Understanding the relationships among PISA scores, economic growth and employment in different sectors

A cross-country study

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When the term 'international assessment' is entered into a computer for an internet search, different types of assessment appear; for example, TIMSS (Trends in International Mathematics and Science Study), PISA (Programme for International Student Assessment), and PIRLS (Progress in International Reading Literacy Scale). Often, these assessments involve many countries and are administered once every few years. The results of the assessments do not only lead to a comparison between countries based on the scores, they also explain why some countries accelerate faster than others and why some lag behind. The differing scores may be due to different factors; on the academic side, the length of the school year, teacher education and training levels, and curriculum implementation may all affect the scores of the assessments to various degrees (McEwan and Marshall, 2004).

The increasing scores of these international assessments lead to the assumption that students are learning more in school, and thus their education system may be interpreted as being more successful when compared with other countries with lower scores. There are different reasons why having a good education system and students having high scores are important to a country. For example, scores on international mathematics and science tests are found to have a direct influence on economic growth across nations (Hanushek and Kimko, 2000). Also, according to the endogenous growth theories which were developed in the 1980s, it is believed that improvement in productivity is linked with extra investment in human capital and a faster pace of innovation, and both the improvement of human capital and innovation cannot be separated from education or knowledge. In fact the term 'endogenous' indicates that economic growth is influenced by the use of investment resources, and one of the important investments is education (Johansson, Karlsson and Stough, 2001).

As mentioned above, an important part of economic growth is related to innovation, and it is an area that is also significantly related to education (Johansson *et al*., 2001). It is important to cultivate innovation and encourage individual members of society to be inventive, and, in order to achieve that, having a good education, very often reflected in high scores on international tests, is essential. Knowledge is the central variable of economic growth in endogenous growth theories, and it is treated as an independent factor of production. The hope is that the knowledge that is generated within a certain firm or sector is able to spill over to other firms or sectors so as to improve the country's innovation and productivity.

Endogenous growth theories suggest that education or knowledge is embedded in the heart of the growth process and generates technological progress in an economy by using a subjective conception of knowledge, which is incorporated in individuals (Lucas, 1988; Monteils, 2004). Endogenous growth economists believe that a high-knowledge economy can produce positive and competitive outcomes in growth industries globally. For example, improvements in knowledge will be able to improve the transformation of inputs into outputs in the production process (Peters, 2003). The society must have the incentive to be innovative and improve its own productivity in order to outperform its competitors. It is anticipated that some of the knowledge associated with the innovation will spread to other economic actors, which in turn increases the ability of these actors to innovate (Huang, 2002).

Well known researchers such as Lucas (1988), Romer (1990), and Rebelo (1991) have applied theories of endogenous growth and have found that knowledge gained occupies the central position in the growth process. In addition, some of the main points of endogenous growth theories include: making investment in research and development the key source of technical progress; developing appropriate government policies to support a higher level of competition in markets by having a higher rate of innovation; and ensuring the protection of property rights and patents to provide the incentive to engage in research and development (Posen, 2002).

When endogenous growth theories indicate that education can increase economic growth the study of particular academic subjects, such as mathematics and science, becomes important. Many studies have focused on achievement in these two subjects, since it is believed that they may help to sustain future economic growth (Hanushek, 2002). Studies have shown that when females do not choose to study subjects like mathematics and science the supply of highly educated science, technology, engineering, and mathematics (STEM) personnel can be seriously threatened and this can lead to a decrease in the economic growth and competitiveness of countries (Jordan and Yeomans, 2003; Van Langen and Dekkers, 2005). Moreover, Van Langen, Bosker and Dekkers (2006) suggest that gender achievement gaps (which can be defined as the delayed performance of one sex as compared with the other) in mathematics and science can be offset by a higher female enrolment rate.

The importance of learning mathematics and science is highlighted in the above paragraphs. However, the contribution of reading literacy to economic development may not have received as much research attention as mathematics and science. Only a limited number of studies have shown that literacy skills drive economic growth (Alibrandi and Bull, 2004; Murray, 2005).

Aims of this study

Since only a limited number of studies have focused on the relationship of reading literacy and economic development, PISA scores for reading, together with PISA scores for mathematics and science, are investigated to find out their relationship with employment in different economic activities across countries and *per capita* GDP. As mentioned above, various well known international assessments are available, but PISA was selected since it includes sections on mathematics, science, and reading. The following economic activities are included: research and development, agriculture, industry, and the service sector. This study examines the relationships among all the above variables.

