Compare: A Journal of Comparative and International Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ccom20

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Published online: 16 Dec 2013.

Compare, 2013
http://dx.doi.org/10.1080/03057925.2013.855002

Routledge
Taylor & Francis Group

Using TIMSS and PISA results to inform educational policy: a study of Russia and its neighbours

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In this paper, we develop a multi-level comparative approach to analyse Trends in International Mathematics and Science Survey (TIMSS) and Programme of International Student Achievement (PISA) mathematics results for a country, Russia, where the two tests provide contradictory information about students' relative performance. Russian students do relatively well on the TIMSS mathematics test but relatively poorly on the PISA. We compare the performance of Russian students with different levels of family academic resources over the past decade on these tests compared to students with similar family resources in Russia's neighbours and to Russian students studying in Latvian and Estonian Russian-medium schools. These comparisons and interviews with educators in Latvia and Estonia help us understand why students in Russia may perform lower on the PISA and to draw education policy lessons for improving international test performance generally and Russian students' PISA mathematics performance specifically.

Keywords: international tests; family academic resources; mathematics achievement; educational policy; natural experiment

International tests such as the Trends in International Mathematics and Science Survey (TIMSS) and particularly the Programme of International Student Achievement (PISA) are increasingly used to influence educational policy on a global scale and to recommend educational reforms (Schmidt, McKnight, and Raizen 1997; McKinsey and Company 2010; OECD 2010a, 2011; Sahlberg 2011). Yet, TIMSS and PISA differ in their objectives and the kinds of skills they measure. Briefly, TIMSS is designed to measure how well students have learned cognitive skills taught in school by the 4th and 8th grades, and PISA, how well 15-year-olds still in school can apply such taught skills to practical, real-life situations and problems (Scott 2004; Gronmo and Olsen 2006). The TIMSS and PISA tests may therefore produce different results and trends over time in mathematics and science

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for students in the same country. Such mixed results, where they occur, send conflicting messages to policy makers (Carnoy and Rothstein 2013).[1]

In this paper, we develop a multi-level comparative approach that analyses PISA and TIMSS mathematics results for a country where the two tests provide contradictory information about students' relative performance. Our focus is on Russia, where students do relatively well on the TIMSS mathematics test but not on the PISA, and which has had a good reputation in teaching students mathematics. We attempt to understand why Russian students do not score well on the PISA and use the results of our analysis to draw some tentative educational policy lessons. Our methodology combines descriptive cross-country empirical data on test results for students categorised by family academic resources, with qualitative analysis based on interviews with education policy makers and school officials.

In the first level of comparison in our multi-level approach, we describe how students with higher and lower levels of family academic resources in Russia have performed on the PISA mathematics test in 2000–2009 compared to students of similar family academic resource in a set of neighbouring former-Communist countries and some Western European countries with social democratic traditions. The comparison 'corrects' for possible differences in the family resource composition of the PISA student samples in each country (Carnoy and Rothstein 2013). Although far from a measure of comparative school effectiveness, it provides a more meaningful comparison of schooling's impact than overall average country scores. The comparison countries are the Czech Republic, Hungary, Poland, Estonia, Latvia, Lithuania, Sweden, Finland and Germany.[2]

Our second level of comparison is of students' results in various countries on the PISA mathematics test and the 8th grade TIMSS. This comparison shows the mixed messages given by results on different international tests. We first compare Russian students' TIMSS 2011 results in mathematics for each family academic resource group with the results for similar students in the Czech Republic, Estonia, Finland, Hungary, Latvia, Lithuania and Sweden. In the second stage, we compare the gains that Russian, Czech, Finnish and Hungarian students in each family academic resource group have made in the TIMSS mathematics test in 1999–2007/2011 with their gains on the PISA mathematics test in a similar period. These are the only countries in our comparison group that took both TIMSS and PISA in 1999–2000 and in 2007/2011–2006/2009.

Our third level of comparison is of a 'natural experiment'.[3] We compare the PISA maths results for Russian students in Russia with Russian-language students attending Russian-language schools in Latvia and Estonia.[4] Thus, we compare the maths performance of Russian students attending Russian-medium schools under different national educational policy conditions. We find different patterns in the results for Russian-language students in the three countries when compared with each other and their Latvian and Estonian-language counterparts.

To explain these patterns, we interviewed educators and testing agency administrators in Latvia, Estonia and Russia. The interviews produced important insights into why Russian students' results may be lower on the PISA than the TIMSS and what this implies for policy makers trying to improve student learning as measured by these tests.

The argument for comparing test scores by students' family academic resources

Our multi-level approach compares students with similar family academic resources across countries. Many studies have shown that various proxy measures of students' family academic resources, such as mother's education, parents' education and books or articles in the home, are correlated with students' academic achievement (for example, for the USA: Coleman 1966; Jencks and Phillips 1998; for the UK: Peaker 1971; for PISA: see Buchmann 2002; Schulz 2006; Adamson 2010; for TIMSS: see Raudenbush, Cheong, and Fotiu 1996; Woessmann 2004; Chudgar, Luschei, and Fagioli 2012; for a meta-analysis across different types of tests: see Sirin 2005; Evans et al. 2010; for Russia and Eastern Europe: see Caro and Mirazchiyski 2012; Martins and Veiga 2010).

There are many reasons why a student's family academic environment could be an important factor in his or her cognitive (and non-cognitive) achievement. Students raised in a family in which reading materials are readily available and where a parent or parents have attained higher levels of schooling are more likely to be exposed to more complex verbal interaction (Bryce Heath 1983), to have been read to as a young child, to have had access to better healthcare and a more nutritious diet (regardless of income), to be subject to higher academic expectations once in school and to interact with peers from similarly reading-oriented, verbal, higher academic expectation families. Whether such family 'investments' during early childhood and during school are considered cultural capital (Bourdieu and Passeron 1970), human capital (Schultz 1961) or social capital (Coleman 1988), the concept is the same: family environment is influential in how well a student achieves in school. Beyond this direct influence, families with more academic resources at home may be more motivated to send their children to schools with more academically motivated students and engage tutors outside school (Bray 2006).

