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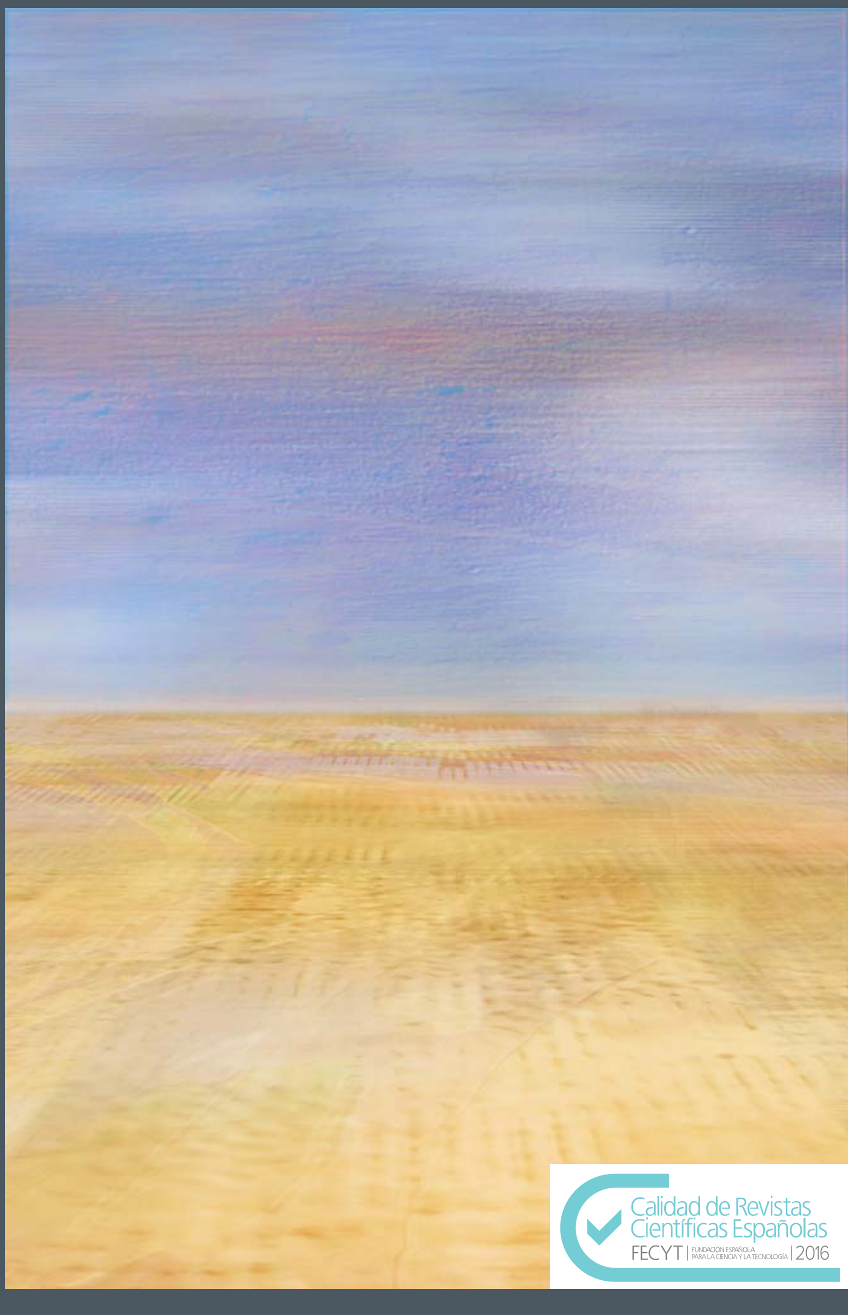

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Comparison of educational efficiency in Europe and Asia: TIMMS 2015

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Abstract

The publication of the last TIMSS' report (2017) embosses the necessity to keep performing studies that value comparatively the patterns followed by different countries, to introduce improvements that mean developments on the learning systems. Educational politics need data to fundament their positions on changes that will facilitate the professional and social development of the population. The objective of the article is to perform a comparative study of the educative efficiency of countries from two very cultural separated continents but with formative qualifications, in occasions, very nearby. Primarily, there will be obtained the levels of efficiency in mathematics and science between only European countries, then, the sample will be enlarged with Asian countries to check which one of these highlights against the Europeans. The empirical analysis will be performed through the technic DEA from TIMSS corresponding to 2015. The results show pretty high efficiency levels on the simple of European countries, therefore, with little effort they could reach the maximum level. England, Russia and Norway highlight as countries completely efficient on both subjects and analyzed degrees. When introducing on the analysis the Asian countries, the variability of the simple increases and only Norway and England are capable of competing and keeping themselves on the maximum levels of efficiency besides the Asians placed on the first positions of TIMSS, such as Singapore or Korea. Therefore, in some countries coincidences between the TIMSS valuations and the efficiency level obtained are accomplished, such as Russia, Korea, England, Japan, Singapore or Hong Kong. Nevertheless, other not so well valued countries

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obtain high efficiency levels, proving the necessity to increase the use of inputs to improve the academic performance, like in the case of Kuwait

Key words: Education, science, mathematics, TIMSS, efficiency, comparative international

