Research Article

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PISA Performance of Natives and Immigrants: Selection versus Efficiency

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Abstract: In most countries, immigrant and native students perform differently in the Programme for International Student Assessment (PISA) due to two main reasons: different immigration regimes and differences in their home-country educational systems. While there is sophisticated literature on the reasons for these performance gaps, it is barely considered in the educational efficiency research. Our approach distinguishes between selection effects caused by immigration policies, and the efficiency of educational systems in integrating immigrant students, given their socio-economic background. Accordingly, we split our sample, which consists of 153,374 students in 20 countries, calculate various different efficient frontiers, and ultimately decompose and interpret the resulting efficiency values. We find large differences in educational system efficiency, when controlling for negative selection effects caused by immigration regimes.

Keywords: Data Envelopment Analysis, Migration, PISA, Efficiency decomposition

JEL Classification: C14 C61 I21

1 Introduction

The differences between natives and immigrants in the Programme for International Student Assessment (PISA), published by the Organisation for Economic Co-operation and Development (OECD), has gained considerable attention in the literature.¹ Apart from social, cultural, religious and

historical reasons, different immigration policies and different levels of success in integrating immigrants are the two most important aspects (Kunz, 2016; Isphording et al., 2016). Countries attract different groups of immigrants with different socio-economic environments, due to country attractiveness, as well as their immigration policies (Entorf & Minoiu, 2005; Hochschild & Cropper, 2010). In most countries, socio-economic endowment is one of the most important factors for the educational success of students (Parr & Bonitz, 2015; Rogiers et al., 2020). This is illustrated by the left panel of Figure 1, which shows a strong positive within-country correlation between the average reading, mathematics and science student scores in PISA, and their average ESCS values, the latter being an index of their socio-economic backgrounds, in 2015.² The index of economic, social and cultural status (ESCS) comprises several subcategories in the areas of parental education, highest parental employment and student housing. It is considered to be an appropriate measure of the students' socio-economic background (Hwang et al., 2018). The right side of Figure 1 shows the strong correlation between socio-economic endorsement gaps (ESCS gaps) and educational performance gaps between natives and immigrants across countries (Rogiers et al., 2020).³

Our descriptive analysis reveals substantial educational (PISA) and socio-economic (ESCS) gaps between immigrants and natives and, that performance comparisons to a large extent implicitly reveal the students' different social and economic backgrounds. Without account-

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1 PISA is a worldwide study that assesses the 15-year-old students' performance in mathematics, science, and reading. In addition, the individual backgrounds of the pupils and school data are collected.

Following the PISA definition of immigration, an immigrant foreign-born in the second or first generation (OECD, 2017).

2 Our included countries are: Australia (AU), Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), Finland (FI), France (FR), Germany (DE), Israel (IL), Italy (IT), Netherlands (NL), New Zealand (NZ), Norway (NO), Portugal (PT), Singapore (SG), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (GB), and the United States of America (US).

3 Figure S1 in the appendix shows the positive correlation between average PISA scores and the average ESCS scores on the country-level. The right panel elucidates that the average PISA scores are negatively correlated with the mean absolute deviations from the median ESCS scores.

Figure 1: Relationship between PISA scores and ESCS values; left: within-country correlation, right: average gaps on country-level

ing for the students' backgrounds, studies run the risk of making implicit statements about immigration policy. We take this problem into account explicitly, by analysing the performance of the educational system, given the varied social backgrounds of immigrant and native students.

An educational system can be integrating, despite a large educational gap, if it at least partially compensates for the gaps in socio-economic background. We use Data Envelopment Analysis (DEA) to examine the efficiency of educational systems. DEA models provide efficiency scores based on the students' performance relative to the performance of the best students comparable in their ESCS endowments. Our analysis is conducted at student-level, the most disaggregated data available in PISA. The students are evaluated according to their ability to maximise PISA scores given their socio-economic endowment. To account for the differences in socio-economic endowment between immigrants and natives, we split the PISA 2015 data into subsamples of natives and immigrants. Efficiency scores are calculated relative to various efficiency frontiers, which provides further insights and fosters our understanding of the relationship between selection effects in immigration, and the integrational abilities of the educational institutions in this context. Educational system performance is then obtained from the average efficiency scores of the students and further decomposed.

Our first efficiency analysis uses the average PISA score of the mathematics, science, and reading scores as output and the ESCS values as input. These three PISA

scores are highly positively correlated. The aggregation into one output enables a straightforward interpretation and decomposition of the efficiency frontiers. In a further analysis we use the ESCS as input and include the three PISA scores (mathematics, science, and reading) as separate outputs. DEA models allow the inclusion of several outputs, whereby all inputs and outputs are simultaneously included in the efficiency assessment by weighting them. The results of the second efficiency assessment confirm our main findings for average scores that in countries with restrictive immigration regimes, immigrants are not only performing relatively well but also use their endowments rather efficiently. Some countries (e.g. Spain and France) perform considerably better according to their efficiency considering their ESCS endowments relative to their PISA ranking.

After this introduction, a literature overview of the performance gaps between natives and immigrants is provided. The third section outlines our methodology. In section four we explain the methodology of the ESCS and PISA scores, the differences between immigration regimes, and provides some initial results. The results of the efficiency analyses and their decomposition are discussed in section five preceding the conclusion.

2 Literature Overview

Differences in country attractiveness for immigrants, and different immigration policy regimes, attract different groups of immigrants, resulting in heterogeneous immigration populations between countries, and a wide range of challenges for the educational systems and societies in general (Entorf & Minoiu, 2005; Hochschild & Cropper, 2010). While some countries attract immigrants whose socio-economic endowments are equal or even higher than those of the natives (Arabian oil-based economies, English speaking countries and Singapore), others, such as Central European countries, mainly attract immigrants who have a poorer socio-economic endowment than the natives (Jerrim, 2015). In Austria, Denmark, and Germany, for example, the differences between native and immigrant students are especially striking (Rindermann & Thompson, 2016).

Besides their levels of educational, human capital, and wealth-related aspects (all part of PISA's ESCS index), native and immigration populations may also differ in cultural, religious, historical, and reputational aspects (Parr & Bonitz, 2015; Kunz, 2016). Immigrants may also face formal rights and legal status challenges, lack accumulated experiences as well as social connections that may result in educational information asymmetries, which can influence the educational performance of their children (Rindermann & Thompson, 2016; Camehl et al., 2018).

Schneeweis (2011) decomposes the educational gap between immigrants and natives using the data of five international student assessment studies. Her results show that institutional characteristics of the education systems can increase differences between immigrants and natives. The results of Borgna & Contini (2014) indicate that educational institutions and socio-economic backgrounds are mostly causing the gaps between immigrants and natives. Furthermore, PISA 2006 and 2009 data reveal that school attendance significantly reduces educational gaps. Dronkers et al. (2014) find that the countries' educational systems and the students' individual characteristics cause the differences between immigrants and natives. Harris et al. (2019) show that the access to certain areas of the curriculum depends at least in part on the socio-economic endowment of the students in the schools. Woessmann (2016) finds that educational institutions and family background have the highest explanatory power in determining educational achievements. Interestingly, the impact of school resources is much smaller than the students' social-economic endowment and institutional characteristics, which is also found by Falck et al. (2018).

Further empirical studies based on PISA data reveal that the different socio-economic backgrounds of immigrants and natives have the highest overall explanatory power regarding differences in educational attainment. Especially in European countries, nearly three-quarters of the performance gaps between natives and immigrants are accounted for primarily by differences in economic, social, and cultural status (Ammermueller, 2007; Levels et al., 2008; Arikan et al., 2017). Other factors, like linguistic barriers (previously considered the most important barrier for immigrants) only partially explain the performance gaps (Isphording et al., 2016; Rindermann & Thompson, 2016).

Another important aspect in explaining performance gaps is the selection process among immigrants. Individual background factors vary between different immigrant groups which themselves vary between the countries (Schnepf, 2007; Arikan et al., 2017). In countries where immigrants are highly educated like Australia, they perform on average better in national and international comparisons than their native counterparts (Dustmann et al., 2012; Jerrim, 2015). The opposite holds for Central European countries in which a considerable share of the immigrants have on average a lower economic, social, and cultural status than the population of their immigration target countries and perform worse in PISA (Dustmann et al., 2012; Rindermann & Thompson, 2016; Arikan et al., 2017).