If students tested in various countries live, on average, in family environments that differ considerably, comparisons of *average* student performance could incorrectly attribute outcomes to educational policies when they may be the result of differing outside-of-school influences. Furthermore, educational policies may affect students from different environments differently. By comparing the academic performance of students in *particular* family and social environments over time, we can better understand the nuances of educational policies in various countries. Such comparisons are the core of our analysis in this study.

Which proxies should be used for measuring family academic resources? There is no precise way to make such comparisons between countries. The PISA and TIMSS collect data on many characteristics that are arguably related to family resources. The PISA also assembles them into an overall index. Although none of the possible indicators of family resource differences is entirely satisfactory, we use the number of books in the home (BH) for our analysis. A very high proportion of students in both the PISA and TIMSS surveys answer the BH question, something less true for other important family academic resource indicator questions asked on the student questionnaires.

We also test statistically to see whether other indicators, such as mother's education, articles in the home or PISA's overall social class (ESCS) index, in addition to BH, would produce a meaningfully different analysis by family resource groups, and determine that they would not. We conclude that BH can serve as a reasonable representation of home influences on students' academic performance. We have made a detailed analysis of the additional effect that mother's education, parents' highest education and the PISA ESCS index have on PISA scores when we add them to the BH categories we use in our analysis. This analysis is available on request.

Comparing PISA 2009 performance

We disaggregate scores in Russia and in nine comparison countries by the six BH categories from the PISA student questionnaire representing six family academic resource groups, from the least to the most advantaged (Groups 1 to 6). We refer to Groups 1 and 2 together as disadvantaged students, to Groups 3 and 4 together as middle advantaged students and to Groups 5 and 6 together as advantaged students (Table 1).

In Table 1, the standard error of each mean score is shown in parentheses beneath the scores. The errors vary because the sizes of the samples for each group can be considerably different. In comparing whether one group's mean score is statistically significantly larger or smaller than another group's score, we use a typical rule of thumb of two standard errors. However, a much larger difference of, say, four standard errors (about 15–25 points, or 0.15–0.25 standard deviations) may be considered 'substantially better', enough to warrant a policy intervention.[5]

Russian students in the lowest BH category perform 'substantially better' than Hungarian students, about the same as students in Lithuania, the Czech Republic and Sweden, worse than in Latvia, Poland and Germany and substantially worse than Estonian and Finnish students. In Group 2, Russian

Table 1. PISA 2009, Mathematics scale scores by family academic resource group for Russia and comparison countries.

	Mathematics									
Family academic-resource group	Russia	Latvia	Lithuania	Estonia	Poland	Czech Rep.	Hungary	Sweden	Germany	Finland
Group 1 (lowest)	423	437	425	470	440	424	370	423	433	490
	(5.6)	(6.8)	(5.0)	(7.1)	(4.2)	(5.0)	(7.5)	(6.0)	(5.2)	(6.0)
Group 2	443	445	445	483	457	451	439	442	466	507
	(3.4)	(4.4)	(3.5)	(4.3)	(3.6)	(3.9)	(4.2)	(5.4)	(4.6)	(4.3)
Group 3	459	479	485	503	492	483	478	480	509	528
	(3.6)	(3.2)	(3.4)	(2.9)	(2.8)	(3.0)	(3.4)	(2.6)	(3.5)	(2.7)
Group 4	488	495	506	520	521	518	508	499	535	552
	(4.8)	(4.4)	(3.9)	(3.1)	(3.5)	(3.6)	(3.3)	(3.8)	(3.8)	(2.6)
Group 5	506	522	526	536	544	543	533	539	571	570
	(4.7)	(4.3)	(5.0)	(3.8)	(5.5)	(3.9)	(4.0)	(3.6)	(3.7)	(3.0)
Group 6 (highest)	502	511	521	549	559	548	557	542	570	580
	(8.5)	(7.3)	(6.3)	(6.1)	(5.8)	(6.7)	(6.6)	(5.9)	(6.5)	(5.9)
Gap (Group 6 – Group 1)	79	74	96	79	120	123	188	119	137	90
Gap (Group 5 – Group 2)	63	77	81	53	87	92	94	97	105	63
National average Maths score	468	482	477	512	495	493	490	494	513	541
	(5.1)	(5.1)	(4.5)	(4.6)	(4.2)	(4.3)	(4.8)	(4.6)	(4.6)	(4.1)
National average Maths score, adjusted for Russian weights	468	480	485	507	499	491	481	484	512	535

Note: Numbers in brackets are standard errors.

students score about the same as students in Latvia, Lithuania, Hungary and Sweden, but worse or substantially worse than students in Poland, the Czech Republic, Germany, Estonia and Finland. In the middle and higher family resource groups, Russian students generally achieve substantially lower average scores in mathematics than students score in the comparison countries.

Table 1 also shows that in every country, students from more advantaged family resource groups outperform students from less advantaged family resource groups. The test score gradient (commonly referred to as the 'achievement gap') is measured in two ways: the gap in average scores between students in Group 1 and students in Group 6, and the gap in average scores between students in Group 2 and students in Group 5. The achievement gaps measured either way are generally large (one standard deviation or more for Group 1–6) except in Russia, Latvia, Estonia and Finland. Lower gaps in scores between students with high and low family resources may be the result of many factors, possibly including a consciously more homogeneous treatment of students (less tracking).[6] In that sense, even if Russian students are not doing particularly well on the PISA test, the educational system may be achieving a different goal, that of more equal outcomes. Yet, for our purposes, the salient point is that the smaller gaps in Estonia and Finland on the PISA are mainly the result of high scores of students in the most disadvantaged groups, but in Russia, the small gap is mainly the result of relatively low scores for *advantaged students*. Without trying to speculate on why achievement gaps are high or low, in this study we are interested in the possible reasons for Russia's advantaged students performing so much lower on the PISA compared to students in other countries. In contrast, Russia's disadvantaged students perform similarly compared to disadvantaged students in a number of other countries.