Resumen

La publicación del último informe de TIMSS (2017) pone de relieve la necesidad de seguir realizando estudios que valoren comparativamente los patrones seguidos por distintos países, para introducir mejoras que supongan avances en los sistemas de aprendizaje. Las políticas de educación necesitan datos para fundamentar sus posiciones ante cambios que faciliten el desarrollo profesional y social de la población. El objetivo del artículo es realizar un estudio comparativo de la eficiencia educativa de los países de dos continentes culturalmente muy separados pero con calificaciones formativas, en ocasiones, muy cercanas. Primeramente, se obtienen los niveles de eficiencia en matemáticas y ciencias entre solo países de Europa, y a continuación se amplia la muestra con países asiáticos para comprobar cuáles de estos últimos destaca frente a los europeos. El análisis empírico es realizado mediante la técnica Análisis Envolvente de Datos (DEA) a partir de TIMSS correspondiente a 2015. Los resultados muestran unos niveles de eficiencia bastante altos en la muestra de solo países europeos, por tanto, con poco esfuerzo podrían alcanzar el nivel máximo. Destacan Inglaterra, Rusia y Noruega como países completamente eficientes en ambas materias y grados analizados. Al introducir en el análisis los países asiáticos aumenta la variabilidad de la muestra y tan sólo Noruega e Inglaterra son capaces de competir y mantenerse en los niveles máximos de eficiencia junto con los asiáticos situados en las primeras posiciones de TIMSS, como Singapur o Corea. Por tanto, en algunos países se cumplen las coincidencias entre las valoraciones de TIMSS y el nivel de eficiencia alcanzado, tal es el caso de Rusia, Corea, Inglaterra, Japón, Singapur u Hong Kong. Sin embargo, otros países no tan bien valorados obtienen altos niveles de eficiencia, demostrando la necesidad de aumentar la utilización de inputs para mejora el rendimiento académico, como es el caso de Kuwait.

Palabras clave: Educación, ciencias, matemáticas, TIMSS, eficiencia, comparativa internacional

Problem statement

Political pressure to evaluate student performance has led to the emergence of education evaluation systems that periodically provide information about the international situation of learning processes. These allow inter-country comparisons to be made and are used as a relative measure of the current global quality of education. According to the OECD (Organisation for Economic Cooperation and Development), educational results depend on many more factors than simply the *per capita* income of a country. As such, all nations could improve student performance if they were to implement suitable policies. The foremost international evaluation programmes are the PISA report (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study). Both contain useful information for governments, enabling them to evaluate the returns on investments in education.

PISA is a project that has been sponsored by the OECD since the end of the 1990s. Its aim is to evaluate the skills acquired by 15-year-old students during their learning process, generating indicators that enable a quantification of the degree of knowledge acquisition. The data provided by TIMSS have been updated every four years since 1995, similarly facilitating international comparisons of education at regional or national level. The TIMSS project evaluates student performance in mathematics and science, quantifying the scope of learning in these two subjects, as well as the context in which it occurs. It seeks to identify factors directly related to the study that can be influenced by education policies, such as the curriculum, the allocation of resources or teaching practices (Acevedo, 2005). Thus, both of these evaluation programmes assess core competencies, like reading comprehension, mathematics and science, presented in terms of a comparison of the average scores achieved by countries; however, they apply different criteria, which means that they may sometimes give rise to diverging conclusions about the same population (Jornet and Backhoff, 2004).

The literature contains a number of national-level studies that use TIMSS data to carry out comparative analyses of different geographical areas. Specifically, Cordero and Manchón (2014) identify the main explanatory variables of the mathematics results achieved by Grade 4 Spanish students, using data from TIMSS 2011. They draw the following conclusions: it is important to start primary school at a suitable age; reading books should be encouraged; and the more experience the teaching staff have, the better the academic results. In the same line of research, Santín and Sicilia (2014) apply DEA to analyse efficiency in primary education, showing that the centres evaluated could improve their results by 12% on average, given their current allocation of education resources.

Similarly, at an international level, Giménez et al. (2003) use information sourced from TIMSS 1999 to evaluate the efficiency and effective-

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ness of the education system in 31 countries, finding that Asian countries are better at managing their education systems. Other developed nations such as Austria and Canada are shown to be inefficient, and thus have some potential to improve their results. A 2016 study by the same authors uses data from TIMSS 2007 and 2011 to calculate the efficiency of the education systems of 28 countries, through a dynamic approach. Overall, they find a deterioration in the average performance of all the education systems analysed, with only Italy and Singapore improving their results.

Within this line of research, the present paper sets out several aims. First, it seeks to determine educational efficiency in mathematics and science in European countries, testing for significant differences between the two subjects in Grades 4 and 8. Second, the sample is extended to include countries from the Asian continent (Middle East and Asia) and a similar analysis is carried out to establish whether Asian countries are genuine rivals in the field of education, checking which of them compare favourably to European countries. The study is based on data from 2015, sourced from the TIMSS database published in 2017.

The rest of the article is structured as follows. Section 2 describes the main features that differentiate the Asian and European education systems, which are the focus of this study. Section 3 presents the method used to measure efficiency, as well as the sample and variables employed in the empirical analysis. Section 4 explains the results obtained from a separate analysis of European countries, while Section 5 presents the efficiency results for both European and Asian countries. Lastly, Section 6 provides a summary of the main conclusions.

Background Information: Description of the Asian and European education systems according to TIMSS

The TIMSS assessments are coordinated by the International Association for the Evaluation of Educational Achievement (IEA) and centre on three clearly-defined areas of action: students' learning objectives, the organisational approach to education and the context in which it occurs (Vázquez and Manassero, 2002). Information is collected through background questionnaires in order to ensure the most comprehensive assessment possible of the academic level achieved. Thus, the framework taken as a benchmark comprises the following contexts: national and community, school, classroom and characteristics, and students' attitudes

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(Mullis et al., 2009). Education policymakers consequently have access to valuable data revealing the extent to which students in each country have acquired, in the first years of their primary education, a sufficient grounding to be able to face future challenges.

The regular publication of this report has provided insights into trends within the education systems of each geographical area, showing how developing countries can hold positions above the TIMSS average (as is the case with Kazakhstan). This can be explained by the fact that, in general, school-based learning in emerging countries is primarily based on the interpretation of knowledge, which is a key consideration in the TIMSS assessments (Froemel, 2006).

Thus, for example, in the Asian region, the success of an education system could be explained by three key factors: military discipline, absolute respect for the teacher and the fact that students study up to twelve hours a day. Pearson (2014)[1] rates the South Korean education system as the best in the world, with Japan in second place, followed by Singapore and Hong Kong. As such, the four top-ranking countries are Asian, where "effort" is rewarded above intelligence *per se*, and clear educational goals are set with a strong culture of commitment and responsibility. Moreover, Asian countries have occupied the top positions ever since the TIMSS databases were first published.