Accordingly, heterogeneous immigrant populations provide specific challenges for educational systems that should be considered in efficiency analysis. Although the ESCS is an input (among others) in most educational efficiency analyses, regarding the importance of socio-economic backgrounds, international efficiency studies are deficient, in how they consider the differences between immigrants and natives within and between countries.

Efficiency scores are based on the relationship between the sum of weighted *output* to the sum of weighted *input* of the students relative to the best students. As the socio-economic status is an environmental or non-discretionary input, it is not amenable to direct control by the educational system, and therefore cannot be regarded as a traditional input in efficiency analysis. But since it is found to have a significant impact in determining performance in PISA, socio-economic status is included in most efficiency analyses (Agasisti & Zoido, 2018). For example, Sutherland et al. (2009) argue that student achievements depend on their social environment (family and peer-groups) and therefore must be included in student efficiency analysis. Similarly, Cordero-Ferrera et al. (2017) argue that student socio-economic background is crucial for evaluating students according to their ability to make the most with their inputs (Cordero-Ferrera et al., 2017). Apari-

cio et al. (2017a) refer to students as “raw material” that is transformed in schools and the impact of which is best reflected by the students’ socio-economic status (Aparicio et al., 2017a).

In the cross-country analyses of Sutherland et al. (2009), Aparicio et al. (2017a), and Agasisti & Zoido (2018), the students are not distinguished according to their country of origin. Moreover, the studies do not account for selection effects caused by immigration policies, that can lead to distinct immigrant groups with different socio-economic backgrounds. Aparicio et al. (2017b) proxy the socio-economic backgrounds of students by including the educational experience of their parents, which is only one aspect of the broader ESCS. As the performance gap determinants are manifold, a more comprehensive index should be preferred. De Witte & Lopez-Torres (2017) provide a broad overview of recent educational efficiency studies.

A considerable number of publications have been published in both the efficiency strand and the literature strand, focusing on the determination of the performance gaps between immigrants and natives. However, no international educational efficiency study so far accounts for the different challenges arising from different immigration policy regimes.

3 Methodology

In this section we explain our notation and our methodological approach in detail using a small artificial data set. As our decomposition approach regards several countries and the two subsets of students with or without immigration background, we introduce index sets denoted in calligraphic characters to facilitate referencing to specific groups of students.

3.1 Sets of students

The set of all countries is denoted $\mathcal{K}$ and individual countries are referred to with index k ($k = 1, \dots, K$). In each country k we have two sets of students. The set of students in country k having an immigration background is denoted with $\mathcal{I}_k$. Immigrant students in country k are referred to using the index i ($i = 1, \dots, I_k$). Native students (home) in country k build the index set $\mathcal{H}_k$ and are indexed with h ($h = 1, \dots, H_k$). All students in country k , that is students with and without immigration background are referred to with $\mathcal{E}_k = \{\mathcal{I}_k, \mathcal{H}_k\}$.

Calligraphic characters without an index refer to the set combining the subsets from all K countries. I.e. $\mathcal{E} = \{\mathcal{E}_1, \dots, \mathcal{E}_k, \dots, \mathcal{E}_K\}$ is the set of all students from all K countries and $\mathcal{I} = \{\mathcal{I}_1, \dots, \mathcal{I}_k, \dots, \mathcal{I}_K\}$ is the set of all students with immigration background from all K countries. We also have $\mathcal{E} = \{\mathcal{I}, \mathcal{H}\}$ with $\mathcal{H} = \{\mathcal{H}_1, \dots, \mathcal{H}_k, \dots, \mathcal{H}_K\}$.

3.2 Students and different frontiers of potential scores

In our illustrating example we only consider two countries, that is k and k' . First, we consider country k and the two subsets $\mathcal{I}_k$ (immigrant students) and $\mathcal{H}_k$ (native students). For each we observe their input x (ESCS-score) and their output y (PISA-score). We represent in Figure 2 native students ($\mathcal{H}_k$) by closed circles and students with immigration background ($\mathcal{I}_k$) with open circles.

We observe that some students with rather similar inputs reach quite different outputs. The observations of the ‘best students’, subsequently named efficient students, are joined with linear junctions and the resulting frontier is used as a yardstick to benchmark the remaining students. How we identify the best students is explained in more detail below (see model 2). As we have three different subgroups, natives ($\mathcal{H}_k$), immigrants ($\mathcal{I}_k$) and all students combined ($\mathcal{E}_k$), we can obtain three different frontiers. These frontiers we denote in general by F and the superscript indicates based on which subset of students the frontier is obtained, accordingly we have drawn the three different frontiers $F^{\mathcal{I}_k}$, $F^{\mathcal{H}_k}$ and $F^{\mathcal{E}_k}$ in Figure 2.

3.3 Benchmarking individual students

The performance of a specific student h , we pick for illustration the one indicated with the square, can now be assessed using three different benchmarks. To ease the readability, the right panel of Figure 2 displays a part of the left panel enlarged.

A benchmark student denoted by $\tilde{h}_1$ is a synthetic student on frontier $F^{\mathcal{H}_k}$. This benchmark student is a linear combination of two efficient native students located at the frontier $F^{\mathcal{H}_k}$ (dotted line). If we compare the obtained score of student h with the score of $\tilde{h}_1$ on the frontier $F^{\mathcal{H}_k}$, we obtain a relative efficiency score of $D^{\mathcal{H}_k}(h) = 2.740/3.230 = 0.850$. We use D for the efficiency score and the superscript indicates on which set of students the frontier is obtained, here we use frontier $F^{\mathcal{H}_k}$. Hence, the student h only obtained 85% of the score that is regarded as being possible given his input amount. Or, equivalently,

Figure 2: Benchmarking of a country with two student groups. The left panel shows three frontiers, the right panel shows the rectangle enlarged.

he could increase his output by 17.6% if he would be as efficient as his benchmark fellow students.

If we compare our native student h with an efficient synthetic student with immigration background $\tilde{h}_2$, which is located at the frontier $F^{\mathcal{J}_k}$ (solid line) obtained from immigration students $\mathcal{J}_k$, we obtain student h score as $D^{\mathcal{J}_k}(h) = 2.740/3.370 = 0.810$, hence, in this comparison he is underperforming by 19%.

And finally we can benchmark student h with synthetic student $\tilde{h}_3$ located at the frontier $F^{\mathcal{E}_k}$ (dashed line) which is based on all students in country k . As this hypothetical benchmark student $\tilde{h}_3$ performs even better than $\tilde{h}_1$ and $\tilde{h}_2$, we find that according to this yardstick, student h underperforms by $D^{\mathcal{E}_k}(h) = 2.740/3.510 = 0.780$, i.e. 22%. Note that in this last comparison the benchmark student $\tilde{h}_3$ is a hypothetical student obtained as a linear combination of an efficient native and an efficient immigrant student.

3.4 Benchmarking sets of students

To obtain a measure of the performance of a complete set of students we use the arithmetic mean of individual scores. E.g. to obtain the average performance of immigrant students $\mathcal{J}_k$ using the frontier $F^{\mathcal{J}_k}$ obtained based on this set of students, we calculate

$$M^{\mathcal{J}_k}(\mathcal{J}_k) = \frac{1}{I_k} \sum_{i=1}^{I_k} D_i^{\mathcal{J}_k}(\mathcal{J}_k) \quad (1)$$

I_k is the number of students benchmarked, here the students with immigrant background in country k . We use M

for arithmetic mean, the superscript $\mathcal{J}_k$ to indicate that we use the frontier $F^{\mathcal{J}_k}$ and the argument in parentheses indicates which group of students is benchmarked.

In our illustrative example considered in Figure 2 we obtain for immigrants $M^{\mathcal{J}_k}(\mathcal{J}_k) = 0.827$ and for natives $M^{\mathcal{H}_k}(\mathcal{H}_k) = 0.839$. For comparing the performance of immigrants and natives, one may like to use the frontier $F^{\mathcal{E}_k}$ obtained considering all students $\mathcal{E}_k$ in country k . In this example we obtain for immigrants $M^{\mathcal{E}_k}(\mathcal{J}_k) = 0.788$ and for natives $M^{\mathcal{E}_k}(\mathcal{H}_k) = 0.796$ as average efficiencies.

