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Education reforms and adult skills: Evidence from Estonia

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Abstract

This paper investigates the impact of education reforms in Estonia on adult skills, using the PIAAC surveys conducted by the OECD. Estonia implemented comprehensive education reforms in the early 1990s throughout Estonian-speaking schools while in Russian-speaking schools less comprehensive reforms were implemented later. A large minority of Estonia's population at the time was enrolled in Russian-speaking schools. This provides a unique opportunity to measure the impact of education reforms on literacy, numeracy and problem-solving skills among adults by comparing improvements in PIAAC performance among Estonian and Russian speakers. Difference-in-difference estimations suggest that the reforms led to an improvement of around 15 per cent of a standard deviation in terms of adult skills. This translates into a wage (productivity) premium of around 6 per cent.

Keywords: education reforms, adult skills, productivity growth, human capital

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1. Introduction

The strong impact of education on economic growth is well documented (see, for instance, Mankiw et al., 1992). It was first shown for the quantity of education typically proxied by years of schooling. A number of studies, in turn, showed how various policies in developing countries can raise the enrolment ratios in primary and secondary education and boost quantity of schooling. Such policies include the use of vouchers, teacher incentives and increases in per capita expenditure on hard infrastructure (see, for instance, Duflo, 2001, 2004; Hsieh and Urquiola, 2006; and Muralidharan and Sundararaman, 2011).

Over time, attention shifted to the quality of education and various internationally comparable measures of skills became available. The quality of education has also been shown to have a profound impact on individual earnings and economic growth (see, for instance, Hanushek and Woessmann, 2008). Building on these findings, various studies estimated potential gains for higher-income economies from boosting the quality of education while keeping enrolment rates constant (Hanushek and Woessmann, 2012).

Policy changes in education have been the subject of many rigorous analyses in attempt to determine which interventions are effective at encouraging cognitive formation (see a survey in Glewwe, 2002). Numerous case studies further suggest a strong variation in terms of how schools achieve superior outcomes in terms of student performance (see Mourshed et al., 2010). Examples include strengthened teacher incentives (Glewwe et al, 2010, Lavy, 2002) or enhanced school resources (Glewwe et al, 2011). The impact of these measures may not always persist in the longer run (see Glewwe et al., 2010).

Cross-country differences in education policies (such as the use of centralised examinations across schools) have been shown to have a substantial impact on educational achievement and productivity (earnings) of graduates (see Hanushek and Woessmann, 2012, who focus on emigrants to the United States). Accountability systems and greater parental choice have also been shown to play a role (Hansushek and Woesmann, 2011). Local autonomy appears to be beneficial in countries with more developed institutions while its impact in countries with weaker institutions is ambiguous or negative (Hanushek et al., 2011). On the other hand, interventions boosting spending on education or the quality of physical infrastructure have been shown to have little causal impact on student performance (Hanushek, 1997, 2003; Hanushek and Woessmann, 2011; Glewwe et al., 2011).

In sum, while the literature establishes a number of best practices in terms of designing education systems, evidence on the way and the extent to which policy interventions can boost the quality of education at the country level is relatively scarce. It is based to a significant extent on the comparison of education systems across countries (Hanushek and Woessmann, 2012) – leaving open the question about the extent to which existing systems may reflect behaviours and cultural norms in a given society. A number of studies look at policy interventions affecting specific schools within countries (see, for instance, Hansushek and Woesmann, 2011) – leaving open the question whether these can be applied economy-wide with the same efficiency.

This paper complements these studies by evaluating the impact of system-wide education reforms in Estonia. In particular, it looks at the impact of education reforms in the 1990s on adult skills using the Programme for International Assessment of Adult Competencies (PIAAC) survey conducted by the Organization for Economic Cooperation and Development (OECD). When evaluating system-wide reforms it is usually difficult to obtain a plausible counterfactual – that is, estimate improvements in educational outcomes that may have occurred in the absence of reforms owing to demographic change, rising incomes or advances in health care (see Hanushek and Zhang (2009) for evidence of shifts in quality of education within countries). The case of Estonia offers such a plausible counterfactual. Our paper therefore, sits in between two approaches which have been widely employed to understand the relationship between improved education and skills. It offers a more general estimate that those provided by evaluations of school-specific interventions, but one with a more credible causal interpretation than might be offered by cross-country analyses.

Estonia implemented comprehensive reforms of secondary and higher education in the 1990s. These involved changes to curricula, student assessment and the retraining of teachers. National-level standards and examinations were combined with a high degree of decentralisation and school autonomy coupled with accountability measures such as school inspections, modelled to a large extent on Finland's approach.

The changes were initially implemented throughout Estonian-speaking schools while in Russian-speaking schools reforms were rolled out later and in a less comprehensive manner. A large minority of Estonia's population at the time studied in Russian-speaking schools. This provides an opportunity to measure the impact of education reforms on literacy, numeracy and problem-solving skills among adults surveyed in PIAAC by comparing

evolution of PIAAC scores by years of schooling separately for Estonian speakers and for Russian speakers.

