44%	85.66%	78.46%
Portugal	82.30%	57.04%	33.10%	24.51%	78.82%	63.88%
Russia	71.09%	73.06%	54.62%	37.37%	72.56%	58.20%
Serbia	90.37%	74.23%	51.23%	85.81%	83.44%	74.23%
Slovakia	70.69%	42.90%	20.19%	13.06%	58.52%	41.91%
Spain	92.17%	87.49%	76.02%	65.17%	90.72%	86.30%
Sweden	90.71%	76.96%	49.92%	32.72%	82.38%	71.63%

Table 9: Reading and Writing Skills

Source: Author's calculations based on TIMSS 2015 data

	Can count max. to 10	Can recognize max. to 10	Can write max. to 10	Can do simple addition	Can do simple subtraction	Can count money	Can measure length or height
Belgium	33.74%	55.26%	68.10%	69.39%	44.53%	27.29%	9.60%
Bulgaria	32.69%	35.20%	43.74%	70.72%	59.15%	49.32%	12.63%
Croatia	16.25%	25.64%	31.14%	87.08%	78.63%	56.35%	17.83%
Cyprus	26.43%	38.71%	45.78%	79.46%	64.23%	38.13%	15.34%
Czech Republic	29.06%	50.24%	58.83%	84.11%	62.17%	45.03%	14.28%
Denmark	18.88%	48.82%	57.60%	72.65%	35.02%	49.19%	9.16%
Finland	20.47%	31.42%	40.28%	86.98%	70.78%	47.26%	18.76%
France	24.47%	44.22%	50.50%	60.51%	30.20%	30.51%	9.94%
Germany	22.44%	51.80%	58.12%	75.27%	55.05%	37.98%	12.31%
Hungary	18.12%	42.98%	57.00%	79.59%	65.94%	48.06%	24.63%
Ireland	15.88%	19.03%	21.65%	91.71%	78.30%	66.46%	26.47%
Italy	36.08%	52.12%	57.03%	42.77%	30.85%	21.52%	6.84%
Lithuania	29.83%	33.62%	41.20%	80.87%	73.01%	53.08%	20.19%
Norway	18.10%	48.44%	57.30%	69.05%	36.19%	60.63%	12.74%
Poland	27.47%	28.49%	32.61%	91.96%	82.17%	58.32%	24.96%
Portugal	28.87%	44.29%	49.59%	62.68%	46.98%	25.40%	12.93%
Russia	28.44%	35.04%	42.55%	89.96%	85.48%	56.14%	27.94%
Serbia	17.52%	31.99%	35.38%	79.70%	68.06%	59.19%	21.13%
Slovakia	46.77%	60.66%	66.29%	74.63%	53.18%	40.11%	13.67%
Spain	20.65%	24.75%	28.02%	81.82%	64.84%	36.16%	13.54%
Sweden	18.94%	30.32%	39.24%	83.46%	61.63%	69.96%	24.87%

Table 10: Counting Skills

Source: Author's calculations based on TIMSS 2015 data

	Read_letters			Read_words			Read_sent			Read_story			Write_letters			Write_words			Count			Read_num			Write_num			Addition			Subtraction			Count_money			Measure		
	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2	Preschool_0	Preschool_1	Preschool_2