3.5 Considering a second country

We now consider a second country k' . We use filled diamonds for native students and open diamonds for immigrant students. The left panel of Figure 3 contains the situation for country k' , again with the three different national frontiers indicated by dotted, dashed and solid lines. The right panel combines the students of both countries and allows us to obtain an international frontier $F^{\mathcal{E}}$ collated from all students of all (here: two) countries.

This allows the benchmarking of the immigrant students of country k ($\mathcal{J}_k$) and of the native students of country k ($\mathcal{H}_k$) using the international frontier. E.g. our student h of country k is now benchmarked based on the score of a synthetic student $\tilde{h}_4$ located at the international frontier $F^{\mathcal{E}}$. Accordingly in this comparison her efficiency score $D^{\mathcal{E}}(h) = 2.740/4.010 = 0.680$ is the lowest obtained in the comparisons and hints for a potential increase in her score of 47%.

Figure 3: Benchmarking of another country with two student groups and for both countries together

Using the international frontier F^E for benchmarking all native students in country k results in an average score $M^E(\mathcal{I}_k) = 0.686$. The immigrants of country k obtain an average score $M^E(\mathcal{J}_k) = 0.698$.

The DEA model

We use the output-oriented BCC model, introduced by Banker et al. (1984). The output orientation implies that students maximise their output given their inputs. For student o the model is defined as:

$$\begin{aligned} \min_{\eta, v, u} \quad & \eta = \sum_i v_i x_{io} - u_0 \\ \text{subject to} \quad & \sum_r u_r y_{ro} = 1 \\ & \sum_i v_i x_{ij} - \sum_r u_r y_{rj} - u_0 \geq 0 \quad (j = 1, \dots, n) \\ & v_i \geq 0 \quad (i = 1, \dots, m) \\ & u_r \geq 0 \quad (r = 1, \dots, s) \\ & u_0 \text{ free in sign.} \end{aligned} \quad (2)$$

Output r of student o is given by y_{ro} and is weighted by u_r ($r = 1, \dots, s$). s equals the number of outputs. Her input i (x_{io}) is weighted by v_i ($i = 1, \dots, m$). m is the number of inputs and n is the number of all students under analysis. The weights are restricted to be non-negative, derived from the data, and most likely vary between students. The weights are not chosen a priori but determined when solving the linear program. The most favourable composition of weights to make student o as efficient as possible are chosen given the restrictions. The linear program is set

up and solved for each student under analysis individually (Behr, 2015; Cooper et al., 2007).

η^* denotes the solution to the minimisation problem. For convenience, we define $D^* = \frac{1}{\eta^*}$. If $\eta^* = D^* = 1$ student o is efficient. The limits of η^* and D^* depend on whether the student o belongs to the group of students she is compared to. If she belongs to the group of students she is compared to, η^* is equal to or greater than one and D^* is equal to or less than one. If student o does not belong to the group of students she is compared to, η^* may be less than one (the student is super-efficient). In this case the student o is above the efficiency frontier of the students she is compared to, and D^* is greater than one (Chen, 2005).

The scalar u_0 is free in sign and implements the assumption of variable returns to scale (VRS). VRS allow non-proportional output changes when the inputs change. The input and output tuples of students are neither allowed to be scaled up (increasing returns to scale) nor down (decreasing returns to scale) in the BCC model.

4 The PISA Study, Migration Regimes and Descriptive Results

We use students' socio-economic status as the input and the average PISA score of the students in reading, mathematics and science, as output in the first efficiency analysis. If necessary, the data are transformed to obtain positive values as DEA can only handle positive inputs and outputs. Outliers are excluded.

4.1 The PISA study and the ESCS

PISA is a worldwide stratified two-stage sample study conducted by the OECD, to measure 15-year-old students' performance in mathematics, science, and reading. It was conceived to offer insights into sources of performance variation within and between countries. It was first performed in 2000 and then repeated every three years. The PISA assessment in 2015 focused on science, and was published in December 2016 (OECD, 2016). Student performance is reported as the corresponding mathematics, science, and reading scores.⁴

A minimum of 150 schools must be selected in each country to ensure quality standards. If a participating country has fewer than 150 schools, all schools are selected. Within each participating school, a predetermined number of 15-years-old students, usually 42 students, is randomly chosen with equal probability. In schools with fewer students, all students are selected. If the response rate is too low, the sample size of schools is increased beyond 150 to ensure a minimum student sample size. A response rate of 85% is required for initially selected schools. If the initial school response rate falls between 65% and 85%, an acceptable school response rate can still be achieved by using replacement schools. Schools are classified into similar groups according to selected variables (region, private or public school, funding,...). A minimum student response rate of 50% within each school is required for a school to be regarded as participating (OECD, 2016).

Since its publication, the results of the PISA study have influenced the design of the education systems of the participating countries. For example, Ho (2016) shows how the insights resulting from PISA were used in Hong Kong, Damiani (2016) in Italy, and Ababneh et al. (2016) in Jordan. Tobin et al. (2016) provide a world wide overview of how large-scale educational assessments influence education policy and most studies find significant effects of secondary education on the economic development of countries (Aduand and Denkyirah, 2017; Karatheodoros, 2017).

The index of economic, social and cultural status (ESCS) comprises three main categories: parental education, highest parental occupation, and home possessions. The latter combines five indices: family wealth, household possessions, cultural possessions, home educational resources, and information and communication technology

resources. These indices are derived from the availability of 16 household items at home, including three country-specific household items. The ESCS's three main components are standardized with a mean of zero and a standard deviation of one, over the full sample. Finally, a principal component analysis (PCA) of the three main components is conducted, and the ESCS is defined as the first principal component score (OECD, 2017).⁵ For first-generation immigrants, parental education and partly the highest parental occupation may result from the educational institutions of their country of origin, rather than from integration results or the educational system of their target country, in whose educational efficiency we are interested. However, both the home possession measures and the success of the second-generation immigrants depend on the integration and education quality in their target country (Reparaz & Sotés-Elizalde, 2019). The ESCS covers a wide range of different economic, social and cultural topics, enabling an approximation of possible determinants of education performance gaps between immigrants and natives. Furthermore, through the use of PCA, the ESCS is a construct that is well suited for capturing and comparing the whole students' socio-economic status (Hwang et al., 2018).

4.2 Migration regimes

When examining the efficiency of educational systems in terms of the immigrant performance, the respective immigration regimes of the countries must be taken into account. Bjerre et al. (2015) and Bonjour & Chauvin (2018) provide an overview of a large number of definitions and distinctions in the literature.

In addition to limiting official immigration policies (strict ones are mainly based on points systems), another important aspect is how many people enter the country through unofficial channels. For example, a comparison between Germany and Australia shows that the proportion of immigrants in Australia for family and humanitarian reasons is far lower and the percentage who do so for economic reasons is higher (Beine et al., 2016). Based on their selective immigration policy and low proportion of non-economic immigration, Australia, Canada, New Zealand, and the United Kingdom can be regarded as having rather restrictive immigration regimes. The United States of America also has a restrictive immigration policy, but unlike

⁴ Now data for 2018 have become available but the preliminary version of 2018 is still incomplete and lacks for example individual scores in of the three subjects for spanish students.

⁵ The common ESCS component weights across cycles are 0.79 (parental occupation), 0.82 (parental education), and 0.74 (home possessions) (OECD, 2014).

the remaining countries in this group, it does not succeed in attracting immigrants who perform on average at least as well as their native peer group, as shown below (see also Camarota & Zeigler (2016)). The European Union introduced a points-based system in 2009, but it is far less strict than in the other countries with a selective immigration policy, and the share of immigrants for family and humanitarian reasons is relatively high. Therefore, we do not regard the members of the European Union as being restrictive (Bertoli et al., 2016).

We use the average occupational status of parents, which is available in PISA (higher values stand for better status) to substantiate our country classification. The occupational status of parents is an important determinant of the educational attainment of immigrants, as the educational mobility of immigrants is generally lower than that of natives (Schneebaum et al., 2016; Reparaz & Sotés-Elizalde, 2019). Descriptive results show that in most countries, the occupational status of parents of natives is higher than that of immigrants. Only in countries with a selective immigration regime, are the gaps close to zero or even negative. Singapore attracts immigrants whose parents have the highest level of education.⁶ These results can be provided upon request.