Our difference-in-difference estimates suggest that the reforms lead to an improvement of around 15 per cent of a standard deviation in terms of adult skills. Estonia's experience is insightful for higher-income economies where enrolment ratios in secondary (and often tertiary) education tend to be high and teacher absenteeism is rare. The counterfactual in the case of Estonia's reforms is the Soviet education system in Estonia. The Soviet baseline is itself regarded as a strong education system (see, for instance, Ammermueller et al. (2015) and World Bank (2000)). Countries of the former Soviet Union tend to perform well in the PIAAC assessment of adult skills, on par with advanced economies and well ahead of Turkey and Chile.

The PIAAC survey also provides an opportunity to estimate the impact of improved test scores associated with systemic education reform on future earnings and, to the extent that earnings reflect productivity, on economy-wide outcomes. In this respect, our study is conceptually similar to Duflo (2001, 2004) who shows that greater provision of school infrastructure across Indonesia, by increasing individuals' years of education, boosted wages by approximately 7-11 per cent, or Hanushek and Woessmann (2012b) who relate incomes of immigrants to the school systems in their countries of origin.

Many simulations of the impact of improved education on economic activity assume that policy interventions can achieve certain improvement – such as implicitly raising student performance by up to one standard deviation (see, for instance, Hanushek and Woessmann, 2012). The current study puts the practical challenge of achieving such economy-wide gains into perspective. In particular, Estonia's comprehensive reforms are estimated to be associated with a 6 per cent increase in individuals' income based on regressions which instrument one's skills with the number of books at home at the age of 16.

The contribution of this paper is thus twofold. Firstly, we are able to show the long-term relationship between wide-ranging educational reforms which are aligned to broader pedagogical objectives and improved adult skills 10-20 years after the reforms. Secondly, we quantify the impact of skills enhancement on mid-career earnings and, by implication, on productivity. These impacts are sizable – yet modest in relation to what policy papers often assume to be feasible.

The rest of the paper is structured as follows. Section 2 describes Estonia's education reforms, both in terms of motivation and implementation. Section 3 discusses the empirical strategy and the data employed to evaluate the reforms. Section 4 presents the results, including ballpark estimates of welfare gains associated with the education reforms. Concluding remarks follow.

2. Education policies and skills: The case of Estonia

2.1. Estonia's education reforms

In 1992, Estonia adopted a law on education and embarked on a comprehensive reform of its education system, moving towards the model employed in Finland. Coincidentally, Estonia sought to adapt key features of Finland's education system well before the results of the first round of the Programme for International Student Assessment (PISA) of the Organization for Economic Cooperation and Development (OECD), conducted in 2000, which brought achievements of Finland's education system into the spotlight internationally (Simola, 2005).

Estonia's reforms, which spanned secondary and higher education and were rolled out over the period 1992-98, involved comprehensive changes to curricula, codified with the adoption of the National Curriculum in 1996 (the discussion of Estonia's reforms below is based on Lees, 2016, and OCED, 2001).

Following the adoption of the law on basic and upper-secondary schools in 1993, responsibility for secondary schooling has been devolved to municipalities and schools. Schoolmasters acquired autonomy in the area of personnel appointments and budget management. Teachers acquired substantial autonomy in terms of choosing study materials and evaluating progress outside the national examination cycle, they were encouraged to support creativity among students. Further amendments to the law clarified rules for school funding and supervision. Teachers and headmasters became subject to regular assessments.

Reforms also covered student assessment and the retraining of teachers. In particular, a high degree of decentralisation and school autonomy were accompanied by national-level standards and examinations and additional accountability measures such as school inspections, modelled to a large extent on Finland's reforms of the 1980s. In particular, an emphasis on trust embedded in Finland's model meant that teachers, in cooperation with parents, were given more independence to determine how best to educate students. National

level examinations and tests were conducted at the end of years 3, 6, 9 and 12 (the first nine years of secondary education are compulsory). The final examination also became a basis for admission to universities.

Average teacher salaries were raised to above the average national salaries. Young teachers received extra allowances conditional on an obligation to teach for a minimum of five years. Additional teacher training was supported by the Open Estonia foundation under its independent school programme launched in 1994. This mirrors Finland's greater emphasis on teacher education with a Master's degree set as a minimum requirement for teachers. There was also a substantial push to computerise education over 1992-98 although its results should perhaps not be overstated, with the ratio of 1 computer per 20 students achieved by 1998.

In sum, the reforms combined a number of structural shifts towards institutional features generally seen as desirable, at least in countries with more developed economic institutions. It is difficult to single out any part of the reforms – they can only be assessed as a package, the adoption of which also coincided with a wider progress in terms of the quality of economic institutions in Estonia, as reflected, for instance, in the Worldwide Governance Indicators of government effectiveness, regulatory quality, the rule of law and control of corruption (see Kaufmann et al., 2009).