In Table 1, the bottom two rows of each subject comparison show the average score of students in each of the nine countries and the score if students taking the test in each country were to have the same social class distribution as in the Russian sample. Overall, Russian average scores remain below or substantially below the average maths performance of students in our comparison countries, even when corrected for compositional differences in the samples.

PISA trends from 2000 to 2009

For policy purposes, we want to know not only in which countries adolescents perform at a higher level than in other countries, but also whether there are socioeconomic factors or educational policies and practices that are influencing a country's performance to improve or deteriorate it.

The PISA test has been administered every three years since 2000, providing an opportunity to estimate changes in PISA mathematics scores over time. By observing such changes, we can assess how Russian academically disadvantaged and advantaged students increased their performance compared to students in seven of the nine comparison countries (Lithuania and Estonia were omitted since they did not participate in PISA 2000).[7] As in the previous section of the paper, we make our estimates by family academic resource group, because changes over time in the composition of a country's test takers by books in the home (or other measures of family resources) can affect a country's average score while masking real changes (or lack of change) in the performance of that country's students.

We have to make some adjustments to compare scores by family resource group in 2000–2009 because the BH categories used in the 2000 survey differ from the categories in subsequent surveys (2003, 2006 and 2009).[8] In the 2000 survey, the BH categories on the student questionnaire were 0, 1–10, 11–50, 51–100, 101–251, 251–500 and more than 500 books in the home. In subsequent years the student questionnaire changed the categories to 0–10, 11–25, 26–100, 101–200, 201–500 and more than 500 books in the home.[9]

Table 2 shows the trends in 2000–2009 for Russia by BH categories compared to the seven comparison countries. The paths by which performance changed from 2000 to 2009 varied by country, so an investigation of why these 2000 to 2009 changes occurred in specific countries should also examine scores disaggregated by changes for three-year periods, which we have estimated and can provide on request.

Russian students in the lowest two BH groups made significant gains in mathematics in 2000–2009. These gains were similar to or larger than gains in the same group in Hungary, Sweden and Finland but smaller than those in Latvia, the Czech Republic and Germany. In the highest two BH groups (5 and 6), Russian students' scores declined substantially more compared to Group 5 and 6 students in all our comparison countries except Sweden. Russian students in Groups 5 and 6 in 2000 were already scoring lower than students in all but Latvia and Poland; thus, advantaged Russian students' PISA mathematics scores fell significantly from levels in 2000 that were already below advantaged students' scores in all but two of the comparison countries.

This analysis suggests that Russia's continued poor showing in PISA's mathematics test is 'located' largely in the academic-resource advantaged Russian student population, for whom test scores have remained lower and stagnant relative to similarly advantaged students' performance in almost all our comparison countries.[10]

An interesting element in the large increase in the Latvian scores is that a high percentage of students (about 20%) in Latvia speak Russian at home and attend Russian-language schools. This is also the case in Estonia, which

Table 2. PISA 2000–2009. Gains in Mathematics scale scores, by family academic resource groups, Russia and comparison countries.

	Mathematics							
Social class groups	Russia	Latvia	Poland	Czech Republic	Hungary	Sweden	Germany	Finland
Group 1 (lowest)	16	42	23	40	−20	−18	52	−17
Group 2	11	38	15	38	28	−16	49	−11
Group 3	2	46	27	15	25	−11	38	1
Group 4	−4	19	33	10	15	−14	28	3
Group 5	−9	29	34	6	9	−2	30	11
Group 6 (highest)	−10	24	45	17	14	−1	20	15
Average score	−10	19	25	−5	2	−16	23	4

Source: Authors' calculations from PISA 2000 and 2009 databases.

began taking the PISA test only in 2006 and averaged much higher than Russia and Latvia in both 2006 and 2009 in all family academic-resource groups. We return to this issue once we compare PISA and TIMSS results for Russia and our comparison countries.

Comparing PISA and TIMSS results

In this section, we focus on students' TIMSS mathematics performance across countries and show that it provides a different picture than PISA's mathematics assessment, particularly for Russian students but also for several other countries' students. We first compare TIMSS mathematics results by family academic resource groups for Russia to the results for Latvia, Lithuania, Estonia, the Czech Republic, Finland, Hungary and Sweden in the latest year each of these countries participated in the test. The TIMSS designates five categories for books in the home in its student questionnaire. They are the same as in the PISA 2003–2009 except for the highest category, more than 200 books, which represents the highest two categories in the PISA questionnaire.

In the second stage of our analysis, we compare the changes in the TIMSS results for Russia, the Czech Republic, Finland and Hungary by family academic resource groups in 1999–2011 to PISA results in those countries in roughly the same period. These are the only countries for which we can compare TIMSS and PISA results for this longer period of time.

A challenge to interpreting international test performance arises because not all countries participate in both PISA and TIMSS. Russia has participated in all PISA assessments, 2000–2009, and in all four eighth grade TIMSS, 1999–2011.[11] Of our nine possible comparison countries, only Lithuania and Hungary participated in the TIMSS in all of these years. The Czech Republic participated in the 1999 and 2007 TIMSS, and Finland participated in the 1999 and 2011 TIMSS. Lithuania, however, did not participate in the 2000 and 2003 PISA.