4.3 The data and descriptive results

Our sample comprises 153,374 students in 20 industrialized countries for PISA 2015.⁷ We combine first- and second-generation immigrants, otherwise several countries would have too few data points in at least one group (e.g. Finland and the Netherlands), and both groups have similar performance differences (relative to the natives),

⁶ In Singapore, the recruitment of skilled workers is systematically promoted and part of the official government strategy, as the following quote from prime minister Goh Chok Tong's speech at the national day rally 2001 shows:

“[. . .] some Singaporeans may again question the need for more global talent. I urge you to understand that this is a matter of life and death for us in the long term. [. . .] If we do not top up our talent pool from the outside, in ten years time, many of the high-valued jobs we do now will immigrate to China and elsewhere, for lack of sufficient talent here.” (Tong, 2001)

Singapore is the most successful of all countries in attracting highly qualified and top performing immigrants. In our analysis, immigrants in Singapore are on average the most efficient.

⁷ Japan, Korea, and Poland are excluded because of having too few immigrants.

which are determined to a similar extent by the ESCS (Rangvid, 2007).

As a frontier based non-parametric technique, DEA is sensitive to outliers. We exclude outliers based on their influence, measured by Cook's distance. We define outliers to have a Cooks' distance of at least eight times the average distance for each country and each regression, which is a reasonable threshold according to Cook (1979).⁸ Table S1 shows the number (between 44 and 207) and the percentages (ranging from 0.759% to 1.186%) of excluded outliers per country.

PISA reading, mathematics, and science scores are constructed to have an international mean of 500 and a standard deviation of 100. The standardization provides student results that are directly comparable between countries. Table 1 summarizes within-country correlations between the scores. All scores are highly positively correlated, and the correlations vary between 0.743 for the mathematics and reading results in Italy, and 0.908 for the reading and science results in Singapore. Table S5 in the appendix depicts the correlation coefficients for each country.

We use the students' average PISA scores as output y , to enable comprehensible visual and contextual illustrations. After discussing the results for the average PISA score as output, we also present the results for the three PISA scores in mathematics, science, and reading as outputs.

Figure 4 presents the average PISA score distributions, using a Gaussian kernel with a bandwidth of 70% of Silverman's "rule of thumb" to disclose more details for immigrant and native students separately for each country (Silverman, 1986). In countries with selective immigration policies, as well as in Israel and Portugal, immigrants and natives perform similarly well. In Singapore, the immigrants perform even better than the natives. In the other countries and especially in most European countries, natives perform better. The differences between natives and immigrants between countries further indicate that the prevailing immigration regime influences the selection among immigrants. However, Figure 4 focuses only on our output and does not distinguish between the selection effects and the efficiency of educational systems. Figures S2 to S4 in the appendix provide the distributions of the three PISA scores. They are rather similar to the distributions of the average PISA scores and the same dis-

⁸ The results are robust for alternative thresholds (e.g. from two times up to 20 times the average distance) and can be provided upon request.

Table 1: PISA scores correlations coefficients, overview

Scores	Min	Country	Max	Country	Mean
Mathematics-Reading	0.743	Italy	0.860	Netherlands	0.795
Mathematics-Science	0.849	Italy	0.899	France	0.883
Reading-Science	0.828	Sweden	0.908	Singapore	0.868

Figure 4: Average PISA scores distributions among natives (straight line) and immigrants (dashed line)

Table 2: Descriptive results of the average PISA scores and the ESCS values

Countries	Group	PISA	Mean diff.	ESCS	Mean diff.	Corr	n
Australia (AU)	Nat	492	−18.872	0.194	−0.100	0.403	10744
	Mig	511	(2.012)	0.294	(0.017)	0.369	2651
Austria (AT)	Nat	508	60.012	0.207	0.542	0.373	5533
	Mig	448	(2.626)	−0.335	(0.026)	0.299	1242
Belgium (BE)	Nat	519	54.107	0.272	0.407	0.446	7684
	Mig	465	(2.573)	−0.135	(0.026)	0.358	1445
Canada (CA)	Nat	514	−7.163	0.487	−0.040	0.319	14555
	Mig	521	(1.481)	0.527	(0.014)	0.281	4057
Denmark (DK)	Nat	510	65.141	0.630	0.699	0.362	5224
	Mig	445	(2.177)	−0.069	(0.027)	0.170	1567
Finland (FI)	Nat	529	64.021	0.281	0.303	0.349	5495
	Mig	465	(6.391)	−0.022	(0.054)	0.289	200
France (FR)	Nat	512	52.708	−0.038	0.515	0.486	5089
	Mig	459	(3.921)	−0.553	(0.032)	0.290	706
Germany (DE)	Nat	528	54.087	0.238	0.539	0.409	4614
	Mig	474	(3.156)	−0.301	(0.032)	0.213	881
Israel (IL)	Nat	481	6.512	0.227	0.160	0.388	5223
	Mig	475	(3.426)	0.067	(0.029)	0.318	1023
Italy (IT)	Nat	502	51.145	−0.006	0.471	0.316	10199
	Mig	451	(2.737)	−0.477	(0.031)	0.196	867
Netherlands (NL)	Nat	519	53.374	0.245	0.485	0.359	4587
	Mig	466	(4.102)	−0.240	(0.035)	0.225	504
New Zealand (NZ)	Nat	512	−1.539	0.173	−0.046	0.417	3031
	Mig	514	(3.403)	0.219	(0.026)	0.457	1075
Norway (NO)	Nat	513	39.224	0.550	0.463	0.294	4535
	Mig	474	(3.465)	0.087	(0.033)	0.202	616
Portugal (PT)	Nat	487	1.512	−0.570	−0.158	0.468	6647
	Mig	486	(4.325)	−0.412	(0.055)	0.456	416
Singapore (SG)	Nat	539	−31.006	−0.120	−0.499	0.450	4734
	Mig	570	(2.913)	0.379	(0.027)	0.342	1164
Spain (ES)	Nat	502	39.959	−0.371	0.572	0.380	5808
	Mig	462	(3.268)	−0.943	(0.044)	0.333	664
Sweden (SE)	Nat	510	59.129	0.425	0.418	0.374	4311
	Mig	451	(3.298)	0.007	(0.031)	0.192	819
Switzerland (CH)	Nat	522	51.076	0.323	0.585	0.356	3907
	Mig	471	(2.528)	−0.262	(0.026)	0.357	1711
United Kingdom (GB)	Nat	502	9.967	0.232	0.052	0.365	11329
	Mig	492	(2.360)	0.181	(0.023)	0.334	1607
United States (US)	Nat	496	21.527	0.280	0.755	0.366	4153
	Mig	474	(2.849)	−0.475	(0.034)	0.302	1215

PISA and ESCS: group-specific country averages; Mean diff.: Differences between the means of natives and immigrants; the values in brackets are a variance measure: $\sqrt{\frac{\text{var}(v_J)}{n_J} + \frac{\text{var}(v_{Jc})}{n_{Jc}}}$ where v represents the students' PISA and ESCS values and n their respective numbers.

tinctions between countries with and without restrictive regimes can be made.

The index of economic, social and cultural status of each student (ESCS) is regarded as input (x'). x' is internationally comparable, has a mean of zero and a standard deviation of one. Radial DEA models can only handle strictly positive variables. Therefore, x' is transformed: $x' - \min(x') + 0.01 = x$. x is the input used in our efficiency analysis and is not further transformed.

Table 2 provides descriptive results and correlation coefficients between the average PISA scores and the ESCS values for each country at the student level, for students with and without an immigration background. In most countries, natives perform better and have a better average socio-economic background. In Australia, Canada, and New Zealand (all countries with selective immigration systems), immigrants achieve higher average PISA scores and have higher ESCS endowments. On average, immigrants in Singapore have ESCS values that are above the PISA average, and the values of the natives are lower (Becker, 2012; Facchini & Lodigiani, 2014). In comparison, both Canadian population groups have above-average ESCS averages and the smallest gap. This hints for the selectivity of the Canadian immigration system, so that the average immigrant in Canada has a socio-economic background similar to that of the average native. The United States has the largest ESCS gap between the two groups. Although the United States has a selective immigration system, it attracts immigrants with relatively poorer socio-economic backgrounds. However, the differences in performance are smaller in the United States than in Germany and Norway, for example. Spanish immigrants have, on average, the lowest ESCS values, and Portugal is the only country in which the natives achieve higher PISA values despite worse socio-economic backgrounds, although the gap is not significantly different from zero. Such specific challenges must be taken into account in an international efficiency analysis of educational systems. Tables S2 to S4 in the appendix provide descriptive results for the individual PISA scores. All scores are greater than zero and students with missing values are excluded from our analyses.