Belgium	508.1	522.2	554.3	507.7	515.1	554.2	507.6	512.7	542.6	508.1	511.2	544.8	511.7	517.4	553.8	510.6	515.4	552.3	508.7	525.8	552.4	508.1	525.5	553.5	507.4	522.5	553.6	510.6	535.1	559.3	513.7	522.5	561.0	510.3	515.3	558.6	495.6	522.2	550.6
	(56.6)	(60.1)	(59.4)	(55.7)	(60.6)	(59.4)	(56.6)	(63.5)	(61.4)	(56.6)	(59.9)	(60.6)	(54.9)	(59.3)	(59.6)	(52.7)	(59.3)	(60.1)	(56.8)	(60.2)	(58.2)	(56.4)	(61.0)	(58.3)	(55.4)	(61.2)	(58.2)	(58.4)	(61.9)	(57.3)	(54.0)	(64.0)	(58.9)	(53.0)	(63.9)	(60.4)	(57.6)	(69.5)	(59.7)
Bulgaria	517.0	531.0	543.6	512.9	539.7	548.9	517.0	540.9	556.3	519.2	543.7	558.9	519.2	530.6	543.5	516.0	533.6	547.2	520.0	520.2	539.8	516.5	521.3	540.7	512.9	521.8	540.9	513.6	530.1	545.3	512.9	530.9	546.3	512.3	523.9	546.1	494.5	520.9	549.5
	(88.9)	(80.4)	(71.4)	(88.7)	(78.5)	(69.8)	(94.7)	(77.9)	(69.6)	(89.5)	(78.1)	(70.3)	(88.9)	(81.5)	(71.2)	(87.4)	(80.9)	(70.7)	(89.3)	(88.1)	(73.1)	(89.2)	(88.6)	(72.5)	(90.6)	(86.2)	(72.5)	(93.2)	(83.5)	(72.3)	(90.0)	(83.6)	(71.4)	(89.0)	(86.8)	(74.4)	(98.7)	(84.1)	(74.1)
Croatia	491.8	497.2	517.0	496.8	499.5	521.1	503.3	503.1	526.1	500.6	501.2	529.7	489.9	497.2	517.7	493.2	497.0	519.7	489.9	495.9	515.5	490.4	496.2	515.8	490.1	495.8	515.9	495.2	499.9	520.2	500.7	504.1	522.5	494.6	504.5	525.5	514.4	515.6	541.6
	(67.2)	(64.3)	(62.4)	(66.6)	(64.0)	(61.2)	(67.8)	(64.8)	(60.5)	(69.6)	(65.5)	(60.0)	(68.2)	(63.8)	(62.5)	(67.3)	(64.4)	(61.5)	(69.1)	(64.5)	(62.9)	(68.6)	(64.5)	(62.8)	(68.9)	(64.7)	(62.9)	(67.5)	(63.4)	(61.7)	(67.2)	(63.4)	(61.9)	(70.9)	(66.5)	(63.1)	(74.4)	(71.7)	(63.0)
Cyprus	509.3	527.5	543.5	512.8	530.6	548.7	517.2	529.1	549.0	525.1	538.4	551.8	509.3	524.0	543.9	514.7	526.7	546.0	500.0	521.3	541.6	498.9	520.5	541.5	498.9	520.6	541.7	506.3	529.4	546.5	513.8	533.0	551.1	499.3	534.2	552.9	518.3	539.7	546.6
	(74.8)	(78.1)	(76.2)	(74.7)	(75.2)	(76.3)	(76.0)	(75.5)	(76.3)	(79.6)	(74.0)	(77.3)	(75.7)	(78.5)	(76.1)	(77.1)	(77.5)	(76.3)	(78.3)	(79.5)	(77.2)	(78.7)	(79.3)	(77.0)	(78.0)	(79.4)	(76.9)	(77.8)	(77.3)	(75.7)	(77.9)	(76.7)	(74.8)	(81.5)	(78.1)	(78.5)	(81.3)	(77.5)	(84.4)
Czech Rep.	496.8	522.1	543.5	513.2	528.4	546.9	513.2	526.7	545.6	509.9	533.3	545.3	496.7	523.3	541.4	509.9	526.2	543.4	494.1	518.8	538.8	495.1	519.9	540.1	496.7	521.8	540.0	512.5	525.1	543.0	515.6	526.4	548.4	504.8	519.3	548.1	517.3	540.3	562.1