Latvia participated in TIMSS in 1999 and in 2003, but not in 2007 or 2011. In 1999, only Latvian-speaking students were included in the sample and in 2003, both Russian- and Latvian-speaking students were sampled. Estonia participated only in the TIMSS 2003 test. It did particularly well, but then shifted to participating in the PISA test.

Comparing TIMSS results

Disadvantaged (Groups 1 and 2) Russian students consistently scored as high or higher on the TIMSS mathematics test in 1999–2007 as disadvantaged students in all our comparison countries, and this is reflected in the results for the latest TIMSS tests in which these countries participated

Table 3. TIMSS 2003, 2007 and 2011: average test scores by family academic-resource groups and by country, latest year country participated.

Family academic-resource group	Russia 2011	Latvia 2003	Lithuania 2011	Estonia 2003	Czech Rep. 2007	Hungary 2011	Sweden 2011	Finland 2011
Group 1 (lowest)	499	453	444	476	451	406	438	465
	(7.3)	(8.2)	(4.9)	(6.7)	(5.5)	(6.5)	(3.8)	(5.2)
Group 2	517	480	486	503	469	462	460	493
	(5.2)	(5.6)	(2.6)	(4.4)	(3.4)	(3.9)	(2.2)	(3.6)
Group 3	541	505	516	(515	506	513	486	514
	(3.5)	(3.3)	(2.9)	(3.5)	(2.4)	(3.4)	(2.2)	(2.5)
Group 4	560	515	532	534	527	538	503	530
	(4.2)	(4.2)	(4.0)	(3.6)	(3.2)	(3.6)	(2.7)	(3.2)
Group 5 (highest)	568	528	545	549	543	555	513	535
	(5.0)	(4.3)	(6.0)	(3.3)	(4.3)	(3.6)	(3.2)	(3.8)
National average	539	508	502	531	504	505	484	514
	(5.0)	(5.1)	(4.1)	(4.3)	(3.8)	(4.2)	(2.8)	(3.7)
Average, Russian weights	539	507	510	524	506	502	483	511

Notes: Numbers in brackets are standard errors. The average score using Russian BH group weights is estimated using the weights of the relevant test year.
Source: Authors' calculations from TIMSS 2003, 2007 and 2011 databases.

(Table 3). By 2011, Russian students in all family resource groups scored higher or substantially higher than in all comparison countries, including Finland, where students took the test for the first time since 1999 (Table 3).[12] Overall, then, Russian students have performed comparatively well on the TIMSS mathematics test, both in terms of average national score and comparing students by family academic resource group.

Comparing TIMSS and PISA, 1999–2000 with 2007 and 2009

Table 4a compares results for Russia, the Czech Republic, and Hungary, using TIMSS 1999, PISA 2000, TIMSS 2007 and a weighted average of PISA mathematics results for 2006 and 2009.[13] We refer to this average as PISA '2007'. Based on the 2003–2009 categories, which we also impose on the PISA 2000 by interpolating test scores, PISA reports BH for six social class groups, whereas TIMSS reports only five, as we reported earlier. Groups 1–4 have identical definitions in the two tests, but TIMSS collapses PISA's two advantaged social class groups into a single top group of 200 or more books in the home, so in this Table, PISA scores for social class Groups 5 and 6 are averaged using the sample proportions in PISA family academic resource Groups 5 and 6 to create a result comparable to TIMSS Group 5.

By focusing on trends, however, we can see from Table 4a that patterns for the Czech Republic and Hungary in TIMSS and PISA are *dissimilar* across all groups, and in Russia they are dissimilar for most groups.[14]

Table 4b compares results for Russia, Finland and Hungary, using TIMSS 1999, PISA 2000, 2009 and an average of TIMSS 2007 and TIMSS 2011. We refer to this average as TIMSS '2009'. Since Finland took the TIMSS test in 2011 and the Czech Republic did not, we include the former and exclude the latter. Finland shows declines in scores for disadvantaged students in both TIMSS and PISA in the 10 years and Hungary generally shows opposite tendencies on the two tests. The biggest change between Tables 4a and 4b is in Russia, where disadvantaged Russian students made very large gains on both tests in the past decade and advantaged students' scores made no gain or declined.

The last columns of Table 4a and 4b emphasise that in Finland and Russia there is more agreement between TIMSS and PISA on students' mathematics performance trends, but in the Czech Republic and Hungary there is no agreement over roughly the same time period. We cannot explain why changes in scores would have diverged so much on these two tests across a wide range of family academic resource groups in two countries and conformed more closely in the other two.

Table 4a. Mathematics score comparisons, Czech Republic, Hungary and Russia, eighth grade TIMSS and 15-year-old PISA, 1999/2000–2007.

Social class groups	TIMSS 1999	TIMSS 2007	Change (scale points)	PISA 2000	PISA '2007'	Change (scale points)	TIMSS-PISA rough agreement?
Czech Republic							
Group 1 (lowest)	448	451	3	384	417	33	No
Group 2	472	469	−3	414	452	38	No
Group 3	506	506	0	468	492	23	No
Group 4	532	527	−5	501	525	24	No
Group 5/6 (higher/ highest)	539	543	4	533	553	20	No
National average	520	504	−16	498	504	6	No
Hungary							
Group 1 (lowest)	429	431	2	390	398	9	No
Group 2	467	469	2	412	432	20	No
Group 3	513	510	−3	453	473	20	No
Group 4	548	538	−10	485	499	14	No
Group 5/6 (higher/ highest)	564	560	−4	530	543	13	No
National average	532	517	−15	488	491	3	No
Russia							
Group 1 (lowest)	460	467	7	407	428	22	No
Group 2	485	484	−1	432	444	12	No
Group 3	517	511	−6	457	464	7	Yes
Group 4	539	533	−6	484	491	7	Yes
Group 5/6 (higher/ highest)	556	540	−16	512	509	−3	No
National average	526	512	−14	478	473	−5	No

Source: Authors' calculations from TIMSS 1999 and 2007 databases and from PISA 2000, 2006 and 2009 databases.