The Korean education system is characterised by its excellence and its commitment to very bright students, attempting to guide them so that they reach their full potential. In this regard, García and Arechavaleta (2011) argue that the high scores obtained by these students in a variety of different international evaluations can chiefly be attributed to two aspects that reflect the country's Confucian heritage: the high social value placed on education; and the structure, objectives and practices of Korean families. Meanwhile, Singapore, has become one of the most advanced and civilised societies on the planet. It has a very centralised educational model, where teachers enjoy a great deal of prestige, students learn in English as well as their native language in a completely practical and logical way, with syllabuses focusing on the most useful knowledge.

Figure I shows the evolution of the top performing countries since TIMSS first started publishing data. Singapore and Korea have alternated

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(1) This report provides an interpretation of the status of education systems from an international perspective.

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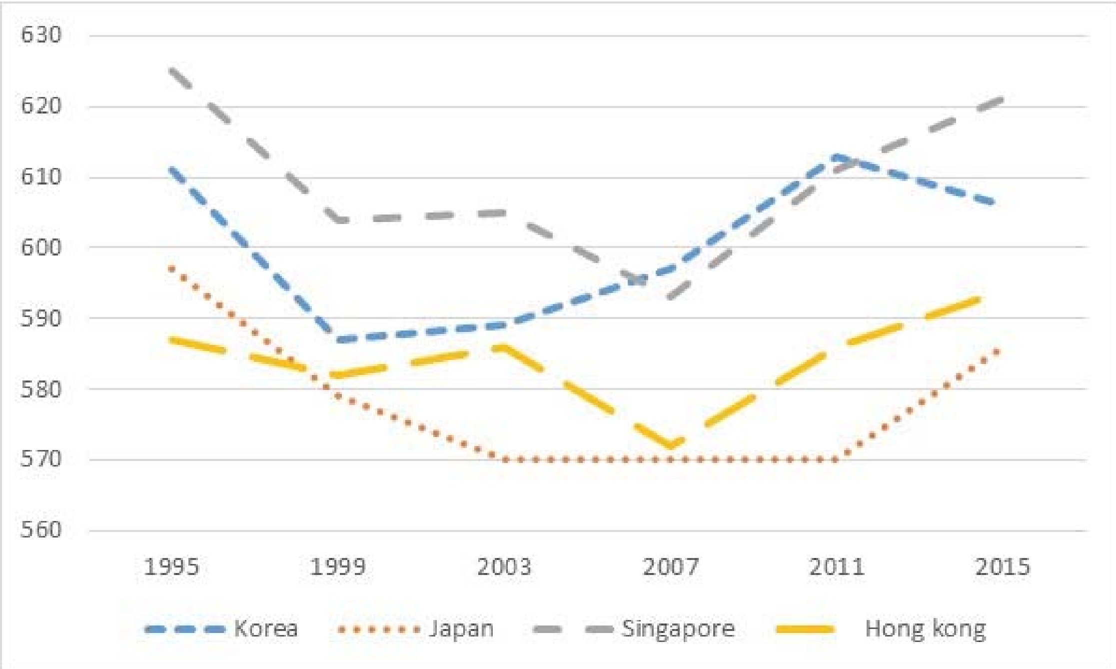
between first and second place, while Japan ceded its third-place position to Hong Kong in 1999.

FIGURE I. Mathematics results for the main Asian countries (Grade 8)



Source: Own elaboration based on TIMSS data (several years)

As can be seen in Figure 1, although changes of up to 50 points have been registered over this 20-year period, these countries' scores have never dropped below 570, a value representing excellence in academic performance. At the other end of the spectrum, however, a number of other Asian countries score below 400 points (Kuwait with 392 points, Jordan with 386 and Saudi Arabia with 368). In these countries, educational reform has become a key requirement to ensure the economic and social development of the country. To that end, efforts should be focused on developing new thinking skills and on respecting a diversity of beliefs and ideas among citizens, in accordance with the legislation in force and its principles. Education should be a tool used to counter the most extreme influences pervasive in Muslim culture, and the renewal and

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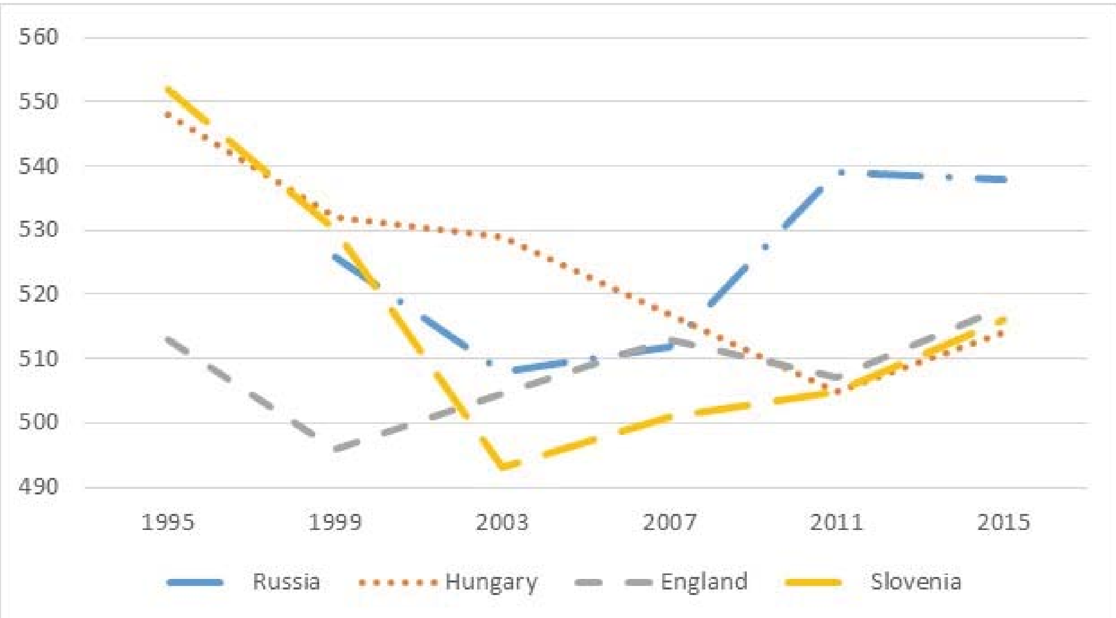
modernisation of curriculums should be encouraged. Teaching materials have a direct impact on students' behaviour and daily lives (Al Fuzai, 2016).