	(76.2)	(71.4)	(66.1)	(74.0)	(70.2)	(65.0)	(72.2)	(71.3)	(64.6)	(71.9)	(70.0)	(64.3)	(76.2)	(72.7)	(67.6)	(76.1)	(71.9)	(67.7)	(80.1)	(73.3)	(67.7)	(78.7)	(72.4)	(67.3)	(77.3)	(72.0)	(67.1)	(73.9)	(70.9)	(66.5)	(74.6)	(72.8)	(66.3)	(69.0)	(74.8)	(67.0)	(74.4)	(76.6)	(65.5)
Denmark	521.1	538.3	551.4	524.5	539.5	557.3	516.8	537.0	554.0	496.8	532.5	549.9	516.8	536.0	550.2	516.0	538.3	553.5	516.0	536.6	547.0	516.0	536.0	548.0	516.0	537.0	548.0	517.7	539.5	556.3	516.0	551.9	566.1	517.7	541.7	556.8	527.3	552.8	568.4
	(76.7)	(76.7)	(72.7)	(72.4)	(80.4)	(71.6)	(83.8)	(90.0)	(74.5)	(47.7)	(88.6)	(74.9)	(77.5)	(73.4)	(72.6)	(71.9)	(77.8)	(71.9)	(74.0)	(77.4)	(73.6)	(74.5)	(78.6)	(73.0)	(75.8)	(77.2)	(72.7)	(76.5)	(75.2)	(72.8)	(78.8)	(79.9)	(69.9)	(95.8)	(76.3)	(72.0)	(68.3)	(72.7)	(74.6)
Finland	549.7	545.6	546.8	561.8	556.8	557.3	570.3	567.5	569.2	571.3	573.4	574.0	548.5	548.5	549.2	551.3	553.2	555.5	535.2	543.4	542.9	533.8	542.9	542.0	535.2	543.3	542.7	540.1	546.1	547.7	550.5	551.9	553.8	561.8	558.9	556.9	551.3	575.2	571.3
	(69.1)	(62.7)	(63.5)	(71.0)	(61.2)	(60.8)	(62.4)	(59.1)	(60.0)	(62.0)	(60.7)	(61.2)	(72.7)	(62.5)	(63.3)	(72.6)	(62.9)	(60.9)	(75.9)	(64.5)	(65.5)	(76.4)	(65.6)	(66.2)	(76.2)	(65.2)	(65.6)	(73.1)	(64.4)	(63.4)	(73.2)	(63.4)	(62.2)	(76.2)	(64.1)	(62.2)	(81.0)	(59.5)	(65.1)
France	455.2	470.1	498.8	451.9	477.1	503.9	455.9	476.1	500.9	463.6	474.7	497.8	448.4	474.4	499.4	454.2	481.6	501.7	455.2	464.1	495.8	455.9	467.6	496.3	455.5	468.4	496.1	465.6	474.9	506.5	451.9	476.5	509.9	448.4	476.5	504.9	433.7	747.2	499.0
	(78.3)	(78.5)	(72.4)	(74.9)	(79.5)	(72.1)	(76.3)	(81.6)	(72.9)	(78.1)	(81.0)	(74.1)	(77.4)	(78.1)	(72.8)	(74.2)	(76.1)	(72.6)	(76.5)	(81.1)	(73.4)	(71.8)	(79.1)	(73.4)	(76.1)	(77.5)	(73.3)	(77.1)	(82.0)	(73.5)	(75.5)	(87.5)	(78.2)	(82.4)	(78.0)	(74.7)	(69.3)	(78.0)	(85.4)
Germany	510.3	529.8	546.1	508.6	535.0	548.3	501.3	545.6	549.1	512.0	536.4	549.1	514.1	530.6	543.5	512.0	530.6	543.8	512.0	527.1	544.3	514.1	527.3	544.8	514.0	526.9	544.9	512.1	535.0	550.3	508.8	541.8	554.3	515.1	523.0	554.7	515.6	500.8	565.2