The PISA performance of Russian-language students in Russian-medium schools in Latvia, Estonia, and Russia

Our analysis has shown that the relative level of mathematics performance for Russian students in the PISA and TIMSS tests differs substantially. We now turn to possible reasons for their much lower performance on the PISA test, particularly for more academically advantaged students. To make that

Table 4b. Mathematics score comparisons, Finland, Hungary and Russia, eighth grade TIMSS and 15-year-old PISA, 1999/2000–2009.

Social class groups	TIMSS 1999	TIMSS '2009'	Change (scale points)	PISA 2000	PISA 2009	Change (scale points)	TIMSS-PISA rough agreement?
Finland							
Group 1 (lowest)	483	468	−15	507	490	−17	Yes
Group 2	492	493	1	518	507	−11	No
Group 3	521	515	−6	527	528	1	Yes
Group 4	527	529	2	544	552	8	Yes
Group 5/6 (higher/ highest)	538	536	−2	560	572	12	No
National average	520	515	−5	536	541	5	No
Hungary							
Group 1 (lowest)	429	419	−11	390	370	−20	No
Group 2	467	466	−2	412	439	28	No
Group 3	513	512	−2	453	478	25	No
Group 4	548	538	−10	485	508	23	No
Group 5/6 (higher/ highest)	564	558	−7	530	544	14	No
National average	532	511	−21	488	490	2	No
Russia							
Group 1 (lowest)	460	483	23	407	423	16	Yes
Group 2	485	501	16	432	443	11	Yes
Group 3	517	526	9	457	459	2	Yes
Group 4	539	547	8	484	488	4	Yes
Group 5/6 (higher/ highest)	556	554	−2	512	505	−8	Yes
National average	526	526	−1	478	468	−10	No

Source: Authors' calculations from TIMSS 1999, 2007 and 2011 databases and from PISA 2000 and 2009 databases.

analysis, we compare the PISA results for Russian students living in Russian-speaking families and attending Russian-language schools in Russia, Latvia and Estonia and the different sets of curricular and teacher preparation policies that provided that context for their schooling. Russian-language schools (including their mathematics curriculum) in Latvia and Estonia are under the jurisdiction of the Latvian and Estonian education systems but employ teachers originally trained in the Russian teacher training system and vary in their adherence to their respective national curricula.

Table 5. PISA 2003–2009. Mathematics scale score, Russians in Russian schools, Russians in Latvian Russian-medium schools and Latvians in Latvian-medium schools, by family academic resources.

Group	2003	2006	2009
Advantaged Russians in Russia	502	511	505
Advantaged Russians in Latvian Russian-medium schools	508	521	527
Advantaged Latvians in Latvian schools	519	524	518
Disadvantaged Russians in Russia	424	440	437
Disadvantaged Russians in Latvian Russian-medium schools	426	432	435
Disadvantaged Latvians in Latvian schools	437	447	445

Source: Authors' calculations from PISA 2003, 2006 and 2009 databases.

Table 5 shows the results of estimating PISA mathematics test scores for Russian students in Russia and in Russian-language schools in Latvia in the period 2003 to 2009. We were unable to estimate scores for Latvian Russian and Latvian-language students in 2000 because PISA 2000 did not identify students by the language of the school they attended.[15] The data in Table 5 suggest that advantaged academic-resource students in Latvia attending Russian-language schools scored much higher in mathematics than their counterparts in Russia, and by 2009 also surpassed their academically advantaged Latvian counterparts in Latvian-medium schools. Disadvantaged Russian students in both Russia and Latvia made gains in 2003–2009, but continued to score lower than Latvian students in Latvian-language schools.

Estonian-speaking students scored higher on both the TIMSS and the PISA than Latvians and Russians. The Estonian average (including Russian-speaking students) on the only TIMSS test Estonians took (2003) was 531 in the mathematics portion. There was a large difference in the performance of students in Estonian- and Russian-medium schools (536 versus 523). So Russian-language students in Estonia performed better than Russian students in Russia on the TIMSS test, but Estonian-language students scored much higher than Russians attending Russian-medium schools in both countries (and in Latvia as well). On the PISA 2006 and 2009, Estonian students in Estonian-medium schools also performed substantially higher in mathematics than Russians in Estonia's Russian-medium schools who, in turn, averaged somewhat higher scores than Russian students in Russia.

The data in Table 6 compare the PISA maths scores of advantaged and disadvantaged students in Estonian and Russian-medium schools with the performance of Russian students in Russia. The contrast with Latvia is particularly interesting. Advantaged Estonian and Estonian Russian-medium students lost significant ground in 2006–2009, whereas advantaged Russian students in Russia and advantaged Latvian-medium students in Latvia stayed about the same (Table 5). Disadvantaged Estonian and Russian-

Table 6. PISA 2006–2009. Mathematics scale score, Russians in Russian schools, Russians in Estonian Russian-medium schools and Estonians in Estonian-medium schools, by family academic resources.