Research methodology

The study examines eleven variables: the PISA scores for mathematics; the PISA scores for science; the PISA scores for reading; the percentage of females employed in agriculture; the percentage of males employed in agriculture; the percentage of females employed in industry; the percentage of males employed in industry; the percentage of females employed in the service sector; the percentage of males employed in the service sector; researchers in R&D (research and development); and GDP *per capita*.

First of all, the three PISA scores (mathematics, science, and reading) were collected from the PISA published by the Organisation for Economic Co-operation and Development (OECD, 2003). PISA is an internationally standardised assessment, and more then forty countries with 4,500 to 10,000 students participated in the 2003 assessment. Basically, the assessment investigates the cross-curricular competences of school students aged 15 in mathematics, reading literacy, and basic scientific knowledge.

Next the following variables were collected from the UN *Human Development Report* (UNDP, 2006): the percentage of females employed in agriculture; the percentage of males employed in agriculture; the percentage of females employed in industry; the percentage of males employed in industry; the percentage of females employed in the service sector; the percentage of males employed in the service sector; and researchers in R&D. There are many different sections in the *Human Development Report* 2006, but this article used data from the sections entitled 'Technology: diffusion and creation' and 'Gender inequality in economic activity'. *Per capita* GDP for the year 2003 was also collected from the *Human Development Report* (UNDP, 2005). For the data on GDP *per capita* this article used data from the section of the report entitled 'Human development index.'

The percentages of males and females in agriculture, industry, and the service sectors show the average percentage of employment in each sector by gender from the years 1995 to 2003. For researchers in R&D the average number of people working in this field per million people from the years 1990 to 2003 is shown. The *Human Development Reports*, published by the United Nations Development Programme (UNDP), have won a well deserved global reputation for excellence and have played an indispensable catalytic role in helping frame and forge concrete responses to the key development policy debates. After compiling the eleven variables from the three sources, thirty-three countries were included in this study. Table 1 shows the data set.

Results

Correlations

Correlations were run first to find out the relationships among the eleven variables. Table 2 shows that the highest correlations are among the three PISA scores, and range from $r = 0.93$ to $r = 0.95$, with a significance level of $p < 0.01$. The three PISA scores were significantly correlated with the percentage of females employed in agriculture and the percentage of males employed in agriculture (range from $r = -0.49$ to $r = -0.67$), and with the percentage of females employed in the service sector and the percentage of males employed in the service sector (range from $r = 0.45$ to $r = 0.51$). The percentage of males employed in industry was significantly correlated with the three PISA scores (range from $r = 0.38$ to $r = 0.40$). The variable researchers in R&D was also positively correlated with the three PISA scores (range from $r = 0.60$ to $r = 0.66$, with $p < 0.01$).

Regression analysis models

Different regression analysis models were run for the variables. First, the three PISA scores were entered as independent variables to predict the percentage of females employed in agriculture and the percentage of males employed in agriculture. Table 3(a) shows that the PISA mathematics score was able to predict 27 per cent of the total variance in the percentage of females employed in agriculture. Interestingly, the slope was negative and the significance level was $p < 0.01$. A similar method and independent variables were applied to predict the percentage of males employed in agriculture. Table 3(b) shows that 45 per cent of the total variance in the percentage of males employed in agriculture is predicted by the PISA mathematics score and the slope is also negative, with a significance level of $p < 0.001$.

To predict the percentage of females and males employed in industry, the three PISA scores were entered again. Table 4(a) shows that 32 per cent of the total variance in the percentage of females in industry is predicted by both PISA science and reading scores. However, Table 4(b) shows that 16 per cent of the total variance in the percentage of males employed in industry is predicted by the PISA science score only.