We use regressions to gauge the relationship between students' average educational performance and their socio-economic endowments for each country separately. The regressions include both a dummy for immigrant background and an interaction term. The results indicate that performance gaps between immigrants and natives are determined strongly by their respective ESCS endowments. Increasing ESCS values have the highest positive impact in France and lowest in Spain and Italy. The results indicate a significantly better performance of immigrants in

Australia, Canada and Singapore and a positive but insignificant relationship in Israel and the United States of America. In all other countries, immigrants perform significantly worse than natives. All results can be provided upon request.

5 Efficiency Results and Efficiency Decomposition

All results are obtained using R (version 3.6) and, unless otherwise stated, the average PISA results are used as output. The efficiency scores indicate how relatively well the students perform, given their socio-economic backgrounds. First, the results are decomposed relative to national and then international frontiers, followed by a comparison of the performance of natives and immigrants, and finally, the impact of the selection processes and the efficiency of educational systems are evaluated.

5.1 National frontiers

Table 3 provides country-specific arithmetic mean efficiency scores for all students, for the student groups rel-

Table 3: Decomposition, national students and national frontiers, average PISA scores as output

	(1)	(2)	(3)	(4)	(5)
	$M^{\mathcal{H}_k}(\mathcal{H}_k)$	$M^{\mathcal{J}_k}(\mathcal{J}_k)$	$M^{\mathcal{E}_k}(\mathcal{H}_k)$	$M^{\mathcal{E}_k}(\mathcal{J}_k)$	$M^{\mathcal{E}_k}(\mathcal{E}_k)$
AU	0.665	0.707	0.665	0.684	0.669
AT	0.694	0.673	0.694	0.649	0.686
BE	0.704	0.706	0.704	0.661	0.697
CA	0.681	0.702	0.680	0.688	0.682
DK	0.727	0.690	0.726	0.668	0.712
FI	0.724	0.701	0.724	0.652	0.721
FR	0.703	0.703	0.702	0.669	0.698
DE	0.716	0.708	0.716	0.669	0.708
IL	0.645	0.699	0.645	0.651	0.646
IT	0.707	0.714	0.707	0.657	0.703
NL	0.707	0.706	0.707	0.664	0.703
NZ	0.696	0.706	0.693	0.692	0.693
NO	0.707	0.726	0.707	0.682	0.704
PT	0.709	0.733	0.709	0.699	0.708
SG	0.699	0.753	0.699	0.711	0.701
ES	0.729	0.727	0.729	0.690	0.725
SE	0.684	0.700	0.684	0.636	0.676
CH	0.725	0.691	0.724	0.684	0.712
GB	0.693	0.701	0.693	0.683	0.692
US	0.671	0.721	0.670	0.691	0.675
Mean	0.699	0.708	0.699	0.674	0.696

ative to both national frontiers, and comparisons between the groups. The column numbers are given above the formal terms to simplify the interpretation.

The initial descriptive results showed that natives have higher average PISA scores (see Table 2 and Figure 4), but they disregard the socio-economic backgrounds of the students, that are taken into account in the efficiency analysis. Column (1) and (2) of Table 3 contain the results of natives and immigrants relative to their respective frontiers for each country. Across all countries, both groups of students are on average almost equally efficient (0.699 in column (1) to 0.708 in column (2)) if compared to their benchmark students from their group.

Columns 3 and 4 of Table 3 show the average efficiency scores when using the national frontier based on both subsets of students. We observe that there are hardly any changes among the natives, if immigrants are also taken into account when calculating the efficient frontier. In contrast, the performance of immigrants decreases when natives are taken into account as revealed by the comparison of column (2) and (4).

Natives outperform immigrants on average by $(M^{\mathcal{E}_k}(\mathcal{H}_k) - M^{\mathcal{E}_k}(\mathcal{J}_k)) \cdot 100 = 5.741\%$ in Denmark, by 7.188% in Finland, and by 5.009% in Italy. Natives also perform better in most countries, but the gaps are not as large as in the previous countries and range from 0.100% in New Zealand to 4.774% in Sweden. In all these countries, immigrants perform far worse, according to their efficiency scores, taking into account their socio-economic endowment. The educational systems do not succeed in fostering both groups equally, which leads to inequalities in educational performance beyond the differences due to their endowments.

In Australia, Canada, Israel, Singapore, and the United States, immigrants perform on average better than their native peer group, considering their efficiency based on ESCS endowments. In the United States, immigrants perform best relative to the natives. The performance difference is 2.066%. In Israel both groups perform similarly, immigrants being slightly better (0.613%).

Column 5 of Table 3 provides the mean efficiency scores for all students, based on their own frontiers for each country. Israel achieves the lowest (0.646) and Spain the highest (0.725) mean. Since the efficiency frontiers are country- and group-specific, they are rather a measure of inequality than a means of comparing efficiency between countries. Table 3 does not provide any information on which students form the efficiency frontiers, and how efficient the national educational systems are.

Figure S5 in the appendix displays the frontiers for each student group within the countries and the interna-

tional frontier, calculated for all students. In several countries, the best-performing students are immigrants for low ESCS values and natives for higher ESCS values (e.g. in Austria, France, Germany, and the United States). In the remaining countries, only natives constitute the efficiency frontier, as is the case in Finland, Portugal, Singapore, Spain, and the United Kingdom. It is striking that the students in Portugal, Singapore, and Spain have input-output combinations that are on average far less distant from the international efficiency frontier than in the other countries. Therefore, these countries are among the top performers in our analysis.

5.2 International comparisons

Including all students, Figure S5 shows that the international efficiency frontier for low ESCS values consists of three Spanish native speakers (one of whom has the lowest ESCS value in the sample), followed by one Portuguese and one Singaporean native speaker (with the highest average PISA value).⁹

Table 4 provides further within and between-country comparisons. $M^{\mathcal{E}}(\mathcal{H}_k)$ is the average score of the native students of country k , $M^{\mathcal{E}}(\mathcal{J}_k)$ is the average efficiency of its immigrant students, and $M^{\mathcal{E}}(\mathcal{E}_k)$ is the mean efficiency of all of students from country k with respect to the international frontier of all students.

Columns 1 and 2 show how well each group performs within each country, and allows within-country comparisons relative to the international frontier consisting of all students. Compared to their native peer group, immigrants perform best in Australia (on average 1.977% better), followed by the United States (1.558%), and Singapore (1.415%). The countries where natives perform best compared to immigrants are Finland (on average 6.646% better), Sweden (5.476%), and Denmark (5.277%).

The results so far have been group-specific. Column 3, on the other hand, provides a comparisons of the efficiencies of the national educational systems. The values result from an international frontier and do not differentiate between natives and immigrants within countries. The mean inefficiencies show how much the average PISA scores of a country could be increased, if its educational system were to enable students to perform similarly to the most efficient international students with comparable ESCS endow-

⁹ Using an output-oriented BBC-model with one input and one output, and variable returns to scale, the student with the highest output value must be efficient by construction.

Figure 5: Arithmetic mean efficiency differences between native and immigrant students in each country relative to the international frontier

Table 4: Decomposition, national students and international frontier, average PISA scores as output

	(1)	(2)	(3)
	$M^E(\mathcal{I}_k)$	$M^E(\mathcal{J}_k)$	$M^E(\mathcal{E}_k)$
AU	0.619	0.638	0.623
AT	0.639	0.590	0.630
BE	0.652	0.603	0.644
CA	0.637	0.645	0.639
DK	0.630	0.577	0.617
FI	0.660	0.594	0.658
FR	0.652	0.615	0.647
DE	0.667	0.624	0.660
IL	0.602	0.604	0.603
IT	0.644	0.603	0.641
NL	0.648	0.606	0.644
NZ	0.643	0.643	0.643
NO	0.631	0.602	0.627
PT	0.663	0.649	0.662
SG	0.696	0.710	0.698
ES	0.672	0.652	0.669
SE	0.632	0.578	0.624
CH	0.652	0.619	0.642
GB	0.632	0.622	0.630
US	0.623	0.638	0.626
Mean	0.645	0.621	0.641

ments. The average inefficiencies over the entire sample are 35.9%. The country with the highest mean efficiency is Singapore. In Finland, Germany, Portugal, and Spain, the mean efficiency scores are also relatively large. The highest inefficiencies exist in Israel and Denmark, given the ESCS backgrounds of their respective students.