In the case of Saudi Arabia, there has never been a separation between education and the country's Islamic roots. According to Saudi culture, curriculums must be developed in line with the provisions of Sharia Law and the Koran, and gender roles continue to deny women educational opportunities (Hernández, 2016). This is a culture that requires the incorporation of a more egalitarian educational system to ensure that the upcoming generation is able to compete in today's globalised structure.

With respect to Western culture, however, Europe is a long way off even the lowest scores of the four top-ranking Asian countries. The political system in place does not represent a differentiating factor in the level achieved by European countries. Since 2007, the position held by Russia has been notable, ranking above Hungary, England and Slovenia. England is in third place; this is a country which encourages creativity, self-reliance and interactivity and which devotes a substantial part of its budget to education, allocating a total amount above the EU average (Figure II).

FIGURE II. Mathematics results for the main European countries (Grade 8)



Source: Own elaboration based on TIMSS data (several years)

The case of Germany is particular striking, as it is considered one of the main economic drivers of the EU, yet in terms of education it ranks far below the Asian countries. This certainly cannot be attributed to its students being lazy or unwilling to learn; rather, the reasons must lie in the intrinsic features of its education system (Bos and Schwippert, 2009). Specifically, in Grade 4 mathematics, the country registered performance levels of 525 in 2007 and 522 in 2015, well below either Russia or England. Despite resistance to reforms due to its federal structure, the German education system has undergone several different transformations since the 2001 publication of the PISA results. Initially, all their efforts to change were focused on the following areas: language skills, improving the connection between the pre-school and primary stages of education, support for special needs students, ensuring educational quality and incentivising all-day schooling. Nevertheless, the results have not been as expected, and education innovations are still being introduced and applied to all the phases and stages of schooling, from pre-school all the way through to teacher training.

Also at a European level, the countries that currently register the worst results in mathematics are Norway (487), Italy (494), Malta (494) and Sweden (501), all of which lie in the so-called "intermediate level". This level comprises the range between 475 and 550, and indicates that students have learnt how to apply fundamental mathematical knowledge in basic problems. According to the Spanish National Institute of Education Assessment (INEE, 2016) Spain scored 505 points in mathematics; that is, 5 points above the TIMSS average (500) but 14 points below the European average (519).

Hence, the purpose of studies such as PISA, TIMSS, IALS (International Assessment of Literacy Survey) or PIRLS (Progress in International Reading Literacy Study) should be to facilitate international comparisons of education systems and enable conclusions to be drawn that lead to continuous improvement in learning processes. The information supplied by these reports has helped redirect the focus from certain, *a priori,* key questions relating to class sizes or the length of lessons, towards others that have proven to be more relevant in inter-country comparative studies. These critical issues include: the teaching approach, the effectiveness of time spent in class, and how teachers respond to the size, homogeneity or heterogeneity of class groups. The results should therefore form the foundations of the educational planning process at national level.

Methodology: variables and sample

The empirical analysis carried out enables the determination of the efficiency levels of different countries' education systems by means of the non-parametric DEA technique. This is one of the most commonly-used procedures to evaluate efficiency in this field. The flexibility of this method makes it suitable for assessing the complex production environments of the education sector, facilitating the measurement of the relative efficiency of homogeneous units. The presence of multiple inputs and outputs further underline its suitability for this type of study. The DEA method involves identifying the best observations by comparing each unit against all possible linear combinations of the variables for the rest of the sample. This enables the construction of an empirical production frontier; the efficiency of each unit under analysis is then measured as its distance from the frontier.

Following the pioneering work of Farrell (1957), the DEA model was developed by Charnes, Cooper and Rhodes (1978), with the aim of finding the optimum set of weights that maximise the relative efficiency (h_0) of the observation being evaluated. Efficiency is defined as the ratio of the weighted sum of outputs to the weighted sum of inputs, subject to the restriction that no other observation can have an efficiency score higher than one when using the same weights. Specifically, the original linear programming problem with constant returns to scale for inputs is as follows:

$$\begin{aligned} &\mathrm{Max}_{u,v} h_0 = \frac{\sum_{r=1}^{s} u_r * y_{r0}}{\sum_{i=1}^{m} v_i * x_{i0}} \\ &\text{s.a.} \frac{\sum_{r=1}^{s} u_r * y_{rj}}{\sum_{i=1}^{m} v_i * x_{ij}} \leq 1 \\ &\qquad u_r , v_i \geq 0 \end{aligned} \tag{1}$$

where:

x_{ij}: amount of input i (i=1,2, …, m) used by the j^{th} observation

x_{i0}: amount of input i used by the observation being evaluated

y_{rj}: amount of output r (r= 1,2, …, s) produced by the j^{th} observation

y_{r0}: amount of output r produced by the observation being evaluated

u_r: weights of the outputs r

v_i: weights of the inputs i

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However, this paper applies a transformed model since the original presents a number of limitations. First, the objective function is not linear, which makes it more difficult to calculate the optimum. Second, in this study, the dual problem corresponding to the linear model (1) is solved, since the number of variables is thus greater than the number of constraints. By implication, this entails the limitation of variables with unknown weights.