Group	2006	2009
Advantaged Russians in Russia	511	505
Advantaged Russians in Estonian Russian-medium schools	517	506
Advantaged Estonians in Estonian schools	560	548
Disadvantaged Russians in Russia	440	437
Disadvantaged Russians in Estonian Russian-medium schools	436	453
Disadvantaged Estonians in Estonian schools	476	488

Source: Authors' calculations from PISA 2006 and 2009 databases.

medium students in Estonia made significant gains in 2006–2009, whereas disadvantaged Russian students in Russia stayed about the same. We have to be careful not to read too much into these changes because we only have Estonian data for two PISA years, but the important feature of the Estonian scores is how similarly the scores of Estonian and Russian-medium students behave in this time period and how large and constant the test score gap is between them. In Latvia, to the contrary, advantaged Russian-medium students have made large gains and score higher relative to both advantaged Latvian-medium and Russian in Russia students.[16]

How can these differences be explained? We conducted extensive interviews with educators and test administrators in Latvia and Estonia in June 2013 to understand why advantaged Russians do so much better in the PISA in Latvia but not in Estonia, and also why Estonian-medium students score so much higher on the PISA than all other groups. In Latvia, we also visited a variety of schools, interviewed principals and academic supervisors and examined the 9th grade mathematics textbooks used in each school as well as the bilingual textbooks being used in some schools. Our findings suggest that the organisations of the school systems in Estonia and Latvia, the curriculum policies in each country regarding Russian-language schools, the types of evaluations used and the relative political importance of the PISA test in each country may all influence how students in different family academic resource groups in dominant-language-medium and Russian-medium schools perform on the PISA (and TIMSS) test. It should be kept in mind that we gathered this information through interviews with informants and did not do a detailed study of the curriculum and the evaluative instruments used in each country. Neither did we observe classrooms. These are important limitations, but, despite them, we believe that our information was detailed and consistent enough among informants to support our general conclusions.

The historical context of the Russian-Baltic state relationship is important. Latvia and Estonia were part of the Russian empire from early in the eighteenth century, gained independence after World War I and, with help from the West, were able to defend themselves against the Red Army in 1919–1920. A significant group of anti-Bolshevik Russian intellectuals remained in Riga. In 1940, the Baltics were occupied by the Soviet Union, then again in 1944 when the Nazis were driven out. These Soviet occupations were extremely repressive. In 1990, Latvia and Estonia (and Lithuania) regained their independence. So, with good cause, the large presence of Russians in these countries is fraught with historical baggage, and the notion of a separate Russian-language school system runs counter to nationalist sentiments.

Since 2000, Latvia has required Russian-medium schools to teach a significant part of the curriculum in Latvian, beginning in the first grade. The result has been a gradual shift of Russian-medium schools into bilingual teaching, and Russian-medium teachers have participated increasingly in professional development to become incorporated into the new system. This 'incorporative' approach to Russian-medium schools is helped by the high percentage of these schools in Riga and the fact that Riga is essentially a bilingual (and becoming, with English, a trilingual) city. According to our interviews with school principals in Riga, the main effects of this 'incorporative' reform on the Russian-medium teachers were to change the textbooks they use (increasingly Latvian-style maths curriculum and some bilingual) and to change their teaching style into the more individual student focus used in Latvian-medium schools. That focus, according to our informants, gives more advanced students more challenging math problem sets. It appears that the change in teaching may have been an important factor in moving advantaged Russian-medium students to score higher on the PISA maths test than their Latvian and Russians in Russia counterparts.

The situation in Estonia differs from Latvia. Most of the Russian-medium schools are in Narva, a city in the Northeast corner of Estonia straddling the Russian border. There is, on average, much more separation between the Estonian and the Russian-medium schools than in Latvia. The separation is reinforced by a political anomaly: Estonian educators were able to reintroduce their own curriculum and teaching philosophy as early as the 1960s (even under Soviet control). These were and continue to be oriented toward individualised instruction and interactive pedagogy more so than Russian teaching methods (Estonian interview; Henno and Reiska 2013). In the Soviet period, Estonian-medium teachers were trained in Estonian universities (as were Latvian teachers in Latvian universities) and Russian-medium teachers were trained in teacher training institutions in Russia. Russian-medium schools are required to teach Estonian as a second language but, unlike Latvia, can use Russian textbooks published in Russia. Teaching styles and much of the curriculum content remain as in Russia

(Estonian interview), in part because the Estonian school system is highly decentralised and relatively small local school districts have little power over school principals. This is in contrast with Latvia and its highly centralised system, which enabled enforcement of Latvian reforms (Estonian interview).

Thus, well before Estonian independence in 1990, Estonian-medium schools had a curriculum and teacher preparation that differed from those in Estonia's Russian-medium schools. As important, however, in the 1990s, Estonia introduced a national evaluation in the 3rd, 6th, 9th and 12th grades, composed entirely of open-ended questions more similar to PISA items than to TIMSS. In effect, teachers in Estonian-medium schools are trained and motivated to teach to this type of evaluation. Further, according to our informants, the Ministry of Education took the TIMSS 2003 and PISA 2006 and 2009 tests seriously as a matter of national pride (in part because of the relatively high performance of Finnish students on these tests). Those in charge of the PISA test, for example, indicated that school heads were told of the importance of students making their best effort on the test – that this was important for Estonia. Yet Russian teachers appear to have little motivation to align their teaching to the Estonian national test and, similarly, Russian-medium schools seem to have little interest in motivating students to attain high scores on the PISA (Estonian interview).[17]

These factors in Estonia may help explain the large difference between Estonian and Russian students' scores (and, indeed, between Estonian and Latvian student scores). Even so, at least in the PISA maths test, it appears that Estonian and Russian student scores moved in parallel in 2006–2009. This is not true for the PISA reading test, where both advantaged and disadvantaged Russian-medium students in Estonia reduced the difference between their scores and Estonian-medium student scores by almost 40 points in 2006–2009. Estonian officials told us that after the low PISA 2006 reading results, they had encouraged Russian-medium school heads to consider doing more 'functional reading', the method used in Estonian-medium schools and geared to the PISA-type reading test items used on the Estonian national evaluation. The officials we interviewed are convinced that this resulted in the higher reading scores in 2009.