5.3 Differences between immigrants and natives

Figure 5 shows the differences between the arithmetic means of students with and without immigration back-

ground, relative to the countries' frontiers, providing an overview of the within-country differences. By including the ESCS as input, our analysis takes into account the socio-economic endowment of the students. Selection effects that result in high or low ESCS scores should therefore not influence the efficiency scores, given the ESCS input levels.

The efficiency gaps between the groups are smallest in Canada (−0.008), Israel (−0.006), New Zealand (0.001), and Portugal (0.010). In the other countries, the differences are greater than 1%. In all European countries and especially in Sweden (0.048), Denmark (0.057), and Finland (0.072), the immigrant students perform on average considerably worse than their native counterparts given their ESCS backgrounds. Finland is often regarded as a country with a superior educational system and integration success, but according to the efficiency scores the educational system in Finland is highly inefficient in closing the gap between natives and immigrants. Recent literature confirms these performance deficits of immigrants in Finland, taking into account background factors such as gender, grades, socio-economic background, home language and age of arrival in Finland (Kirjavainen (2015); Yeasmin & Uusiautti (2018)). However, these results have not yet attracted much attention in recent literature. Arikan et al. (2017), for example, claim that reducing the ESCS gap would close the performance gap between natives and immigrants in Finland, but our results indicate that especially an efficient use of the ESCS endowment is more important than the low ESCS levels (Arikan et al., 2017). We argue that the sole use of PISA results in native immigrant comparisons mainly reflects selection effects due to different immigration policies, rather than an analysis of the educational systems. Given the social structure of immigrants (and natives) we evaluate the educational systems according their ability to transform social endowments into good PISA results.

Figure 6: Country rankings based on mean PISA scores of immigrants and of mean efficiency

5.4 Selection effects and educational efficiency

In the upper line of Figure 6, the countries are arranged in descending order according to their immigrants' average PISA scores. The order is solely based on the absolute performance of immigrants in PISA. Here, the efficient countries are characterised by a strict immigration policy, selecting immigrants who achieve the highest PISA levels. In the lower line, the countries are ordered according to their immigrants' average efficiency relative to the international frontier ($M^E(J_k)$). Thus, the countries are ranked according to their students' performance, given their ESCS endowments. Therefore, the impact of selection procedures is to a large extent controlled for, and the ranking reveals how successfully educational systems use the ESCS endowment.

The arrows indicate the rank changes. In both analyses, students perform best in Singapore and worst in Denmark. The ranks of all other countries change due to taking the ESCS endowment into account. Without regarding the ESCS endowment (upper ranking), countries with strongly selective immigration systems rank second to fifth. Taking into account the socio-economic backgrounds of their stu-

dents (lower ranking), their ranks deteriorate to four, five, six and nine. This indicates that simple PISA score comparisons examine rather immigration policy and less so the efficiency of educational systems.

Austria, Denmark and Sweden are the countries where immigrants perform worst according to their average DEA scores. Given the socio-economic background of their students, these countries could achieve much higher PISA scores, if they were to adapt their educational systems to those of the efficient countries.

Without including the ESCS as input, immigrants in Spain perform relatively poorly, but on average they perform very well regarding their efficiency. France (five ranks), Italy (four), and Portugal (three) are also countries which improve their rankings compared to the simple PISA score comparison. Regarding their socio-economic backgrounds, these three countries have relatively less favourable immigrant compositions, but their educational systems are relatively more efficient than in most other countries. Our analysis shows that, despite a very large educational gap (see Table 2), the French school system performs well on average, because it at least partially compensates for the large differences in the socio-economic background of immigrants. While most countries lose up

Table 5: Correlation coefficients between the efficiency scores for the average PISA score and the three PISA scores as outputs

	$M^{\mathcal{H}_k}(\mathcal{H}_k)$	$M^{\mathcal{J}_k}(\mathcal{J}_k)$	$M^{\mathcal{E}_k}(\mathcal{H}_k)$	$M^{\mathcal{E}_k}(\mathcal{J}_k)$	$M^{\mathcal{E}_k}(\mathcal{E}_k)$	$M^{\mathcal{H}_k}(\mathcal{H})$	$M^{\mathcal{J}_k}(\mathcal{J})$	$M^{\mathcal{E}_k}(\mathcal{E})$
AU	0.985	0.983	0.985	0.984	0.985	0.986	0.986	0.986
AT	0.981	0.978	0.981	0.980	0.981	0.987	0.985	0.987
BE	0.988	0.990	0.988	0.990	0.989	0.988	0.989	0.988
CA	0.983	0.984	0.984	0.983	0.984	0.986	0.986	0.986
DK	0.985	0.974	0.985	0.979	0.984	0.983	0.980	0.983
FI	0.981	0.961	0.981	0.972	0.981	0.986	0.979	0.986
FR	0.985	0.985	0.985	0.988	0.985	0.988	0.991	0.988
DE	0.984	0.981	0.984	0.981	0.983	0.987	0.985	0.986
IL	0.981	0.985	0.981	0.981	0.981	0.986	0.987	0.986
IT	0.982	0.972	0.982	0.980	0.982	0.983	0.979	0.983
NL	0.987	0.983	0.987	0.986	0.987	0.990	0.989	0.990
NZ	0.985	0.981	0.984	0.980	0.983	0.986	0.986	0.986
NO	0.984	0.974	0.984	0.979	0.983	0.984	0.978	0.983
PT	0.989	0.975	0.990	0.986	0.990	0.989	0.986	0.989
SG	0.983	0.983	0.985	0.978	0.984	0.988	0.981	0.986
ES	0.987	0.977	0.987	0.986	0.987	0.988	0.989	0.989
SE	0.975	0.979	0.974	0.978	0.976	0.983	0.980	0.983
CH	0.986	0.985	0.987	0.988	0.988	0.983	0.985	0.984
GB	0.986	0.978	0.986	0.982	0.985	0.987	0.985	0.987
US	0.982	0.986	0.982	0.982	0.982	0.989	0.989	0.989

to three ranks, Israel (nine), and the United Kingdom (four) are far worse ranked, indicating relatively poorly performing educational systems. Immigrants in Denmark perform worst both when their ESCS endowment is considered and when it is not considered.

5.5 PISA scores as separate outputs

The DEA allows the inclusion of separate outputs that are simultaneously included in the efficiency assessment. In this section, students are assessed on the basis of their ability to maximize the three PISA scores, given their ESCS end-points. Model (2) allows for specialisation so that the efficiency of students focusing on a subset of the three abilities is adequately taken into account. Tables S6 and S7 in the appendix contain the decomposition of the efficiency results for national and international frontiers.

The efficiency scores of the average PISA score and three separated PISA scores as outputs are highly positively correlated. The Pearson correlation coefficient between the DEAs are 0.984 for $M^{\mathcal{H}_k}(\mathcal{H}_k)$, 0.981 for $M^{\mathcal{J}_k}(\mathcal{J}_k)$, and 0.984 for $M^{\mathcal{E}_k}(\mathcal{E}_k)$. Table 5 provides the correlation coefficients of the efficiency scores based on the aggregated output and that of the three outputs for each country.

The inclusion of the separated PISA scores as outputs allows the DEA model to weight the outputs separately and thus to calculate overall higher efficiency scores. The similarity of the results to those of the previous analysis shows that students who perform well on average also perform quite well in the individual PISA subjects. These results confirm that immigrants in countries with restrictive immigration regime perform relatively better than in other countries and that immigrants in Spain, Portugal, and Singapore perform relatively best given their socio-economic endowments.

6 Conclusion

Our analysis focuses on the abilities of the national educational systems to integrate immigrants, given their socio-economic backgrounds. Country-specific means of efficiency scores based on national frontiers reveal that in Denmark, Finland, and Sweden, native students perform substantially better than immigrants. In Australia, Canada, Israel, Singapore, and the United States, immigrants are more efficient than their native peer group.

Relative to the international frontier consisting of all students and compared to their native peer groups, immi-

grants in Australia, Singapore, and the United States perform relatively best. The opposite is true in Finland, Sweden, and Denmark.