When applying the DEA technique, the choice of orientation depends on the ability of each observation to control the quantity of outputs/inputs. Since countries' public education systems have *a priori* established inputs in the budgets, this study uses an output-oriented DEA model, which seeks to maximise output with a given level of inputs.

The measurement of efficiency takes a value between 0 and 1, and can be interpreted as follows:

- If $h_0=1$, the observation (country) is efficient relative to other countries and will therefore be located on the production frontier.
- If $h_0<1$, another observation (country) is more efficient than the one under analysis.

However, the DEA technique is not without its limitations. It has been said that it does not account for random error in the data (errors in the database, or randomly caused ones): all deviations from the frontier are assumed to be due to inefficiency. Furthermore, the results can be affected by the presence of outliers, often caused by errors in the database, and the fact that it is a non-parametric method makes it difficult to apply statistical tests of hypotheses.

The application of this methodology initially requires the definition of the production function which then enables the mathematical programming model to be solved. Following Giménez et al. (2016), the model specification was carried out using the following variables:

- Output: academic achievement, identified as mathematics and science results provided by TIMSS, on a scale from 0 to 1000 points, with an internationally standardised average of 500 points and a standard deviation of 100 points.
- Inputs: number of teaching hours in mathematics and science, and the quality of teaching staff measured as the percentage of students whose teachers feel "very well" prepared for teaching these subjects. Given the characteristics of the empirical study, it was deemed

appropriate to include a third input, the years of experience of the teaching staff, which translate to the acquisition of skills and abilities and, therefore, better student performance.

The cognitive skills testing carried out in TIMSS is evaluated by means of plausible values methodology. This approach involves the use of all available data, students' responses to the items administered together with all the background data, in order to directly estimate the characteristics of student populations and subpopulations. The usual plausible values approach consists of generating multiple imputed scores, called plausible values, based on the estimated ability distributions. These are then employed for analyses and reports, using standard statistical software. By including all available background data in the model, a process known as "conditioning", the relationships between these background variables and the estimated proficiencies are suitably accounted for in the plausible values.

Therefore, analyses carried out using plausible values provide an accurate representation of these underlying relationships and ensure accurate estimates of the proficiency distributions for all TIMSS populations as a whole and, in particular, for comparisons between subpopulations. An additional advantage of this method is that the variation between the five plausible values generated for each student reflects the uncertainty associated with proficiency estimates for individual students. However, retaining this component of uncertainty requires the use of additional analytical procedures to estimate students' proficiencies (Martin et al., 2016).

The production function defined above is first applied to a sample of 25 European countries[2] for Grade 4 mathematics and science[3], with the sample being reduced to 11 European countries for Grade 8 science and 10 countries for Grade 8 mathematics. Next, 16 Asian countries[4] are incorporated for Grade 4 and 17 for Grade 8. Table I below shows the main statistics for the variables used in the analysis of European countries.

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(2) European Countries: Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, England, Finland, France, Germany, Hungary, Ireland, Italy, Lithuania, the Netherlands, Norway, Poland, Portugal, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden and Turkey.

(3) The sample selection is dependent on the information provided by TIMSS.

(4) Asian Countries: Bahrain, China (Taipei), Georgia, Hong Kong, Indonesia, Iran, Japan, Jordan, Kazakhstan, Korea, Kuwait, Oman, Qatar, Saudi Arabia, Singapore and the United Arab Emirates.

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TABLE I. Main statistics on output and inputs from European countries (Grade 4 and 8)

	Mathematics								Science							
	25 European countries (Grade 4)				10 European countries (Grade 8)				25 European countries (Grade 4)				11 European countries (Grade 8)			
	L	H	S	E	L	H	S	E	L	H	S	E	L	H	S	E
Mean	525	148	48	20	506	141	46	15	526	70	47	19	519	132	49	14
Max	564	275	66	28	538	194	66	25	567	124	66	27	551	243	75	23
Min	483	105	30	11	458	113	29	9	481	32	28	10	481	87	27	8
Error Standard	19	43	10	4	22	23	13	4	21	22	10	5	22	48	16	4

Note: (L): Academic Achievement; (H): Hours Taught; (S): Teacher Quality; (E): Teacher Experience Years
Source: Own elaboration

In these four samples, differences are observed between grades and subjects taught. Thus, while in Grade 4 student success (L) in mathematics is similar to that in science, the number of teaching hours in science is less than half that dedicated to mathematics, with the teaching quality and years of experience slightly lower in science. Very different performance can be seen as students progress through the grades. In Grade 8, academic achievement (L) in science is higher than in mathematics, with fewer hours taught, better quality teaching staff and similar teacher experience. In short, it can be seen that in Europe, during students' early education, more time is spent on fundamental mathematical tasks, to the detriment of other more specific subjects such as science; nevertheless, this is not reflected in better results in this subject.

The production function is then also applied to another four samples comprising both Asian and European students. Table II below shows the main statistical results:

The introduction of Asian countries into the analysis slightly changes the characteristics of the samples used. Particularly noteworthy is the fact that in Grade 4 fewer hours are taught in science but the academic results produced are of the same order of magnitude; in Grade 8, on the other hand, with the same number of average teaching hours in both subjects, student performance in science is slightly better. Additionally, the inclusion of Asian countries has increased the variability in academic achievement and teaching hours, while student satisfaction and years of experience remain similar. This is due to the fact that among the Asian countries, some are very advanced while others require drastic changes to improve their scores (standard deviations for L of around 20 when focusing only on European countries and around 60 for European and Asian countries together).