	(62.1)	(67.4)	(63.4)	(61.9)	(68.3)	(62.0)	(58.5)	(64.7)	(65.5)	(57.1)	(64.9)	(69.1)	(60.9)	(68.3)	(64.2)	(60.5)	(66.8)	(64.0)	(62.2)	(66.4)	(63.1)	(61.5)	(66.1)	(63.4)	(61.7)	(66.9)	(63.8)	(61.2)	(63.5)	(61.6)	(60.9)	(64.1)	(61.4)	(60.4)	(67.8)	(62.7)	(57.8)	(62.0)	(58.2)
Hungary	503.4	506.6	553.9	509.5	507.1	562.0	546.6	495.9	565.3	546.6	487.5	561.1	528.1	511.4	549.8	571.6	516.2	552.2	506.5	504.1	548.2	506.5	508.8	549.2	506.5	505.7	548.5	526.8	514.5	558.2	517.0	519.7	563.4	506.5	501.2	555.2	521.4	514.3	554.5
	(63.8)	(100.0)	(83.6)	(65.4)	(99.6)	(85.7)	(75.1)	(112.0)	(90.1)	(82.8)	(115.4)	(94.3)	(96.7)	(107.4)	(86.5)	(114.3)	(106.4)	(88.1)	(84.0)	(102.1)	(84.3)	(79.7)	(101.9)	(83.2)	(84.8)	(101.3)	(84.0)	(89.9)	(97.2)	(79.5)	(93.8)	(97.9)	(79.9)	(92.6)	(103.6)	(86.5)	(84.8)	(108.9)	(86.7)
Ireland	533.9	555.0	564.6	543.6	556.8	566.3	545.7	560.3	568.1	550.3	562.7	570.3	534.2	555.9	565.1	541.2	557.6	566.4	530.5	552.5	562.7	533.4	552.8	563.1	535.4	553.2	563.1	543.6	556.8	566.9	549.2	559.8	568.9	545.4	563.2	571.5	553.3	570.6	578.9
	(78.2)	(69.8)	(67.4)	(79.0)	(68.4)	(66.7)	(79.7)	(67.1)	(66.1)	(80.3)	(66.3)	(65.8)	(78.7)	(69.3)	(67.6)	(79.3)	(68.5)	(67.0)	(78.2)	(71.0)	(68.2)	(79.1)	(70.5)	(67.6)	(77.6)	(70.7)	(67.9)	(78.5)	(68.7)	(66.4)	(78.6)	(68.9)	(66.1)	(81.9)	(68.6)	(65.8)	(85.1)	(68.1)	(67.1)
Italy	481.0	502.7	520.8	499.8	506.2	527.4	507.3	511.7	531.2	507.0	511.5	538.3	485.3	498.2	520.4	495.6	499.1	521.9	483.9	494.0	518.6	485.3	496.1	519.5	492.7	496.1	519.5	514.6	505.0	532.3	511.3	498.2	532.9	507.0	493.2	524.2	496.5	493.1	526.6
	(76.9)	(70.7)	(68.4)	(69.8)	(69.9)	(68.4)	(59.7)	(69.1)	(70.6)	(62.4)	(64.3)	(71.7)	(71.7)	(71.7)	(69.0)	(72.0)	(71.8)	(69.1)	(75.6)	(71.6)	(68.8)	(75.7)	(72.0)	(68.4)	(74.9)	(71.2)	(69.1)	(71.8)	(70.0)	(69.0)	(73.3)	(72.1)	(71.4)	(77.7)	(71.1)	(73.0)	(70.0)	(96.2)	(79.8)
Lithuania	522.1	528.4	551.9	531.4	534.4	558.2	543.3	541.9	563.1	549.0	544.9	565.2	518.4	525.4	552.1	528.4	531.1	556.5	512.0	520.6	548.8	513.1	520.9	549.0	514.9	520.9	549.4	520.4	528.4	554.3	522.3	530.6	555.8	517.9	523.1	556.7	516.0	533.0	566.8