Faster and more comprehensive reforms were carried out in Estonian-speaking schools, with a reform plan for private Russian-speaking schools not being put forward until much later, in 1998. The law allowed for substantial deviations from the reformed Estonian-speaking school system. A plan to provide all education in Estonian was approved in late 2007 (see Lees, 2016).

Major reforms of higher education started in 1995, with a switch from a five-year degree to a four-year Bachelors and a two-year masters and changes in curricula. External accreditation of higher education programmes was launched in 1997. The second wave of higher education reforms focusing on funding and curricula was launched much later, in 2013.

3. Estimating the impact of education reforms

3.1. Data

The analysis of the impact of Estonia's reforms draws on the PIAAC (Programme for International Assessment of Adult Competencies) surveys conducted in 2011-14 by the Organization for Economic Cooperation and Development (OECD) in 31 countries, primarily high-income OECD member countries as well as some middle-income comparator economies including Russia.

The surveys cover a representative sample of adults aged 16-65. In addition to assessments of skills (literacy, numeracy and problem solving) the survey included questions about people's backgrounds, education, employment and well-being.

The average skill levels observed in the PIAAC data are strongly correlated with the country-level measures of human capital (typically based on average years of education (see Barro and Lee, 2013) or average years of education adjusted for the results of tests conducted among students (see World Bank, 2018). Estonia performs strongly in the PIAAC surveys, consistent with its strong performance in PISA (OECD Programme for International Student Assessment), international tests for students aged 15-16 (OECD, 2018). At the time of the surveys, around 90 per cent of Estonia's adults had completed secondary education.

3.2. Estimation strategy

The strategy for identifying the causal impact of the reforms of the 1990s on the skills of Estonia's population relies on the distinction between Estonian native speakers educated in Estonian-speaking schools and Russian native speakers educated predominantly in Russian-speaking schools. The percentage of schools with Russian instruction in Estonia is relatively high and has been declining only gradually, from 32 per cent in 1996-97 to 27 per cent in 2000-01, based the data from the National Report of Estonia Education.

Approximately 800 Estonians participated in the PIAAC assessment, 27 per cent of whom were Russian speakers. Of those educated after 1998, around 17 per cent identified themselves as Russian speakers, consistent with the trends reported in the official data.

Estonian speakers and Russian speakers do not exhibit large differences in their background characteristics (see Table 1 summarizing descriptive statistics for the PIAAC sample and

Annex 1 for definitions of variables). If anything, Estonian speakers perform marginally better in the tests, making it, if anything, harder to achieve further improvements.

Table 1. Descriptive statistics for selected variables

	Baseline Balance										
	Estonian speaking					**Russian speaking**					
Variable	**N**	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**	**P-value**
Age	2490	52.63	7.53	35.00	65.00	1143	53.54	7.44	36.00	65.00	0.00
Books	2480	2.68	1.34	0.00	5.00	1134	2.37	1.36	0.00	5.00	0.00
Education	2482	1.22	0.68	0.00	2.00	1140	1.36	0.64	0.00	2.00	0.00
Father Education	2328	0.47	0.70	0.00	2.00	1050	0.67	0.76	0.00	2.00	0.00
Gender	2490	0.54	0.50	0.00	1.00	1143	0.59	0.49	0.00	1.00	0.00
Health	2488	1.50	0.93	0.00	4.00	1139	1.32	0.80	0.00	4.00	0.00
Mother Education	2440	0.47	0.66	0.00	2.00	1115	0.57	0.70	0.00	2.00	0.00
Normalised Literacy	2490	-0.16	0.96	-3.86	2.78	1143	-0.56	0.93	-3.77	1.99	0.00
Normalised Numeracy	2490	-0.16	0.97	-4.14	2.39	1143	-0.42	0.96	-4.04	2.37	0.00
Normalised Problem Solving	2490	-0.31	0.94	-3.95	2.67	1143	-0.54	0.89	-3.73	2.45	0.00

Note: Gender = 1 for females. Education measured on a scale of 0-2 where 1 = bachelor degree and 2 = master degree. Books measured on a scale of 0-5 where 1= 11-25 books, 2= 26-100 books, 3=101-200 books,4= 201-500 books, 5 = 500 books or more. Health is measured on a scale of 0-4 where 0 = Poor and 5 = Excellent.

Source: OECD PIAAC and authors' calculations.

In the analysis that follows we compare the performance of people who began studying after the implementation of education reforms with that of people who graduated before 1992 and also look at differences in dynamics seen for Estonian speakers (who were more exposed to reforms) and the Russian-speaking population. This difference-in-difference strategy delivers plausibly causal estimates of the skill dividend from these reforms. In the absence of such a counterfactual it may be difficult to distinguish between the impact of the reform package and general improvements in student performance over time referred to as the cohort effect (see also Hanushek and Zhang (2009) for evidence of changes in quality of schooling within countries).

3.3. Difference-in-difference specifications

The outcome variable of interest is an average PIAAC test score *y* of an individual *i* (individuals completed numeracy, literacy and problem solving tests). We are interested in the impact of an individual being subjected to an education reform even though we cannot

observe the same individual in the absence and in the presence of the reforms. We thus estimate the average treatment effect on the treated.