Even if the differences in the socio-economic endowment of the students are taken into account, differences between natives and immigrants persist. According to PISA scores, as well as the efficiency scores, in most countries with more selective immigration regimes, immigrants perform on average similar or even better than natives. The persistent differences are somewhat surprising, as the broad ESCS should capture the most relevant socio-economic factors.

We find that the Spanish educational system is relatively best in increasing immigrants' performance, and Israel's system is worst, given the respective socio-economic backgrounds of their immigrants. Australia, Canada, the United Kingdom, and New Zealand are countries with selective immigration policies, which attract immigrants who perform relatively better or almost as well as their natives. If, however, the socio-economic backgrounds are taken into account, the immigrants in these countries perform on average worse than in Spain and Portugal. The latter have low PISA values, but highly efficient education systems.

The result that countries with relatively selective immigrant policies perform not only well in absolute PISA scores, but are also quite efficient given their ESCS input levels, is truly astonishing. This result implies that the selection process not only affects ESCS levels, but also the immigrant capacity to use their endowments efficiently.

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Supplementary results

Figure S1: Country-level average PISA scores relative to the average ESCS scores and mean absolute deviations from the median ESCS scores; left: average scores, right: average PISA scores and mean absolute deviations from the median ESCS scores

Table S1: Excluded outliers

	Amount	Percentage
Australia	151	1.079
Austria	67	0.966
Belgium	77	0.815
Canada	207	1.066
Denmark	67	0.959
Finland	67	1.153
France	52	0.875
Germany	57	1.012
Israel	72	1.108
Italy	110	0.971
Netherlands	59	1.108
New Zealand	49	1.131
Norway	56	1.059
Portugal	65	0.900
Singapore	60	0.985
Spain	53	0.794
Sweden	63	1.186
Switzerland	44	0.759
United Kingdom	115	0.851
United States of America	51	0.905

Table S2: Descriptive results of the PISA mathematics scores

Countries	Group	Min	Max	Median	Mean	Sd.	n
AU	Nat	166.883	800.542	484.679	483.382	91.113	10744
	Mig	225.436	757.799	505.180	504.928	91.018	2651
AT	Nat	193.875	797.841	516.602	512.318	88.728	5533
	Mig	170.358	731.659	446.329	448.960	84.998	1242
BE	Nat	197.540	818.559	529.075	523.481	90.932	7684
	Mig	237.039	727.384	468.027	468.323	90.944	1445
CA	Nat	218.370	807.652	504.818	504.624	81.876	14555
	Mig	261.416	810.875	516.563	517.336	83.974	4057
DK	Nat	266.826	751.205	518.059	516.057	76.720	5224
	Mig	213.486	700.433	455.982	457.803	74.074	1567
FI	Nat	245.949	751.693	516.953	515.419	78.857	5495
	Mig	208.933	695.899	457.889	466.733	88.732	200
FR	Nat	197.621	765.411	515.105	507.942	91.081	5089
	Mig	200.976	723.209	455.736	456.625	96.992	706
DE	Nat	227.368	803.717	524.496	522.885	85.158	4614
	Mig	218.142	715.613	475.107	475.467	84.294	881
IL	Nat	147.251	776.097	479.573	476.417	98.822	5223
	Mig	122.084	728.409	476.589	471.336	103.668	1023
IT	Nat	171.668	792.029	505.564	503.999	87.043	10199
	Mig	224.551	674.787	459.160	458.088	82.293	867
NL	Nat	203.188	783.104	528.884	523.470	87.652	4587
	Mig	229.374	689.471	473.280	470.753	87.335	504
NZ	Nat	248.467	768.730	497.402	497.696	86.419	3031
	Mig	249.591	766.447	511.344	508.374	94.368	1075
NO	Nat	240.418	748.189	507.671	507.450	82.138	4535
	Mig	264.560	702.677	469.598	471.186	77.707	616
PT	Nat	157.556	783.224	485.353	483.819	95.255	6647
	Mig	214.974	702.556	470.405	474.209	93.780	416
SG	Nat	242.225	847.230	555.887	552.496	93.070	4734
	Mig	293.152	842.615	591.471	584.756	88.716	1164
ES	Nat	244.435	752.071	499.491	496.916	79.837	5808
	Mig	226.047	690.859	454.489	455.834	79.728	664
SE	Nat	206.226	771.176	507.830	507.146	82.513	4311
	Mig	221.587	712.981	451.156	452.016	84.530	819
CH	Nat	254.399	800.594	539.532	536.024	87.237	3907
	Mig	183.867	779.058	486.424	488.177	90.664	1711
GB	Nat	185.785	769.712	495.911	494.442	84.650	11329
	Mig	205.712	729.779	492.467	488.871	91.280	1607
US	Nat	204.268	766.785	477.317	477.480	85.992	4153
	Mig	227.198	720.594	458.297	457.413	84.894	1215

Table S3: Descriptive results of the PISA science scores

Countries	Group	Min	Max	Median	Mean	Sd.	n
AU	Nat	191.045	833.478	504.560	501.608	100.573	10744
	Mig	227.272	803.415	519.730	515.728	100.702	2651
AT	Nat	227.032	826.725	513.994	511.576	91.553	5533
	Mig	204.623	741.154	443.153	447.522	86.996	1242
BE	Nat	231.127	813.512	525.989	518.910	94.424	7684
	Mig	210.139	711.469	459.965	461.836	96.402	1445
CA	Nat	213.671	821.825	521.184	519.625	88.046	14555
	Mig	250.632	828.142	526.060	523.003	91.824	4057
DK	Nat	202.866	758.113	507.808	507.843	86.583	5224
	Mig	219.308	731.502	430.812	432.864	85.046	1567
FI	Nat	232.233	852.902	540.267	537.439	92.260	5495
	Mig	239.698	735.533	462.255	462.091	96.635	200
FR	Nat	226.574	784.065	517.705	511.625	95.790	5089
	Mig	189.502	746.084	451.341	453.775	100.996	706
DE	Nat	253.093	810.494	536.333	531.437	92.732	4614
	Mig	188.335	781.910	464.048	467.684	92.284	881
IL	Nat	181.542	825.603	476.171	476.777	102.558	5223
	Mig	116.428	742.017	471.508	470.807	105.217	1023
IT	Nat	209.030	772.320	502.760	498.819	86.628	10199
	Mig	219.710	711.228	451.098	449.931	82.727	867
NL	Nat	233.621	786.983	525.554	520.158	96.996	4587
	Mig	225.921	685.571	468.732	461.069	93.907	504
NZ	Nat	245.909	795.682	525.200	521.620	97.949	3031
	Mig	185.943	800.925	521.780	518.146	108.474	1075
NO	Nat	204.571	819.329	509.873	508.423	92.275	4535
	Mig	247.333	699.818	458.451	460.458	87.591	616
PT	Nat	195.810	781.855	491.015	490.120	91.883	6647
	Mig	252.490	726.540	482.707	488.197	87.464	416
SG	Nat	248.752	870.020	549.887	542.634	101.790	4734
	Mig	265.541	835.631	580.107	574.010	97.278	1164
ES	Nat	230.400	740.724	506.647	503.965	82.564	5808
	Mig	226.049	724.153	457.635	460.772	85.888	664
SE	Nat	166.987	845.611	511.242	508.842	95.297	4311
	Mig	165.070	739.310	437.695	440.494	96.810	819
CH	Nat	242.234	771.501	525.921	522.781	90.129	3907
	Mig	219.737	750.943	459.952	465.410	94.428	1711
GB	Nat	214.389	807.431	511.242	509.452	93.702	11329
	Mig	271.842	792.647	495.884	497.483	97.426	1607
US	Nat	238.079	806.788	504.314	505.552	95.449	4153
	Mig	239.927	737.466	475.062	477.650	91.942	1215