	(77.0)	(73.4)	(65.1)	(76.5)	(73.9)	(63.6)	(74.2)	(73.1)	(63.6)	(73.9)	(74.2)	(64.2)	(80.7)	(74.1)	(66.1)	(80.3)	(74.7)	(64.8)	(80.6)	(75.3)	(67.7)	(82.1)	(75.5)	(67.5)	(81.3)	(75.9)	(67.4)	(78.0)	(75.3)	(65.5)	(79.5)	(74.4)	(65.6)	(82.6)	(78.9)	(67.0)	(79.2)	(86.7)	(66.4)
Norway	536.3	564.7	576.6	497.3	572.3	585.0	496.0	564.7	597.4	494.7	569.7	604.1	536.3	557.5	578.4	504.2	564.7	583.7	514.8	543.5	569.5	533.3	544.5	570.1	533.3	546.0	570.8	513.5	564.7	578.8	533.3	569.2	593.3	513.5	548.5	578.2	517.7	601.6	597.0
	(70.4)	(68.6)	(67.6)	(72.5)	(68.8)	(67.9)	(77.7)	(68.0)	(69.2)	(96.2)	(79.8)	(67.6)	(68.7)	(72.4)	(67.3)	(71.2)	(72.5)	(67.7)	(78.7)	(70.5)	(68.3)	(76.8)	(69.2)	(67.9)	(76.8)	(67.6)	(67.6)	(67.1)	(70.8)	(65.4)	(66.1)	(72.6)	(64.9)	(63.7)	(70.5)	(66.0)	(60.8)	(74.2)	(71.0)
Poland	521.1	525.8	554.4	531.3	532.3	557.1	545.8	537.8	560.4	545.8	541.2	562.5	529.9	525.6	555.7	530.8	528.0	556.7	521.1	523.4	551.8	521.1	523.9	552.7	528.9	523.4	553.0	521.1	525.5	554.4	513.3	527.5	555.9	510.0	532.2	558.5	466.5	544.2	564.7
	(102.9)	(71.6)	(69.1)	(94.5)	(68.8)	(67.9)	(75.4)	(67.0)	(66.7)	(76.9)	(67.3)	(67.7)	(102.8)	(70.6)	(69.4)	(97.5)	(70.3)	(68.2)	(98.7)	(72.3)	(70.1)	(100.6)	(72.5)	(69.7)	(98.8)	(72.8)	(69.7)	(100.0)	(71.5)	(69.5)	(102.5)	(72.0)	(70.0)	(89.0)	(70.4)	(69.7)	(108.5)	(70.5)	(70.6)
Portugal	518.7	531.2	551.0	518.8	532.2	553.1	514.5	536.0	547.4	504.8	536.4	552.1	519.3	531.4	550.3	519.2	531.2	549.5	510.3	526.5	547.3	510.6	527.9	548.7	513.7	527.9	549.3	523.4	536.5	560.0	523.4	545.5	562.3	518.8	549.1	560.6	498.6	544.7	547.0
	(71.4)	(66.9)	(68.6)	(71.0)	(66.3)	(68.9)	(69.3)	(67.3)	(69.5)	(63.9)	(66.8)	(69.3)	(70.6)	(68.5)	(69.3)	(70.9)	(68.3)	(69.2)	(71.2)	(69.5)	(69.8)	(70.1)	(69.6)	(69.5)	(70.1)	(69.8)	(69.1)	(71.1)	(69.6)	(69.3)	(70.1)	(69.0)	(69.8)	(74.7)	(68.4)	(70.2)	(68.5)	(61.9)	(75.0)
Russia	566.3	571.6	574.8	570.0	574.8	581.2	582.1	582.8	587.0	585.7	593.3	592.7	565.5	572.3	576.8	568.7	574.0	581.7	558.0	568.7	573.0	559.4	569.0	572.8	560.1	568.8	572.8	562.9	571.3	575.7	564.5	571.6	576.8	564.5	569.9	576.4	566.1	572.1	585.5
	(71.4)	(70.1)	(68.0)	(68.5)	(68.0)	(65.5)	(66.7)	(64.7)	(65.4)	(65.7)	(63.3)	(64.5)	(70.5)	(72.1)	(66.9)	(70.4)	(69.9)	(67.3)	(74.7)	(71.6)	(69.1)	(74.4)	(72.0)	(69.2)	(73.7)	(72.1)	(69.2)	(72.3)	(71.0)	(67.9)	(71.3)	(71.1)	(67.6)	(72.9)	(71.8)	(68.5)	(72.4)	(74.9)	(69.4)