Table 1 Data set of this study

Year	*2003*			*1995–2003*						*2003*	*1990–2003*
				Agriculture		*Industry*		*Service*			
Country	*PISA mathematics*	*PISA science*	*PISA reading*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*GDP per capita*	*Researchers in R&D*
Australia	524	525	525	3	6	10	30	87	64	29,632	3,670
Austria	506	491	491	6	5	14	43	80	52	30,094	2,968
Belgium	529	509	507	1	3	10	36	82	58	28,335	3,478
Brazil	356	390	403	16	24	10	27	74	49	7,790	344
Canada	532	519	528	2	4	11	33	87	64	30,677	3,597
Czech Republic	516	523	489	3	6	28	50	68	44	16,357	1,594
Denmark	514	475	492	2	5	14	36	85	59	31,465	5,016
Finland	544	548	543	4	7	14	40	82	53	27,619	7,992
France	511	511	496	1	2	13	34	86	64	27,677	3,213
Germany	503	502	491	2	3	18	44	80	52	27,756	3,261
Greece	445	481	472	18	15	12	30	70	56	19,954	1,413
Hong Kong	550	539	510	n.a.	n.a.	10	27	90	73	27,179	1,564
Hungary	490	503	482	4	9	26	42	71	49	14,584	1,472

Table 1 Data set of this study (continued)

Year	*2003*			*1995–2003*						*2003*	*1990–2003*
				Agriculture		*Industry*		*Service*			
Country	*PISA mathematics*	*PISA science*	*PISA reading*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*GDP per capita*	*Researchers in R&D*
Ireland	503	505	515	2	11	14	39	83	50	37,738	2,674
Italy	466	486	476	5	6	20	39	75	55	27,119	1,213
Japan	534	548	498	5	5	21	37	73	57	27,967	5,287
Korea	542	538	534	12	9	19	34	70	57	17,971	3,187
Latvia	483	489	491	12	18	16	35	72	47	10,270	1,434
Mexico	385	405	400	6	24	22	28	72	48	9,168	2,68
Netherlands	538	524	513	2	4	9	31	86	64	29,371	2,482
New Zealand	523	521	522	6	12	12	32	82	56	22,582	3,405
Norway	495	484	500	2	6	9	33	88	58	37,670	4,587
Poland	490	498	497	19	19	18	40	63	40	11,379	1,581
Portugal	466	468	478	14	12	23	44	63	44	18,126	1,949
Russia	468	489	442	8	15	23	36	69	49	9,230	3,319
Spain	485	487	481	5	8	15	42	81	51	22,391	2,195
Sweden	509	506	514	1	3	11	36	88	61	26,750	5,416
Switzerland	527	513	499	3	5	13	36	84	59	30,552	3,601
Thailand	417	429	420	48	50	17	20	35	30	7,595	286
Turkey	423	434	441	56	24	15	28	29	48	6,772	341
United States	483	491	495	1	3	12	32	87	65	37,562	4,484
Uruguay	422	438	434	2	6	14	32	85	62	8,280	366

Table 2 Correlations of the eleven variables

Variables	*Mean*	*Std deviation*	*n*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1 PISA mathematics	490.73	47.05	33	1.00										
2 PISA science	492.85	38.03	33	0.95**	1.00									
3 PISA reading	487.00	35.42	33	0.93**	0.91**	1.00								
4 Agriculture female	8.56	12.53	32	−0.52**	−0.49**	−0.48**	1.00							
5 Agriculture male	10.66	9.69	32	−0.67**	−0.64**	−0.65**	0.81**	1.00						
6 Industry female	15.24	5.11	33	−0.17	−0.05	−0.28	0.11	0.16	1.00					
7 Industry male	35.12	6.12	33	0.38**	0.40*	0.35*	−0.46**	−0.56**	0.51**	1.00				
8 Service female	76.12	13.75	33	0.51**	0.46**	0.53**	−0.94**	−0.78**	−0.46**	0.19	1.00			
9 Service male	54.30	8.48	33	0.49**	0.45**	0.49**	−0.62**	−0.78**	−0.57**	−0.16	0.75**	1.00		
10 Researchers in R&D	2,862.55	1,895.91	33	0.66**	0.60**	0.65**	−0.49**	−0.53**	−0.30	0.22	0.52**	0.37*	1.00	
11 GDP *per capita*	22,692.58	9,682.18	33	0.67**	0.58**	0.70**	−0.60**	−0.68**	−0.48**	0.20	0.69**	0.60**	0.68**	1.00

Note * and ** indicate significance at the 5% and 1% levels respectively.