TABLE II. Main statistics on output and inputs from European and Asian countries (Grade 4 and 8)

	Mathematics								Science							
	25 European and 16 Asian countries (Grade 4)				10 European and 17 Asian countries (Grade 8)				25 European and 16 Asian countries (Grade 4)				11 European and 17 Asian countries (Grade 8)			
	L	H	S	E	L	H	S	E	L	H	S	E	L	H	S	E
Mean	510	147	52	17	492	137	47	16	507	78	51	17	500	137	46	15
Max	618	275	83	28	621	194	66	27	590	125	83	27	597	243	75	24
Min	353	100	23	9	368	99	26	9	337	32	27	8	396	71	19	8
Error Standard	63	37	13	5	68	22	12	5	56	24	13	5	52	51	14	5

Note: (L): Academic Achievement; (H): Hours Taught; (S): Teacher Quality; (E): Teacher Experience Years
Source: Own elaboration

These 8 samples, corresponding to Grades 4 and 8, will be used to quantify the efficiency of the education system. The results will enable a comparative analysis to be carried out and valid conclusions to be drawn regarding future education policies.

Results and discussion of European educational efficiency in mathematics and science

The efficiency analysis was first carried out for a sample of European countries, with Grade 4 and Grade 8 students of mathematics and science. The results obtained by applying the DEAP program[5] appear in Appendix

(5) DEAP 2.0 is the software program designed by Coelli (1996)

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1 (Tables A1, A2, A3 and A4), while Table III contains a summary of the main characteristics of the four estimations. It should be borne in mind that the samples used are not identical; due to a lack of information, the sample for Grade 8 was reduced from 25 countries to 10 for mathematics and to 11 for science. As a result, the comparison between the two levels could be affected.

TABLE III. Efficiency results according to subject matter between European countries (Grade 4 and 8)

	Grade 4		Grade 8	
	Mathematics	Science	Mathematics	Science
Average efficiency	0.96	0.95	0.975	0.954
Maximum Efficiency	1	1	1	1
Minimal Efficiency	0.875	0.872	0.913	0.873
% Efficient countries	32%	32%	50%	36,4%

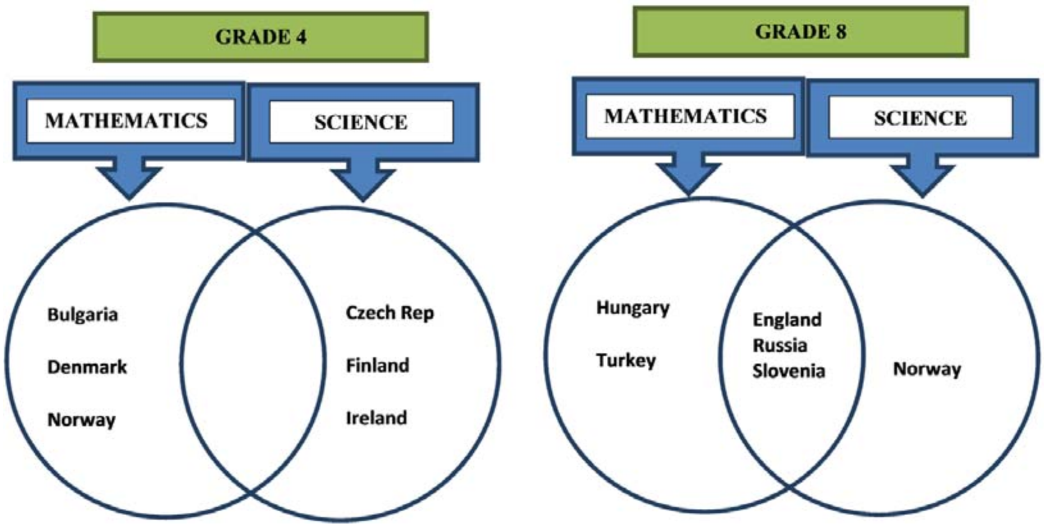
Source: Own elaboration

The first notable finding is the lack of significant differences between the subjects analysed, despite the disparities in terms of teaching load. The average level of efficiency achieved in both years is very high, attesting to European efficiency in teaching mathematics and science, with an average value above 0.95. Furthermore, 32% of the countries analysed are fully efficient in Grade 4 in both subjects, while in Grade 8, 50% of the countries are fully efficient in mathematics and more than 36% in science. In all cases, the minimum efficiency is above 0.87; in other words, with a little effort, European countries would be able to reach maximum levels of efficiency (given the available inputs, they have the scope to improve their output by at least 13%).

The results demonstrate that, at a European level, the education system for students aged between 10 and 14 is adequate. With the available resources, these countries can reach almost the highest possible level of academic achievement. In short, they can be considered a good model to follow for other geographical areas that are culturally and economically similar.

Figure III shows the countries that have been fully efficient in each of the levels analysed.

FIGURE III. European countries fully efficient according to subject matter



Source: Own elaboration

In Grade 4, it is noteworthy that the level of efficiency achieved in mathematics does not always go hand in hand with performance, in other words, with the scores awarded by TIMSS. Such is the case with France, Bulgaria and Sweden: ranking below the European average according to the latest TIMSS report, their efficient use of inputs enables them to obtain the highest possible academic achievement. Their education systems have proven to be fully efficient. In the case of science, on the other hand, there is a certain overlap between the efficiency attained and the scores awarded in the TIMSS valuation. Russia, for example, achieves the maximum score and is fully efficient in both subjects using fewer inputs than other countries (for example, 49 classroom hours compared to other countries with up to 124).

In Grade 8, the sample is reduced to 10 countries, and although the results are not fully comparable with the lower grade, England and Russia can be seen to hold their positions in the list of efficient countries for both subjects. Just as in Grade 4, Hungary and Turkey do not occupy the top positions in the TIMSS ranking but they have been able to manage their inputs very efficiently, obtaining the maximum academic achievement possible.

Results and discussion of European and Asian educational efficiency in mathematics and science

The Asian countries are then incorporated into the sample of European countries in order to calculate the efficiency and evaluate the performance of the top-rated countries in TIMSS in terms of efficiency, revealing any divergences between them. The aim is to show the distance in 2015 in terms of efficiency between those countries that have historically occupied the top spots in the TIMSS ranking and the European countries. The application of the DEA method has yielded the following results for the two grades analysed (Table IV and Tables A5, A6, A7 and A8 in Appendix 2). Once again, the results are not comparable because the information available means that it is not possible to evaluate the same countries in Grades 4 and 8.