Serbia	513.3	520.5	549.7	527.9	528.6	553.1	536.7	533.9	561.6	544.8	535.0	562.4	513.3	520.4	550.4	519.9	525.6	552.8	511.6	516.5	546.1	513.3	519.5	547.2	513.7	517.6	546.2	520.7	528.2	552.4	527.4	531.4	556.9	511.0	522.9	551.6	505.6	527.6	563.6
	(98.3)	(80.1)	(76.4)	(98.5)	(77.5)	(74.6)	(103.4)	(76.4)	(75.7)	(99.8)	(75.7)	(74.8)	(100.1)	(81.6)	(76.8)	(101.0)	(79.7)	(74.8)	(100.4)	(83.5)	(77.5)	(95.2)	(82.3)	(77.7)	(94.8)	(81.9)	(77.2)	(93.9)	(79.8)	(75.8)	(94.3)	(78.4)	(75.9)	(108.0)	(85.0)	(76.5)	(116.1)	(88.1)	(82.2)
Slovakia	425.5	496.5	521.6	434.9	501.4	526.7	431.6	501.1	526.7	428.2	501.6	527.8	432.6	492.9	521.3	421.7	496.1	521.6	424.2	489.7	519.4	429.8	491.7	520.8	430.3	491.9	520.1	421.2	497.1	525.3	405.4	497.4	529.3	399.8	482.1	520.7	428.2	493.4	536.8
	(94.9)	(81.4)	(69.8)	(100.1)	(81.2)	(70.9)	(101.9)	(93.1)	(76.3)	(110.9)	(93.4)	(79.1)	(95.3)	(81.3)	(70.6)	(94.7)	(84.3)	(71.4)	(92.5)	(82.9)	(69.7)	(94.0)	(81.1)	(68.8)	(94.9)	(80.3)	(69.4)	(96.1)	(80.0)	(69.5)	(98.5)	(82.3)	(71.1)	(93.8)	(89.1)	(74.1)	(102.8)	(91.4)	(79.6)
Spain	504.7	516.9	534.7	508.5	519.5	537.2	513.1	522.5	540.1	516.7	525.1	544.9	502.9	517.0	534.9	507.0	519.3	535.9	500.8	513.0	531.2	501.5	513.6	531.4	502.9	514.4	531.6	506.1	519.5	536.4	505.9	520.4	538.1	507.2	524.3	543.3	517.0	519.7	536.2
	(65.1)	(63.7)	(63.7)	(64.4)	(63.1)	(62.7)	(64.6)	(62.0)	(61.6)	(64.9)	(60.8)	(61.3)	(65.8)	(63.4)	(63.5)	(65.4)	(63.3)	(62.8)	(67.1)	(64.7)	(65.1)	(66.5)	(64.4)	(64.7)	(67.0)	(64.4)	(64.6)	(67.2)	(63.5)	(64.1)	(68.7)	(63.6)	(63.9)	(69.7)	(61.3)	(63.5)	(71.4)	(69.7)	(68.1)
Sweden	491.1	512.5	536.6	507.7	516.6	542.4	496.7	527.6	549.1	479.4	534.9	553.5	478.8	512.4	538.8	485.5	515.3	541.2	491.1	513.3	533.1	491.1	512.1	533.2	488.6	512.4	533.5	496.8	525.5	540.6	497.7	525.5	547.1	488.6	516.4	541.9	479.4	528.4	550.0
	(72.8)	(70.1)	(63.7)	(71.2)	(70.4)	(62.8)	(77.9)	(69.6)	(62.1)	(80.4)	(71.3)	(63.9)	(74.0)	(69.8)	(63.5)	(72.3)	(69.6)	(63.0)	(71.9)	(68.0)	(64.0)	(71.3)	(68.7)	(64.0)	(72.6)	(67.7)	(63.8)	(69.8)	(64.4)	(62.9)	(71.8)	(69.1)	(61.7)	(72.0)	(67.6)	(63.0)	(80.2)	(69.8)	(65.4)