Table S4: Descriptive results of the PISA reading scores

Countries	Group	Min	Max	Median	Mean	Sd.	n
AU	Nat	96.374	832.034	497.103	491.976	101.709	10744
	Mig	169.719	800.578	519.464	512.925	102.203	2651
AT	Nat	131.917	762.012	506.123	499.912	94.060	5533
	Mig	183.376	712.661	447.364	447.287	94.479	1242
BE	Nat	205.263	807.437	524.693	515.790	93.568	7684
	Mig	184.550	720.464	468.211	465.703	96.005	1445
CA	Nat	223.017	798.814	520.883	517.968	87.553	14555
	Mig	219.633	812.414	526.823	523.367	91.836	4057
DK	Nat	213.575	781.762	509.405	505.788	83.225	5224
	Mig	192.824	713.168	440.661	443.598	83.058	1567
FI	Nat	200.763	778.198	538.810	533.374	86.657	5495
	Mig	194.514	716.262	474.596	465.347	99.653	200
FR	Nat	169.224	850.750	524.294	515.017	103.111	5089
	Mig	181.602	753.531	474.086	466.058	110.194	706
DE	Nat	201.098	808.879	538.702	530.944	92.075	4614
	Mig	171.798	749.074	481.730	479.852	97.112	881
IL	Nat	123.358	861.854	496.734	490.971	109.097	5223
	Mig	161.619	781.152	491.460	482.487	107.601	1023
IT	Nat	218.244	766.463	507.069	502.664	85.794	10199
	Mig	185.012	676.707	448.731	444.028	86.843	867
NL	Nat	151.081	778.437	521.125	513.710	96.334	4587
	Mig	176.822	741.653	470.805	465.394	93.320	504
NZ	Nat	169.027	810.103	520.348	516.821	99.665	3031
	Mig	231.686	811.821	520.667	514.233	107.019	1075
NO	Nat	183.062	807.994	528.604	523.727	94.026	4535
	Mig	239.430	777.681	494.664	490.283	93.814	616
PT	Nat	159.732	773.769	492.554	488.197	91.653	6647
	Mig	216.284	723.842	500.284	495.196	91.901	416
SG	Nat	230.626	818.352	529.974	522.078	97.500	4734
	Mig	162.940	782.729	560.674	551.459	92.967	1164
ES	Nat	161.767	767.832	511.244	505.802	81.443	5808
	Mig	162.794	708.353	475.377	470.201	90.464	664
SE	Nat	181.227	826.607	520.679	515.129	94.084	4311
	Mig	127.785	756.546	465.677	461.219	99.536	819
CH	Nat	204.781	771.608	510.955	506.492	90.407	3907
	Mig	192.295	747.702	456.481	458.481	94.613	1711
GB	Nat	213.622	846.678	503.169	501.540	89.369	11329
	Mig	186.130	794.240	487.340	489.179	94.946	1607
US	Nat	198.408	772.617	508.019	503.818	95.449	4153
	Mig	181.668	742.142	491.332	487.206	98.431	1215

Table S5: PISA scores correlation coefficients

	Mathematics–Reading	Mathematics–Science	Reading–Science
AU	0.789	0.879	0.872
AT	0.794	0.886	0.864
BE	0.834	0.891	0.897
CA	0.766	0.878	0.865
DK	0.769	0.874	0.863
FI	0.783	0.863	0.861
FR	0.828	0.899	0.892
DE	0.796	0.885	0.856
IL	0.823	0.887	0.892
IT	0.743	0.849	0.829
NL	0.860	0.899	0.891
NZ	0.772	0.884	0.866
NO	0.778	0.885	0.836
PT	0.806	0.889	0.862
SG	0.829	0.890	0.908
ES	0.756	0.888	0.847
SE	0.756	0.881	0.828
CH	0.801	0.882	0.871
GB	0.783	0.879	0.869
US	0.826	0.890	0.889

Table S6: Decomposition, national students and national frontiers, three PISA scores as outputs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$M^{\mathcal{I}_k}(\mathcal{I}_k)$	$M^{\mathcal{J}_k}(\mathcal{J}_k)$	$M^{\mathcal{E}_k}(\mathcal{I}_k)$	$M^{\mathcal{E}_k}(\mathcal{J}_k)$	$M^{\mathcal{E}_k}(\mathcal{E}_k)$	$\left(\frac{M^{\mathcal{J}_k}(\mathcal{J}_k)}{M^{\mathcal{I}_k}(\mathcal{I}_k)} \cdot \frac{M^{\mathcal{I}_k}(\mathcal{I}_k)}{M^{\mathcal{J}_k}(\mathcal{J}_k)}\right)^{\frac{1}{2}}$	$\frac{M^{\mathcal{E}_k}(\mathcal{I}_k)}{M^{\mathcal{E}_k}(\mathcal{J}_k)}$
AU	0.681	0.725	0.680	0.701	0.684	0.970	0.970
AT	0.715	0.704	0.715	0.668	0.706	1.074	1.071
BE	0.718	0.721	0.718	0.672	0.710	1.076	1.068
CA	0.700	0.718	0.698	0.708	0.700	0.986	0.986
DK	0.744	0.718	0.742	0.688	0.730	1.081	1.079
FI	0.744	0.739	0.744	0.676	0.741	1.101	1.101
FR	0.716	0.717	0.716	0.679	0.711	1.059	1.055
DE	0.731	0.725	0.730	0.686	0.723	1.069	1.065
IL	0.670	0.714	0.669	0.675	0.670	0.992	0.991
IT	0.722	0.736	0.722	0.671	0.718	1.080	1.075
NL	0.726	0.734	0.725	0.683	0.721	1.072	1.062
NZ	0.714	0.730	0.711	0.713	0.712	0.999	0.997
NO	0.724	0.753	0.724	0.703	0.721	1.034	1.029
PT	0.717	0.761	0.717	0.713	0.716	1.009	1.005
SG	0.717	0.770	0.716	0.736	0.720	0.977	0.974
ES	0.742	0.751	0.742	0.703	0.738	1.053	1.054
SE	0.710	0.719	0.709	0.657	0.700	1.080	1.078
CH	0.738	0.710	0.735	0.696	0.723	1.049	1.057
GB	0.709	0.720	0.708	0.701	0.707	1.010	1.010
US	0.691	0.734	0.690	0.708	0.694	0.978	0.975
Mean	0.716	0.730	0.716	0.692	0.712	1.037	1.035

Figure S2: Mathematics scores distributions among natives (straight line) and immigrants (dashed line)

Figure S3: Science scores distributions among natives (straight line) and immigrants (dashed line)

Figure S4: Read scores distributions among natives (straight line) and immigrants (dashed line)

Figure S5: Efficiency frontiers

Table S7: Decomposition, national students and international frontier, three PISA scores as outputs

	(1)	(2)	(3)	(4)	(5)	(6)
	$M^{\mathcal{E}}(\mathcal{H}_k)$	$M^{\mathcal{E}}(\mathcal{J}_k)$	$M^{\mathcal{E}}(\mathcal{E}_k)$	$\frac{M^{\mathcal{E}}(\mathcal{H}_k)}{M^{\mathcal{E}}(\mathcal{E})}$	$\frac{M^{\mathcal{E}}(\mathcal{J}_k)}{M^{\mathcal{E}}(\mathcal{E})}$	$\frac{M^{\mathcal{E}}(\mathcal{E}_k)}{M^{\mathcal{E}}(\mathcal{E})}$
AU	0.635	0.656	0.639	0.968	1.000	0.974
AT	0.655	0.606	0.646	0.999	0.923	0.984
BE	0.668	0.617	0.659	1.018	0.941	1.005
CA	0.654	0.664	0.656	0.997	1.012	1.000
DK	0.650	0.597	0.637	0.991	0.910	0.972
FI	0.677	0.612	0.675	1.033	0.933	1.029
FR	0.667	0.625	0.662	1.017	0.952	1.009
DE	0.684	0.639	0.676	1.042	0.974	1.031
IL	0.620	0.621	0.620	0.946	0.946	0.946
IT	0.662	0.620	0.659	1.010	0.944	1.004
NL	0.663	0.619	0.659	1.011	0.943	1.004
NZ	0.661	0.660	0.661	1.007	1.007	1.007
NO	0.652	0.627	0.649	0.994	0.955	0.989
PT	0.674	0.666	0.673	1.027	1.016	1.026
SG	0.710	0.731	0.714	1.082	1.114	1.088
ES	0.684	0.662	0.682	1.043	1.010	1.039
SE	0.654	0.601	0.645	0.997	0.916	0.983
CH	0.672	0.635	0.660	1.024	0.968	1.007
GB	0.646	0.638	0.645	0.985	0.973	0.984
US	0.637	0.650	0.640	0.970	0.991	0.975
Mean	0.661	0.637	0.658	1.008	0.971	1.003