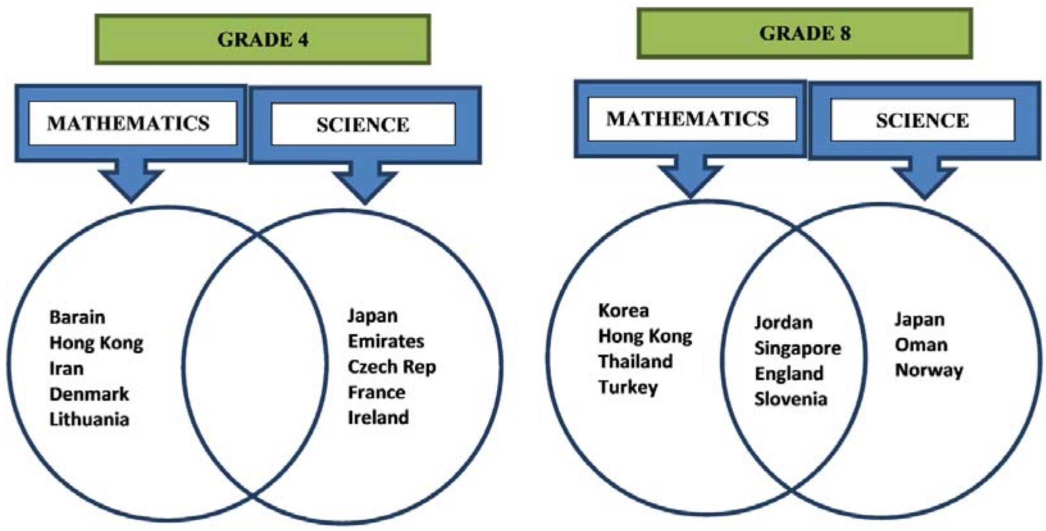
TABLE IV. Efficiency results according to European and Asian subjects (Grade 4 and 8)

	Grade 4		Grade 8	
	Mathematics	**Science**	**Mathematics**	**Science**
European and Asian countries				
Average efficiency	0.888	0.910	0.882	0.896
Maximum Efficiency	1	1	1	1
Minimal Efficiency	0.647	0.667	0.611	0.708
% Efficient countries	22%	25%	30%	25%
European countries				
Average efficiency	0.880	0.924	0.897	0.909
Maximum Efficiency	1	1	1	1
Minimal Efficiency	0.791	0.819	0.797	0.806
% Efficient countries	12%	20%	36.3%	25%
Asian countries				
Average efficiency	0.899	0.886	0.871	0.885
Maximum Efficiency	1	1	1	1
Minimal Efficiency	0.647	0.667	0.611	0.708
% Efficient countries	37.5%	33.33%	29.41%	25%

Source: Own elaboration

A joint evaluation of the efficiency of Asian and European countries yields worse results, with average efficiency falling by about 10% overall and the minimum by more than 30% compared to the evaluation of European efficiency only. It should be borne in mind that this sample also includes certain Asian countries whose education systems are a long way off the global one analysed. The percentage of fully-efficient Asian countries in Grade 4 is higher than in Europe, and similar in Grade 8. The countries in this continent with advanced education systems (Singapore, Japan and Korea) outscore the old continent. Certain Asian cultures have shown a commitment to differentiated learning, rewarding effort and dedication by both parties (students and teachers). Nevertheless, the minimum efficiency is below that of Europe due to the inclusion of countries that are relatively culturally restrictive, such as Saudi Arabia, Iran and Indonesia.

FIGURE IV. Fully efficient European and Asian countries



Source: Own elaboration

Figure IV shows how the inclusion of the Asian countries has relegated European countries –such as Poland, Sweden and Finland in Grade 4, and Russia and Hungary in Grade 8– from the maximum levels of efficiency. This coincides with the results of the 2015 TIMSS, where the enormous

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power of the Asians and their effective management in education position them ahead of many countries from the old continent. The education systems of England and Singapore, in addition to being very highly rated in the latest TIMSS report, have been able to manage their inputs in such a way as to reach the highest levels of achievement possible. These two countries –one European, the other Asian– boast education systems that represent a model to follow in the development of other geographic areas that need to make improvements in their learning processes.

Conclusion

The evaluation of education systems should assist countries in sound decision-making when setting educational policy. This article is focused on measuring the efficiency of European and Asian countries in mathematics and science in 2015, in order to detect similarities and differences that could inform potential education system reforms.

The TIMSS database has provided sufficient information on the countries under analysis, enabling the construction of a production function with an output consisting of student performance, and three inputs (teaching hours, teachers' years of experience and percentage of students whose teachers feel satisfied with their teaching). Furthermore, DEA methodology was considered the best approach for this type of static analysis.

While it is very interesting to compare countries that differ as notably as European and Asian ones, it is important to bear in mind that student performance is the result of a multiplicity of factors related to the school environment as well as the national and local education policies in place. It is also affected by the social, cultural, political and economic conditions that contextualise the comprehensive development of students and their families. Accordingly, all comparisons have their limitations and will not always be relevant. TIMSS has made major strides in addressing some of these defects but it has not been able to eliminate them entirely, since it is still a common assessment approach applied to very distinct countries.

At European level, average efficiency levels are over 0.95; in other words, with a little effort, maximum levels could be achieved. It has been shown that the socio-political systems of European countries do not affect the results; England, Russia and Norway all stand out as fully efficient countries in both subjects and grades analysed. Furthermore, it can be seen that very efficient countries such as France and Norway do not hold high positions in the TIMSS ranking (they lie below the average score of 500 in Grade 4 science). Education policies should be aimed at increasing the inputs used, since even if these are adequate with respect to the performance level attained, insufficient inputs prevent countries from improving their TIMSS ranking. Thus, the results reveal that improvements to learning procedures sometimes occur through an increase in public spending on education. The system requires more resources as those currently available are insufficient to ensure optimal academic performance.