Table 11: Median Math Test Scores by Pre-school Attendance and Skills

Source: Author's calculations based on TIMSS 2015 data

	Math Domains						Science Domains					
	NUM	GEO	DAT	KNO	APP	REA	LIF	PHY	EAR	KNO	APP	REA
Belgium	541.85	562.08	521.96	552.29	542.82	534.73	511.27	504.72	511.08	495.90	511.77	524.13
	(62.18)	(63.12)	(71.51)	(63.87)	(61.62)	(68.29)	(65.63)	(64.56)	(71.58)	(67.18)	(61.32)	(70.92)
Bulgaria	529.65	524.99	505.38	527.36	522.86	521.50	544.11	531.78	533.44	553.39	538.62	508.73
	(74.84)	(96.45)	(118.84)	(80.11)	(87.51)	(92.60)	(103.53)	(101.56)	(95.22)	(100.07)	(99.18)	(108.42)
Croatia	501.67	516.68	502.18	505.91	502.57	511.66	533.90	537.72	538.18	537.18	532.72	537.56
	(64.22)	(78.04)	(75.27)	(64.15)	(67.97)	(79.41)	(62.30)	(68.50)	(73.99)	66.81()	(64.46)	(68.78)
Cyprus	528.38	523.69	507.36	519.07	528.75	518.63	480.92	485.86	462.79	467.59	489.04	489.71
	(79.49)	(80.57)	(106.52)	(79.47)	(84.25)	(89.58)	(74.66)	(80.72)	(98.35)	(77.52)	(78.12)	(79.08)
Czech Rep.	529.89	533.15	527.11	521.01	530.25	545.52	539.22	531.75	533.05	546.05	529.73	530.09
	(67.98)	(78.77)	(85.94)	(69.62)	(70.97)	(79.41)	(69.84)	(74.92)	(86.72)	(75.91)	(71.23)	(75.89)
Denmark	535.60	555.61	526.61	536.42	538.33	547.99	534.15	515.84	530.42	524.12	529.27	526.02
	(73.81)	(87.54)	(89.25)	(78.29)	(78.48)	(76.22)	(69.79)	(71.97)	(87.77)	(72.35)	(68.88)	(77.66)
Finland	531.81	539.50	542.26	530.57	536.37	540.03	556.91	548.32	561.37	556.80	554.03	552.77
	(69.57)	(67.65)	(81.62)	(74.33)	(64.95)	(73.99)	(64.80)	(67.54)	(80.34)	(70.16)	(66.99)	(68.21)
France	478.39	497.10	469.40	478.64	483.10	485.09	484.80	476.74	478.91	477.29	488.86	476.70
	(76.38)	(78.60)	(85.45)	(77.47)	(76.33)	(84.97)	(77.37)	(75.07)	(95.12)	(78.52)	(79.50)	(79.37)
Germany	515.33	531.02	535.19	524.25	515.47	535.33	528.29	532.65	519.22	527.72	529.08	532.08
	(65.03)	(69.91)	(86.57)	(67.85)	(64.50)	(72.38)	(68.71)	(72.11)	(90.09)	(78.25)	(68.09)	(73.07)
Hungary	540.15	545.46	522.61	540.71	535.95	539.86	558.82	542.38	545.11	559.47	547.31	541.03
	(82.37)	(95.01)	(99.12)	(82.64)	(88.95)	(98.45)	(82.23)	(85.90)	(96.64)	(89.33)	(81.32)	(83.50)
Ireland	549.92	540.45	545.16	552.97	546.89	533.85	527.64	521.61	532.38	526.24	528.03	523.97