In this exercise, the Russian-language schools serve as a plausible counterfactual mimicking Estonian-language schools in the absence of reforms. In particular, we look at the differences between Estonian-language speakers educated before and after the reforms as well as the corresponding difference for Russian-language speakers.

This estimate also differences out the cohort and aging effects (whereby younger generations tend to perform better in the tests while performance tends to decline with age from the early 30s onwards; see Desjardin and Warnke (2012) and Skirbekk et al. (2013) for a discussion).

The difference-in-difference effect is estimated using the following specification:

$$y_{it} = \beta_0 + \beta_1 EstonianSpeaker_i + \beta_2 Reform_t + \beta_3 EstonianSpeaker_i * Reform_t + \gamma X_{it} + \varepsilon_{it} \quad (1)$$

where $EstonianSpeaker_i$ is a dummy which denotes whether the individual deems Estonian to be their native language, a good proxy for having been educated in an Estonian-language school. $Reform_t$ is a dummy which denotes whether the individual graduated after the reforms (that is, in 1999 or later). Control variables X_{it} include gender, level of education, immigration status, native language, parents' education, as well as the number of books at home at the age of 16.

We further estimate a difference-in-difference by employing a cohort variable to assess after how many years the treatment has an effect. Intuitively, we would expect the effect to be stronger under a stronger treatment. In this case, a stronger treatment is given by more post-reform education years.

$$y_{it} = \beta_0 + \beta_1 Cohort\ 1_i + \beta_2 Cohort\ 2_i + \beta_3 Cohort\ 3_i + \beta_4 Cohort\ 4_i + \beta_5 Reform_t + \beta_6 Cohort\ 1 * Reform_t + \beta_7 Cohort\ 2 * Reform_t + \beta_8 Cohort\ 3 * Reform_t + \beta_9 Cohort\ 4 * Reform_t + \gamma X_{it} + \varepsilon_{it} \quad (2)$$

To facilitate estimation in a limited, finite sample, we have grouped post-treatment individuals into four, three-year cohort groups. For each of these groups, a separate β will be estimated, in attempt to infer how the impact of the treatment varies according to treatment intensity.

The treatment in this natural experiment is necessarily broadly defined rather than being a specific intervention. The results can provide a useful estimate of what a comprehensive package of education reforms might achieve rather than an evaluation of a specific policy.

4. Results

4.1. Baseline results

The dependent variable in this analysis is the average test score across numeracy, literacy and problem solving. Table 2 displaying the partial correlation coefficients of conventional correlates of test score results confirms the expected patterns for Estonia, which are in line with those seen in the PIAAC survey in general.

Having a tertiary (university) degree is, predictably, associated with higher average skills when compared with respondents who have only completed secondary education or primary education (the latter being the baseline group covering 48 per cent of survey respondents). Scores tend to improve with age as survey participants gain extra years of training before declining in older age (specifications include age and age-squared to account for non-linear effects.

Other controls variables include gender, migration status of the respondent and their parents, mother's and father's level of education, being a native language speaker, the country of residence, voluntary engagement in civic organisations, self-reported measure of health and one's industry of employment. Notably, respondents who had a larger number of books at home at the age of 16 perform significantly better in tests of cognitive ability later in life.

Table 2. Correlates of test scores in PIAAC assessment

	Dependent variable:					
	Numeracy Estonia	Numeracy Other PIAAC	Literacy Estonia	Literacy Other PIAAC	Problem Solving Estonia	Problem Solving Other PIAAC
	(1)	(2)	(3)	(4)	(5)	(6)
Age	-0.054***	-0.008**	-0.056***	-0.026***	-0.080***	-0.009***
	(0.007)	(0.004)	(0.006)	(0.004)	(0.007)	(0.003)
Age^2	0.001***	0.00002	0.001***	0.0001***	0.001***	0.00000
	(0.0001)	(0.00004)	(0.0001)	(0.00004)	(0.0001)	(0.00003)
Mother Education	0.110***	0.079***	0.102***	0.095***	0.107***	0.090***
	(0.020)	(0.008)	(0.021)	(0.007)	(0.021)	(0.007)
Father Education	0.028*	0.079***	-0.003	0.076***	0.021	0.075***
	(0.016)	(0.005)	(0.016)	(0.005)	(0.017)	(0.005)
Childhood exposure to Books	0.151***	0.123***	0.150***	0.110***	0.132***	0.121***
	(0.010)	(0.003)	(0.009)	(0.003)	(0.010)	(0.003)
Health	0.054***	0.071***	0.061***	0.058***	0.068***	0.068***
	(0.012)	(0.004)	(0.013)	(0.003)	(0.013)	(0.003)
Cultural engagement	0.044***	0.056***	0.036***	0.052***	0.049***	0.051***
	(0.010)	(0.003)	(0.010)	(0.003)	(0.010)	(0.003)
Gender	-0.204***	-0.186***	-0.028	-0.078***	-0.053**	-0.033***
	(0.028)	(0.006)	(0.023)	(0.005)	(0.023)	(0.005)
Secondary	0.477***	0.430***	0.384***	0.400***	0.354***	0.389***
	(0.040)	(0.025)	(0.037)	(0.029)	(0.036)	(0.025)
University or higher	0.792***	0.784***	0.629***	0.709***	0.565***	0.731***
	(0.040)	(0.032)	(0.041)	(0.033)	(0.040)	(0.029)
Native Language Speaker	-0.031	0.300***	-0.028	0.316***	-0.094	0.317***
	(0.065)	(0.021)	(0.063)	(0.023)	(0.058)	(0.020)
Observations	7,011	138,767	7,011	138,767	7,011	138,767
R^2	0.291	0.415	0.266	0.403	0.300	0.398