However, although disadvantaged Russian-medium students in Estonia did make much larger gains in reading than their Russian-medium counterparts in Russia and Latvia, PISA reading results for advantaged Russian students in Russia and Latvian Russian-medium schools increased just as much as those of Estonia's advantaged Russian students in 2006–2009, without visits from government officials urging teachers and students to maximise effort on the test.[18]

Advantaged Russian-medium students in Latvia made large gains in reading in 2006–2009 from much higher average 2006 levels than Russian students in either Russia or Estonia. Russian-medium school principals we interviewed in Riga thought this was the result of the bilingual policies put in place earlier in the decade. The principals we interviewed in Latvian schools that had participated in PISA tests reported no efforts as in Estonia to motivate Latvian students to do especially well on the PISA.

Both the Latvian and Estonian case studies tend to support the argument that school instructional factors may be important in explaining Russian students' pattern of results on the PISA test, but for different reasons. The Latvian reforms in 2000 incorporated Russian-medium schools into the Latvian system by requiring them to teach some courses in Latvian to Russian students beginning early in primary school. Although we need to be careful in drawing conclusions from our qualitative analysis, Latvian reforms seem to have had the effect of moving Russian teaching styles in Russian-medium schools closer to Latvian-style individualised instruction. They also seem to have particularly benefited advantaged Russian-medium students. Advantaged Russian-language students now score higher in mathematics than advantaged Latvian-language students and much higher than advantaged students in Russia.

Estonian reforms, which began in the 1960s, were applied only in Estonian schools. Again, drawing conclusions from our Estonian interviews with care, it appears that even after 1990, the curriculum has had much less influence on Russian schools because of a greater physical and cultural separation between the two language groups than in Latvia. Both disadvantaged and advantaged Estonian students in Estonian-medium schools do very well on the PISA math test, but advantaged students in Estonia's Russian-medium schools fare no better than Russian students in Russia. Although disadvantaged Russian-medium students did better than their counterparts in Russia in 2009, they still fare far worse than Estonian disadvantaged students. Therefore, until now, Estonian teaching and curricular philosophy seem to be restricted to Estonian-medium schools (with the exception of the noted 'convincing' of Russian school heads to teach the 'functional reading' method employed in Estonian schools).

What lessons for educational policy?

Although we need to be careful in drawing lessons for policy makers from our analysis, we suggest four. The first lesson is that the message is indeed mixed on how well Russian students do in mathematics. If their TIMSS score is a good measure of how well they are learning mathematics, they are performing quite well at all levels of family academic resources, better than their counterparts in most neighbouring countries. If their PISA performance is a good measure of their mathematics skills, Russian advantaged and middle family-resource students are indeed performing relatively poorly and advantaged Russian students are making little progress in improving how much they learn when measured by the PISA definition of maths knowledge.

The second, more tentative, lesson is that Russian PISA performance for more advantaged students (where Russian students' scores are relatively the lowest) could possibly be improved substantially, probably even with Russia's current teacher corps. The experience with advantaged Russian-language students in Latvia is quite convincing on this point. By showing teachers how to include more individualised, customised instruction – how to provide more challenging mathematics work to students who are able to handle it and to teach in a less 'one-size-fits-all' style – it is likely that this would particularly benefit more academically advantaged students. Emphasising improvement among advantaged students does not mean that Russian policy makers should deemphasise trying to improve the scores of disadvantaged students at the same time. Both advantaged and disadvantaged students in Russia do well on the TIMSS compared to students in other countries.

If Russian educators and policy makers consider the PISA test a better measure than the TIMSS of the knowledge students require to meet their needs and the needs of Russian society, there is a third lesson suggested by this study. The PISA mathematics (and reading and science) scores for all family academic resource groups could probably be improved substantially by changing the national curriculum and national evaluation systems to include many more PISA-type items as part of the daily work in the schools and part of the national testing systems in the lower grades (for example, Russia's regional 9th grade evaluation test). This appears to be a major reason why students in Estonian-medium schools do as well as they do on the PISA test. For example, their emphasis on PISA-style 'functional reading' probably contributes to higher PISA scores in all subjects since even PISA maths and science items are heavily reading oriented. Again, this requires a broader policy decision about some very controversial issues, such as what the different international tests actually measure and what the relationship is between those measures and Russia's economic and social needs.

There is a fourth, less positive, lesson suggested by our study. Unfortunately, scores on international tests have taken on a life of their own, connected symbolically to claims of higher economic growth and national prestige. Yet, in most countries, including Latvia and Russia, the tests are very low-stakes for students and schools. Scores on PISA (and TIMSS) might be made to improve substantially if national authorities were able to convince school heads, teachers and, ultimately, students, that doing well on the test is important (for national honour, if nothing else). Estonian officials have made high scores on international tests a high priority and have successfully conveyed this objective to teachers and students, at least to Estonian-medium schools. Putting lesson three into effect makes implementing lesson four easier, but it is possible that under any conditions, increasing the perceived stakes of the test probably could have a positive impact on test scores. Sadly, making the tests higher stakes does not mean that students are learning more, but it does mean that they may perform better on the test, providing whatever value that may have for national pride.

There is some overlap between the first three lessons we draw from our analysis – particularly in greater emphasis on individualised instruction – and the typical lessons appearing in recent policy literature. The latter focus on improved instruction, more time on task and aligning instruction with a clear set of goals for teachers (McKinsey and Company 2010). Nevertheless, for a country such as Russia, whose students have proved to be good in mathematics on one type of test, if educators consider that the knowledge measured by the PISA is important for Russia's future, the main issue in getting their PISA scores up may be simply to align instruction with that test. This means teaching students how to do a different type of mathematics problem and how to read and interpret text in a somewhat different way. To accomplish this new objective probably would require some retraining of teachers, but it may just require teaching to a different type of test, giving more PISA-type homework (practical maths applications) and more PISA-type tests in class.

Funding

The research was funded by the National Research University Higher School of Economics. It continues and builds upon analytic methods developed for a comparison of TIMSS and PISA performance in the United States and six comparison countries (Carnoy and Rothstein 2013). Thanks to Indra Dezde and Maie Kitsing for their invaluable help in Latvia and Estonia.