	(72.06)	(80.65)	(85.32)	(75.16)	(75.13)	(81.07)	(75.01)	(69.47)	(78.65)	(73.54)	(70.63)	(74.22)
Italy	511.32	505.91	499.90	512.69	506.03	504.50	520.94	514.54	512.65	522.13	515.10	513.19
	(69.65)	(80.11)	(82.54)	(74.47)	(73.16)	(76.00)	(71.12)	(64.56)	(83.93)	(71.32)	(69.68)	(69.86)
Lithuania	534.86	519.92	533.40	528.25	532.26	529.55	517.88	524.82	508.53	516.16	517.64	524.64
	(74.38)	(74.75)	(91.18)	(69.43)	(76.17)	(86.16)	(76.26)	(77.80)	(86.05)	(77.77)	(73.77)	(85.77)
Norway	543.17	560.08	567.64	546.00	551.32	557.18	547.02	522.21	549.48	533.21	542.29	537.23
	(71.07)	(79.77)	(84.52)	(71.53)	(71.21)	(78.48)	(64.19)	(63.50)	(79.00)	(64.21)	(66.06)	(71.66)
Poland	537.31	536.45	541.18	519.61	543.77	548.69	558.78	541.26	543.04	546.12	555.35	544.04
	(75.19)	(75.31)	(84.24)	(77.06)	(70.60)	(79.64)	(70.67)	(74.36)	(81.64)	(74.64)	(68.53)	(77.46)
Portugal	537.67	536.59	543.23	545.03	536.85	528.62	505.75	499.91	510.02	504.27	505.98	503.49
	(71.22)	(82.48)	(82.95)	(72.97)	(75.05)	(79.34)	(60.80)	(62.29)	(81.76)	(65.80)	(63.94)	(61.29)
Russia	567.95	557.74	574.78	557.32	567.74	571.13	569.88	568.20	563.50	569.44	569.68	561.77
	(69.40)	(86.07)	(93.14)	(68.18)	(76.72)	(83.76)	(70.48)	(74.01)	(79.18)	(75.33)	(69.97)	(75.61)
Serbia	530.82	508.50	523.34	518.93	527.35	523.87	536.10	533.99	502.32	532.33	527.84	525.31
	(81.85)	(96.06)	(98.90)	(80.43)	(88.86)	(96.16)	(79.33)	(83.14)	(90.63)	(85.64)	(79.18)	(83.83)
Slovakia	502.70	491.58	496.49	491.02	497.49	515.76	518.79	526.29	514.92	530.82	517.70	508.52
	(79.12)	(80.81)	(99.93)	(76.73)	(81.66)	(93.70)	(84.59)	(96.55)	(92.43)	(92.03)	(89.42)	(91.54)
Spain	513.65	512.30	519.81	515.34	514.40	511.62	533.59	519.33	531.75	533.73	525.32	526.91
	(67.54)	(73.71)	(84.54)	(71.50)	(67.52)	(76.52)	(67.18)	(74.29)	(78.77)	(74.67)	(69.07)	(71.23)
Sweden	515.90	524.87	531.73	502.90	523.26	543.98	542.08	536.87	554.86	540.60	542.35	544.52
	(70.17)	(75.21)	(80.56)	(72.53)	(66.97)	(78.36)	(72.88)	(74.07)	(88.71)	(75.57)	(75.60)	(73.19)

Table 12: Mean Achievement in Math and Science by Particular Domains (Standard Deviations in Parantheses)

Source: Author's calculations based on TIMSS 2015 data