Source: Authors' calculations.

Note: Standard errors in parentheses are clustered at the cohort level. *, **, *** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively. Regressions control for age, education, parents' education, exposure to books in youth, health, cultural engagement and employment sector fixed effects. Regressions for the larger PIAAC sample include country fixed effects. Other PIAAC refers to broad PIAAC sample excluding Estonia.

When these controls are included in the difference-in-difference regressions, the analysis shows that improvements in test scores following the implementation of reforms were indeed significantly larger among Estonian speakers, with the difference between Estonian speakers and non-Estonian speakers totalling 15 to 19 per cent of a standard deviation of test scores (see Table 3).

Table 3. Difference-in-difference estimates of the impact of reforms

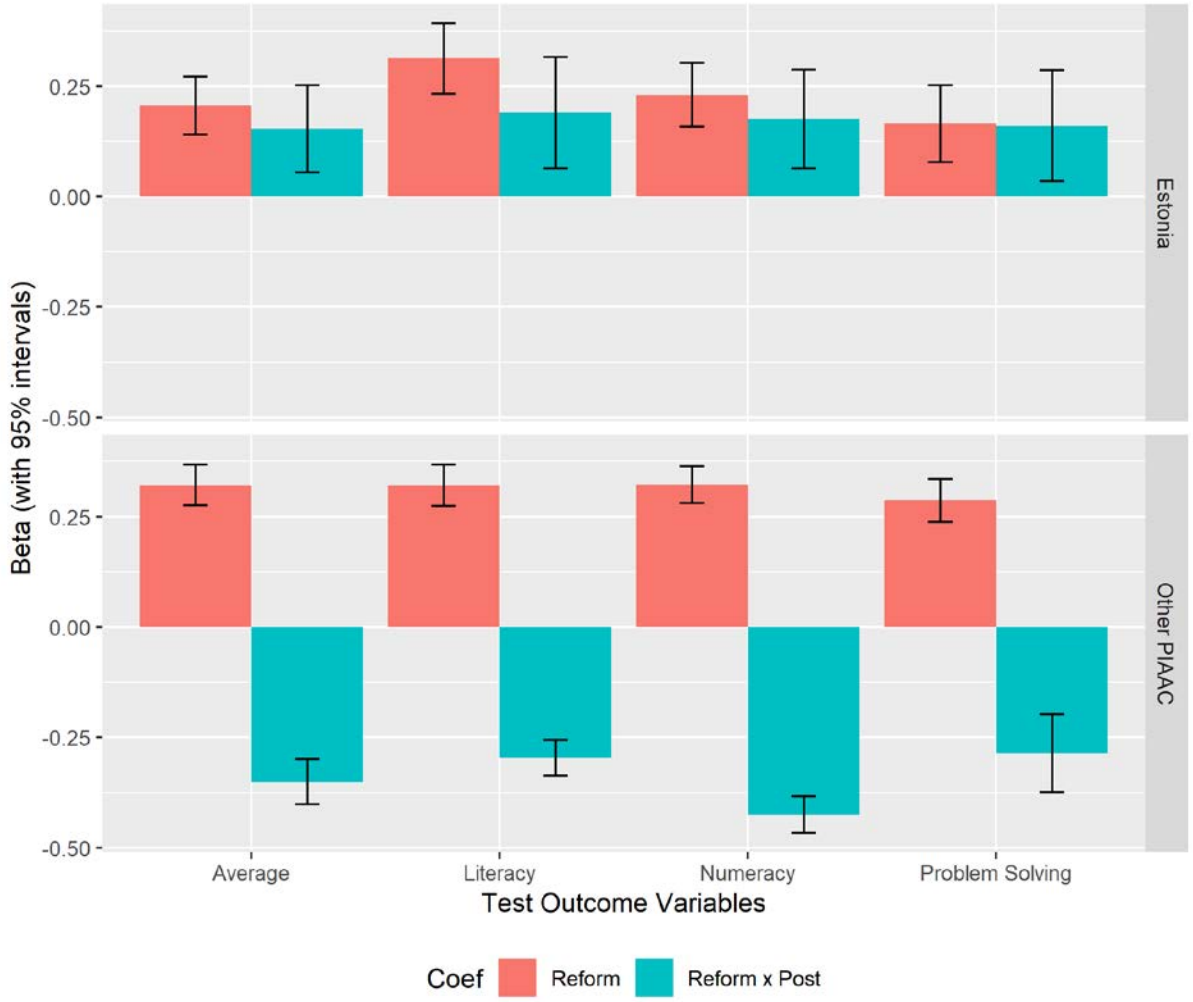
	Dependent variable:			
	Literacy Z-Score	Numeracy Z-Score	Problem Solving Z-Score	Generic Skill Z-Score
	(1)	(2)	(3)	(4)
Graduated after the Reforms	-0.118	-0.190	-0.076	-0.112
	(0.114)	(0.129)	(0.113)	(0.097)
Estonian Speaker	0.313***	0.231***	0.165***	0.206***
	(0.041)	(0.037)	(0.044)	(0.034)
Age	-0.054***	-0.064***	-0.081***	-0.058***
	(0.012)	(0.014)	(0.014)	(0.011)
Age^2	0.001***	0.001***	0.001***	0.001***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Grad Reforms x Estonian Speaker	0.190***	0.176***	0.161**	0.153***
	(0.064)	(0.057)	(0.064)	(0.051)
Observations	4,217	4,217	4,217	4,228
R^2	0.221	0.242	0.234	0.236