Table 3 Regression analysis model
(a) Predicting percentage female in agriculture

Variable	*B*	*SE B*	β
Mathematics PISA score	–0.14	0.04	–0.52**

Note $R^2 = 0.27$; $\Delta R^2 = 0.24$ (*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

(b) Predicting percentage male in agriculture

Variable	*B*	*SE B*	β
Mathematics PISA score	–0.14	0.03	–0.67***

Note $R^2 = 0.45$; $\Delta R^2 = 0.43$ (*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

Table 4 Regression analysis model
(a) Predicting percentage female in industry

Variable	*B*	*SE B*	β
Science PISA score	0.16	0.05	1.16**
Reading PISA score	–0.19	0.05	–1.34***

Note $R^2 = 0.32$; $\Delta R^2 = 0.27$ (*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

(b) Predicting percentage male in industry

Variable	*B*	*SE B*	β
Science PISA score	0.06	0.03	0.40*

Note $R^2 = 0.16$; $\Delta R^2 = 0.13$ (*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

The PISA score for reading was able to predict 28 per cent and 24 per cent of the total variances in the percentage of females employed in the service sector and the percentage of males employed in the service sector respectively. The slopes for both models were positive, with a significance level of $p < 0.01$ for the percentage of females employed in the service sector and $p < 0.01$ for the percentage of males employed in the service sector. Tables 5(a) and 5(b) show the results.

Table 6 shows the regression analysis model for predicting researchers in R&D. Forty-three per cent of the total variance in researchers in R&D was predicted by the PISA mathematics score. The slope was positive, with a significance level of $p < 0.001$.

To predict the GDP *per capita* across the thirty-three countries, the independent variables the percentage of females employed in agriculture, the percentage of males employed in agriculture, the percentage of females employed in industry, the percentage of males employed in industry, the percentage of females employed in the service sector, the percentage of males employed in the service sector, and researchers in R&D were entered

Table 5 Regression analysis model
(a) Predicting percentage female in services

Variable	*B*	*SE B*	*β*
Reading PISA score	0.20	0.06	0.53**

Note $R^2 = 0.28$; $\Delta R^2 = 0.25$ (*** $p < 0.001$; ** $p < 0.01$; *$p < 0.05$).

(b) Predicting percentage male in services

Variable	*B*	*SE B*	*β*
Reading PISA score	0.09	0.03	0.49**

Note $R^2 = 0.24$; $\Delta R^2 = 0.22$ (*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

Table 6 Regression analysis model predicting researchers in R&D

Variable	*B*	*SE B*	*β*
Mathematics PISA score	26.45	5.46	0.66***

Note $R^2 = 0.43$; $\Delta R^2 = 0.41$ (*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

Table 7 Regression analysis model predicting GDP *per capita*

Variable	*B*	*SE B*	*β*
Researchers in R&D	1.40	0.80	0.27
Percentage female in services	271.74	95.24	0.38**
Reading PISA score	85.98	41.46	0.31*

Note $R^2 = 0.67$; $\Delta R^2 = 0.64$ (*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

into the regression analysis model. Table 7 shows that 67 per cent of the total variance in GDP *per capita* is predicted by the researchers in R&D, the percentage of females employed in the service sector and PISA reading score.

Discussion

Generally speaking, the results of this study show that PISA scores are significantly related to employment in different economic activities across countries. First, the PISA science score is able to predict both male and female employment in the industrial sector. The PISA score for reading is able to predict female and male employment in the service sector. The PISA mathematics score is able to positively predict the number of researchers in the field of R&D, but predicts female and male employment in the agricultural sector negatively. Overall, the three PISA scores in mathematics, science, and reading had very high correlations. Countries that score high in one area seem also to have high scores in the other two areas. In fact it may be important for countries to outperform others academically in order to stay competitive in this knowledge-based globalisation environment.

To be globally competitive, universities have introduced degrees related to mathematics and science to prepare their graduates for employment in a wide range of sectors—technical, management, business, government, industry, and so on (Tobias and Sims, 2006). Indeed, for people to enter the above sectors, they must be good at both mathematics and science. Similarly, the results of this study show that high male and female employment rates in industry are predicted by high PISA scores in science. In addition, to enhance competitiveness within globalisation, students must be well prepared for the complex working environment so that their finances can start on a firmer footing. Suggestions have been made for changes in education in order to meet the demands of a competitive global economy (Sanchez, 2003). First, since the global economy values a knowledge-based environment, it is important for students to be information-literate and able to make good use of knowledge. Second, students should be encouraged to be multilingual so that people can play an important role in the global economy. Third, new technology has changed people's lives and is also a major source of employment, so that there is a need to train students to be highly skilled in this area. Finally, as the world has become smaller, and contact between people around the world has increased, students should be able to work with others both inside and outside the workplace. Based on the suggestions above, countries that want to be competitive in the knowledge-based economy must make sure that their students possess good mathematics, science, and reading skills in order to enter and stay in careers that are able to enhance economic growth to the maximum.