The inclusion of Asian countries in the analysis greatly increases the variability of the sample, with only Norway and England managing to compete with the top-rated Asian countries in TIMSS such as Singapore or Korea, and maintain maximum efficiency levels. In addition, Kuwait should adopt education policies aimed at boosting the number of teaching hours, the quality of teaching and teachers' years of experience, since despite being fully efficient, its academic performance falls short of the world average and it is the country with the lowest Grade 4 science scores.

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Annex I

TABLE A1. Efficiency results of European countries. Science Grade 4

Countries	Efficiency
Belgium	0.921
Bulgaria	0.976
Croatia	0.942
Cyprus	0.895
Czech Rep	1
Demark	0.999
England	1
Finland	1
France	1
Germany	0.947
Hungary	0.963
Ireland	1
Italy	0.916
Lithuania	0.931
Netherland	0.931
Norway	0.992
Poland	1
Portugal	0.903
Russia	1
Serbia	0.938
Slovakia	0.923
Slovenia	0.96
Spain	0.925
Sweden	1
Turkey	0.872

Source: Own elaboration

TABLE A2. Efficiency results of European countries. Science Grade 8

Countries	Efficiency
England	1
Hungary	0.965
Ireland	0.962
Italy	0.906
Lithuania	0.942
Malta	0.873
Norway	1
Russia	1
Slovenia	1
Sweden	0.947
Turkey	0.895

Source: Own elaboration

TABLE A3. Efficiency results of European countries. Mathematics Grade 4

Countries	Efficiency
Belgium	0.984
Bulgaria	1
Croatia	0.892
Cyprus	0.947
Czech Rep	0.979
Denmark	1
England	1
Finland	0.976
France	1
Germany	0.947
Hungary	0.956
Ireland	0.997
Italy	0.919
Lithuania	0.949

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Netherland	0.958
Norway	1
Poland	1
Portugal	0.966
Russia	1
Serbia	0.929
Slovakia	0.894
Slovenia	0.924
Spain	0.904
Sweden	1
Turkey	0.875

Source: Own elaboration

TABLE A4. Efficiency results of European countries. Mathematics Grade 8

Countries	**Efficiency**
England	1
Hungary	1
Ireland	0.997
Italy	0.923
Lithuania	0.97
Norway	0.913
Russia	1
Slovenia	1
Sweden	0.946
Turkey	1

Source: Own elaboration

Annex 2

TABLE A5. Efficiency results from European and Asian countries. Science Grade 4

Countries	Efficiency
Bahrein	0.856
Belgium	0.879
Bulgaria	0.976
China	0.941
Croatia	0.904
Cyprus	0.884
Czech Rep	1
Denmark	0.898
England	1
Finland	0.940
France	1
Georgia	0.765
Germany	0.919
Hong Kong	0.953
Hungary	0.941
Indonesia	0.673
Iran	0.714
Ireland	1
Italy	0.88
Japan	1
Kazakhstan	0.959
Korea	1
Kuwait	1
Lithuania	0.926
Netherland	0.876
Norway	0.906
Oman	0.956
Poland	0.978

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Portugal	0.861
Qatar	0.813
Russia	1
Saudi Arabia	0.667
Serbia	0.893
Singapore	1
Slovakia	0.916
Slovenia	0.92
Spain	0.878
Sweden	0.921
Turkey	0.819
Emirates	1

Source: Own elaboration

TABLE A6. Efficiency results from European and Asian countries. Science Grade 8

Countries	**Efficiency**
Bahrein	0.809
China	0.997
England	1
Georgia	0.751
Hong Kong	0.976
Hungary	0.955
Iran	0.783
Ireland	0.894
Italy	0.836
Japan	1
Jordan	1
Kazakhstan	0.948
Korea	0.938
Kuwait	0.727
Lithuania	0.904
Malaysia	0.871

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Malta	0.806
Norway	1
Oman	1
Qatar	0.825
Russia	0.947
Saudi Arab	0.708
Singapore	1
Slovenia	1
Sweden	0.882
Thailand	0.834
Turkey	0.863
Emirates	0.824

Source: Own elaboration

TABLE A7. Efficiency results from European and Asian countries. Mathematics Grade 4

Countries	**Efficiency**
Bahrein	0.955
Belgium	0.883
Bulgaria	0.896
China	0.977
Croatia	0.822
Cyprus	0.85
Czech Rep	0.907
Denmark	0.891
England	0.926
Finland	0.892
France	0.803
Georgia	0.756
Germany	0.851
Hong Kong	1
Hungary	0.87

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Indonesia	0.647
Iran	0.707
Ireland	0.89
Italy	0.82
Japan	1
Jordan	1
Kazakhstan	0.889
Korea	1
Kuwait	1
Lithuania	0.88
Netherland	0.869
Norway	1
Oman	0.952
Poland	1
Portugal	0.875
Qatar	0.904
Russia	0.959
Saudi Arab	0.656
Serbia	0.843
Singapore	1
Slovakia	0.815
Slovenia	0.848
Spain	0.821
Sweden	1
Turkey	0.791
Emirates	0.943

Source: Own elaboration

TABLE A8. Efficiency results from European and Asian countries. Mathematics Grade 8

Countries	Efficiency
Saudi Arab	0.611
Jordan	1
Kuwait	0.794
Oman	0.868
Thailand	1
Iran	0.721
Qatar	0.704
Georgia	0.801
Bahrein	0.732
Turkey	1
Malaysia	0.889
Emirates	0.749
Norway	0.805
Italy	0.797
Malta	0.878
Sweden	0.818
Lithuania	0.823
Hungary	1
Slovenia	1
England	1
Ireland	0.876
Kazakhstan	0.987
Russia	0.88
Japan	0.981
Hong Kong	1
China	0.978
Korea	1
Singapore	1

Source: Own elaboration

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