Source: Authors' calculations.

Note: Standard errors in parentheses are clustered at the cohort level. *, **, *** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively. Regressions control for age, education, parents' education, exposure to books in youth, health, cultural engagement and employment sector fixed effects.

That difference (depicted in Chart 1) is statistically significant at the 5 per cent level and can be attributed to the effect of Estonia's education reforms in the 1990s. Estonian speakers also tend to perform better than non-Estonian speaker, controlling for other characteristics, regardless of whether they were educated before or after the reforms.

Chart 1. Improvement in test scores associated with being educated after the education reforms



Source: PIAAC and authors' calculations.

Note: These estimates are based on difference-in-difference regressions of average skills on (i) a dummy variable for individuals educated after the reforms and (ii) an interaction term between that dummy variable and one for individuals speaking the national language. All specifications take account of gender, level of education, immigration status, native language, parents' education, the number of books at home at the age of 16 and other relevant characteristics. 95 per cent confidence intervals are shown for the estimates of marginal effects corresponding to the top portion of each bar.

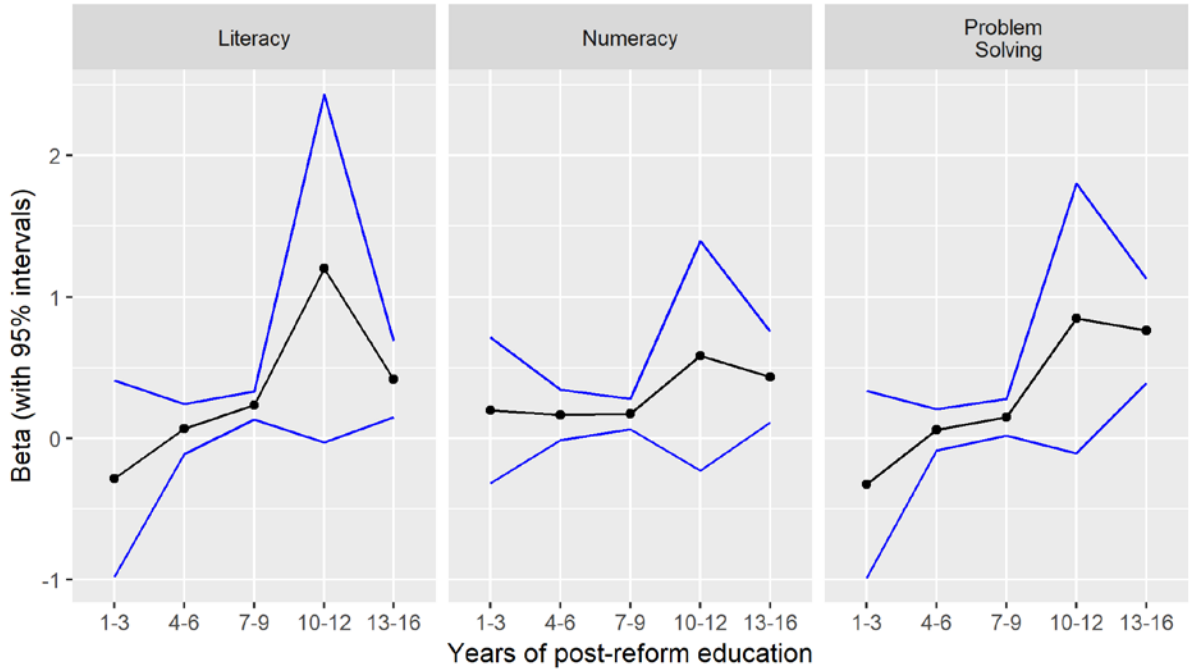
4.2. Cohort treatment estimations

We can also investigate the impact of reforms in a cohort-treatment framework looking at the years of exposure to the post-reform education system, although the sample size for each duration of treatment becomes relatively small. In this exercise, the treatment duration (the

number of years of education in the post-reform context) replaces the dummy variable for being educated after the reform.