Notes

1. Notable cases of countries whose students have made gains in the past decade on TIMSS but not on PISA are the USA, Russia and England/UK. Students there now score relatively higher on TIMSS than PISA compared to other developed countries. A counter example is Finland: Finnish students scored high on the PISA 2009 after a modest decline since 2000, whereas they score much lower on the TIMSS and showed no progress in 1999–2011 (OECD 2010a; TIMSS and PIRLS International Study Center 2011).
2. In its 2009 PISA report, the OECD compares all participating countries' average scores adjusted for the PISA socioeconomic background index (ESCS) for both reading and mathematics and compares changes in reading scores in 2000–2009, unadjusted and adjusted for socioeconomic index changes within country (OECD 2010b, Table II.3.2; OECD 2010c, Figure V.2.9). The trends it displays are similar to those we report for the 10 countries on which we focus. However, the OECD does not employ its ESCS index to compare how students perform within countries from different ESCS backgrounds or to compare trends over time across countries for students of similar family resource backgrounds.
3. A 'natural experiment' in this case refers to the situation where students of similar ethnic/cultural family background attend Russian-medium (with most

teachers originally trained in Russian institutions) schools in Russia, Latvia and Estonia, but where all three countries have different education policies, including different curricula and national evaluation systems.

4. The PISA data in those two Baltic countries allow us to identify language groups and the language medium of the school. In Lithuania, this was not possible.
5. Policy analysts generally consider intervention effects of 0.2 standard deviations or more to be 'effective'.
6. Below, we show that the gaps between high and low family-resource groups on the TIMSS are also low in these same countries, including Russia, but in the TIMSS, the lowest and highest groups are both high scoring.
7. According to the OECD, the 2000 PISA mathematics test score may not be completely comparable to later-year scores. However, the trends in 2000–2003 maths scores by family academic resource group are not substantially different from trends in reading scores across the eight countries we study so we feel confident in the comparability of our estimated trends.
8. The categories used for mother's and parents' education also change between the 2000 and subsequent surveys.
9. Because of these changes in categories we need to interpolate scores for Groups 2–5. We estimate the interpolated scores by assuming that students' average scores increase linearly from category to category. We assume that that average score corresponded to students with the average number of books in the category – 30 books. The similar social class in the 2003, 2006 and 2009 PISA samples was 11–25 books in the home – an average of 17.5 books. The next lowest social class category in 2000 was 1–10 books in the home, an average of 5 books. We assume that students with 17.5 books would score lower than those with 30 books by the proportion (17.5–5)/(30–5) of the difference in test score between categories. This is the average score we assign to the interpolated category of 11–25 books in the home (Group 2) in 2000. We make similar estimates for the interpolated categories, 26–100 books (Group 3), 101–200 books (Group 4) and 201–500 books (Group 5) for the 2000 PISA math test in each comparison country. These are the estimates we use in calculating test score differences by books in the home groups in 2000–2009.
10. When we use other measures of family academic resources (for example, PISA's ESCS index) to proxy family resources, advantaged Russian students also score relatively much lower on the PISA test.
11. There was a TIMSS administration in 1995, but because we are interested primarily in comparison with PISA results beginning in 2000, we do not examine TIMSS 1995.
12. The standard errors vary among family resource groups. Our statements about significant differences follow the general rule of thumb of two SDs as constituting a significant difference.
13. In order to create a comparison year for PISA as close as possible to 2007, the PISA score for 2006 is weighted twice that of the PISA score for 2009.
14. The absolute scores reported in Table 3 for TIMSS cannot be compared to the PISA scores in Table 3 because the scales differ. As above, we use two standard errors as the basis of our statements concerning significant differences – we approximate significance in comparing TIMSS and PISA gains by averaging twice the TIMSS SD and twice the PISA SD for the same family resource group.

15. On the PISA 2000, Latvian students (excluding Russians living in Latvia) scored 466 in mathematics compared with 478 for Russian students in Russia. On PISA 2003, Latvian students in Latvian schools scored 491 in maths (up 25 points from 2000) compared to Russian students in Russia, who scored 468 (down 10 points from 2000). Latvian students' scores remained about the same on the two TIMSS tests they took (1999 and 2003) and Russian students' scores declined. Thus, Russian students' performance declined on both the TIMSS and PISA in 1999/2000 to 2003, but Latvian students performed about the same on the TIMSS and made big gains on the PISA.
16. Russian-language students are much more likely to live in urban areas and particularly in the largest city, Riga, than Latvian-language students. But the relative proportion of Russian students living in Riga did not change significantly in 2003–2009, so the gain shown by advantaged Russian-medium students would not be affected by their relative urban location.
17. In order to integrate Russian-medium schools more into the overall system, Estonia has recently required Russian-medium schools to teach 60% of their courses in Estonian beginning in the 10th grade. This should not affect PISA scores since the Estonian sample is, as in Finland, almost entirely 9th graders, but it may influence Russian-medium schools to prepare their students in an 'Estonian' mode in earlier grades. How this will affect PISA scores is unclear.
18. The PISA reading gains in Estonia and Latvia were as follows:

Group	2006	2009
Advantaged Russians in Russia	475	499
Advantaged Russians in Estonian Russian-medium Schools	476	504
Advantaged Russians in Latvian Russian-medium Schools	506	532
Advantaged Estonians in Estonian Schools	549	539
Advantaged Latvians in Latvian Schools	517	516
Disadvantaged Russians in Russia	397	421
Disadvantaged Russians in Estonian Russian-medium Schools	399	441
Disadvantaged Russians in Latvian Russian-medium Schools	424	435
Disadvantaged Estonians in Estonian Schools	469	475
Disadvantaged Latvians in Latvian Schools	435	448

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