As expected, the effect of education reforms on test performance of adults increases with the duration of treatment (Chart 2). The magnitude of the results is broadly consistent with that reported in Table 3 and Chart 1.

Chart 2. Difference-in-difference estimates (cohort treatment effect)



Source: Authors' calculations.

Note: Duration of exposure on the horizontal axis. The vertical axis shows the difference-in-difference coefficient on the treatment variable. The dependent variable in all regressions is the z-score of the PIAAC test-score. All regressions control for age, education, parents' education, exposure to books in youth, health, cultural engagement and employment sector fixed effects. The 95 per cent confidence intervals shown.

4.3. A placebo test

A concern remains, however, that the results may reflect national language speakers' inherently superior ability to improve their skills relative to speakers of other languages. For example, taking a PIAAC test in one's native language is associated with a statistically significant improvement in test scores (of around one third of a standard deviation in the cross-country PIAAC sample).

As a placebo test, the estimations run for Estonia have been repeated for the rest of the PIAAC sample where differences between the scores of national language speakers educated before 1992 and after 1998 are compared with those for non-national language speakers. This mimics "exposure" to Estonia's reforms for individuals educated outside Estonia.

Unlike in Estonia, the differential estimated for other countries is very small and not significantly different from zero in the statistical sense, or negative (see Table 4). This suggests that in other countries speaking a native language and being educated after a certain point in the 1990s was not an advantage when it comes to taking the PIAAC tests.

Table 4. A placebo test: The effects of "exposure" to Estonia's reforms outside Estonia

	Dependent variable:			
	Literacy Z-Score	Numeracy Z-Score	Problem Solving Z-Score	Generic Skill Z-Score
	(1)	(2)	(3)	(4)
Graduated after the Reforms	-0.195***	-0.203***	-0.317***	-0.246***
	(0.069)	(0.067)	(0.066)	(0.021)
Native language speaker	0.321***	0.323***	0.287***	0.322***
	(0.024)	(0.021)	(0.025)	(0.016)
Age	-0.030***	-0.030***	-0.052***	-0.039***
	(0.006)	(0.006)	(0.006)	(0.001)
Age^2	0.0002***	0.0002***	0.0004***	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.00002)
Grad Reforms x Native language speaker	-0.036	-0.071**	0.017	-0.032*
	(0.036)	(0.034)	(0.034)	(0.019)
Observations	86,555	86,555	86,555	86,555
R^2	0.389	0.418	0.408	0.421

Source: Authors' calculations.

Note: Standard errors in parentheses are clustered at the cohort level. *, **, *** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively. Regressions control for age, education, parents' education, exposure to books in youth, health, cultural engagement and employment sector fixed effects.

4.4. Discussion: quantifying the gains

How valuable are improvements in adult skills as measured by the PIAAC surveys? At an individual level, a better performance in PIAAC tests is associated with better socio-

economic outcomes: an increased likelihood of being employed, higher wages and greater job satisfaction (see OECD, 2013).

To quantify the benefits of systemic reforms crudely, one can regress the logarithm of wages of respondents in the PIAAC survey on their test scores and other characteristics such as age, gender or country of residence. In reality, the numeracy, literacy and problem-solving skills that are assessed in PIAAC tests may act as a useful – albeit imprecise – measure of the broader skill sets accumulated by adults, which in turn to a significant extent determine their income. The imprecise measurement of relevant skills may result in attenuation bias. A further bias may arise if the nature of individual's work determines both their pay and the ability of respondents to retain and develop further their basic cognitive skills.

To mitigate these concerns, the average PIAAC test score is instrumented with the number of books the respondent had at home at the age of 16. The number of books at home is a characteristic of the learning environment during childhood and thus a strong predictor of an individual's taste for learning and ability to acquire skills. Earlier analysis confirmed that it predicts performance in the adult tests of cognitive ability. On the other hand, it should not directly influence an individual's wage or other labour market outcomes, nor can it be influenced by an individual's nature of work. This measure also has a meaningful variation. For instance, the percentage of respondents who had at least 100 books at home at the age of 16 ranges from 2 per cent in Turkey to 34 per cent in Estonia.[1]

The wage premium associated with a one standard deviation improvement in test scores is estimated at around 50 per cent, or around 32 per cent if estimates are based on the global PIAAC sample (see Table 5). This is broadly in line with estimates of returns to schooling obtained in the earlier studies (see, for instance, Card and Krueger, 1992) and a notion that returns to schooling may be higher in fast-growing emerging market economies like Estonia's in the 2000s.

[1] The question about books at home is a multiple-choice question with various ranges of books.

Table 5. Regressions of wage on skills

	Dependent variable: Log Wage			
	OLS		IV	
	Estonia	Other	Estonia	Other
	(1)	(2)	(3)	(4)
Generic Skill	0.102***	0.109***	0.378***	0.306***
	(0.016)	(0.005)	(0.076)	(0.021)
Age	0.077***	0.108***	0.085***	0.111***
	(0.007)	(0.002)	(0.007)	(0.002)
Age^2	-0.001***	-0.001***	-0.001***	-0.001***
	(0.0001)	(0.00003)	(0.0001)	(0.00002)
Observations	4,021	69,455	4,021	69,455
R^2	0.271	0.342	0.218	0.225

Note: Standard errors in parentheses are clustered at the cohort level. *, **, *** denote statistical significance at the 10 per cent, 5 per cent and 1 per cent levels, respectively. Regressions control for age, the level of education, parents' education, health, cultural engagement and employment sector fixed effects. The number of books at home at the age of five is used as an IV for skills.

These estimates suggest that Estonian reforms boosted wages (and, by implication, labour productivity) by around 6 per cent (the reforms are estimated to have improved skills by around 15 per cent of a standard deviation) for those that attended the reformed schooling system.

5. Conclusion

This paper investigated the impact of education reforms in Estonia in the 1990s on adult skills using PIAAC survey conducted by the OECD. Estonia implemented comprehensive education reforms in the early 1990s throughout Estonian-speaking schools while in Russian-speaking schools less comprehensive reforms were rolled out later. Between three-quarters and two-thirds of Estonia's population over the reform period went through Estonian speaking schools while the other one-third to one quarter went through Russian-speaking schools providing an opportunity to measure the impact of the reforms on literacy, numeracy and problem-solving skills among adults. Difference-in-difference estimation suggests that being educated after the reforms is associated with an improvement of 15 per cent of a standard deviation in terms of adult skills and a gain of around 6 per cent in terms of income (and, implicitly, productivity) for those that attended the reformed schooling system.

This is broadly consistent with the assumptions of simulations in Hanushek and Woessmann,(2012), for instance, where an improvement of half a standard deviation in test scores is assumed to lift average annual GDP growth by close to 0.9 of a percentage point per annum. It also highlights, however, that such an underlying improvement in average test scores is hard to achieve – even with the scale of reforms that have been implemented in Estonia. This, in turn, suggests that improvements in health and living conditions may be needed to underpin significantly better learning outcomes across the board (through, for instance, better memory).

Importantly, the effects of comprehensive structural reforms to education system appear to persist far into adulthood (the impact is measured by analysing literacy, numeracy and problem solving tests administered to adults). This is consistent with earlier findings on the importance of early learning for life-cycle skills formation (see, for instance, Cunha et al., 2006).

Annex I: Definition of variables

Variable	Definition
Age	Age of individual at the time of the PIAAC survey
Books	The number of books at home of the surveyed individual at the age of 16. 1= 11-25 books, 2= 26-100 books, 3=101-200 books,4= 201-500 books, 5 = 500 books or more
Education	Education of the surveyed individual at the time of the survey. 0 = No bachelor/master, 1 = bachelor, 2 = master.
Parents' Education	As described above, for the surveyed individual's parents.
Gender	Gender of the surveyed individual. 1 for females, 0 for males.
Normalised Literacy	The participants score on the PIAAC literacy assessment. The variables are normalised for the full sample of Estonian respondents, with mean 0 and standard deviation 1.
Normalised Numeracy	The participants score on the PIAAC numeracy assessment. The variables are normalised for the full sample of Estonian respondents, with mean 0 and standard deviation 1.
Normalised Problem Solving	The participants score on the PIAAC problem solving assessment. The variables are normalised for the full sample of Estonian respondents, with mean 0 and standard deviation 1.
Health	Self-assessed health of the respondent with values: 0- Poor, 1 – Fair, 2 – Good, 3 – Very good, 4 – Excellent.
Cultural Engagement	The frequency of voluntary work. 0 – Never, 1 – Less than once a month, 2- Less than once a week but at least once a month, 3 – At least once a week but not every day, 4 – Every day
Secondary	A dummy which indicates if the individual's attainment level of education is secondary level schooling. 0 – No secondary education, 1 – secondary education.
University or higher	A dummy which indicates if the individual's attainment level of education is university level education or higher (ex PhD). 0 – No University (or higher) level of education, 1 – University level (or higher) level of education
Native Language Speaker	A dummy which indicates if the survey respondent is a native language speaker. 0 – non-native language speaker, 1 – native language speaker
Estonian Speaker	A dummy which indicates if the individual is a native Estonian language speaker. Used as a proxy for Estonian schooling. In specification 1, Estonian language is used as a proxy for Estonian schooling. 0 – Russian speaker, 1 – Estonian speaker.
Reform	Survey respondent was educated after the Estonian education reforms. 0 – Respondent was educated before the reforms, 1 – respondent was educated after the reforms.

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