As previously noted, the PISA science score predicts employment in the industrial sector positively. Industry, which is an important category of business activity, may be shown either as a very precise activity or as a more generic one. According to the US National Academy of Engineering (2003), many fields of science and engineering at the university level have a huge impact on the new knowledge and capabilities of a variety of industries. These subjects are important for the development, transfer, diffusion, and application of new knowledge and technology in different industries. The results of this study indicate that if students do well in science subjects at the secondary level, it may enable universities to develop improved science programmes, so that a higher quality of graduate can enter the industrial sector.

The PISA score for reading, on the other hand, positively predicts the employment of females and males in the service sector. As mentioned above, most studies examine how science or mathematics subjects affect economic development, and reading literacy is often ignored. In a study by Swinton (1988) basic education, such as reading literacy, affects the wages and structures of the service sector. There is always a misconception that jobs in the service sector require only low-skilled workers. In fact, many jobs in this field require employees with high literacy levels, in particular reading literacy, since the service sector includes a wide range of occupations—such as library clerks, teachers, lawyers, editors, insurance agents, and so on (Benner, 2002). All these occupations require people to have good reading literacy in order to do well in their jobs. Moreover, as noted above, Sanchez (2003) suggested that possessing good literacy skills is a basic requirement for meeting the demands of a competitive global economy.

This study also shows that the PISA score for mathematics is able to predict researchers who work in the field of R&D across countries. Due to the advance of technology, the world has become smaller and every region has to compete not only with nearby regions but also with regions worldwide. Most countries nowadays have chosen economic growth as their goal and they are under great pressure to achieve it. It is very common to see the implementation of education reforms that have been introduced in order to attain economic goals (James and Mok, 2003; Sanchez, 2003; Smith, 2003; Aberšek, 2004; Jang and Kim, 2004).

The use of technology is a very important element in increasing the competitiveness of an economy (Sikka, 1997). The foundation stone for a country wishing to achieve a competitive edge technologically is the possession of a good knowledge of mathematics by its work force. In fact, comparisons of academic achievement in mathematics between countries have received more attention from the public and from policy makers than other types of academic achievement. If we recall the previously described endogenous growth theories, in which knowledge is at the heart of the growth process, then the development of new technologies and of human capital is an important element in outperforming competitors. The development of a work force better trained in mathematics can contribute to technological innovation in developed countries in the following areas: as a source of technological opportunities; as a source of trained researchers; as a catalyst for the development of improved research techniques and instruments; and as a source of tacit and public knowledge (Albuquerque, 2001). It is therefore understandable that, as this study has demonstrated, a high PISA score in mathematics will predict the number of researchers in the R&D sector.

Interestingly, this study also demonstrates that a low PISA score in mathematics can predict high female and male employment rates in agriculture. In other words, when a mathematics PISA score is high, a lower employment rate will be found in the agriculture sector. Based on the above results, people who are good at mathematics should be able to work as researchers in the R&D sector. Without a good knowledge of mathematics, and without the three PISA scores being so highly correlated, people who have a low level of education may have limited choices in their career or may be left with occupations that do not require them to have high mathematics skills, such as in the agriculture sector. Studies show that, in some developing countries, people, especially women, who are illiterate and poor are engaged only in agricultural jobs (Dixon, 1983). In addition, it is important to note that the countries included in this study are mostly developed countries, in which the economy is focused mainly on the service, industrial, or IT sectors rather than the agricultural sector.

Finally, researchers in R&D and the employment rate of people in the service sector significantly predict GDP *per capita* positively. Bryson and Rusten (2006) have already suggested that the most advanced economies are service economies, where more than 70 per cent of value added and employment is in services. In terms of R&D, when more people are working as researchers in R&D, it means that more studies will be generated in this area. In other words, mathematics and science PISA scores affect the economic situation indirectly. Benavot (1992) showed that emphasising science and mathematics in the school curriculum can positively influence the development of the economy. This study can contribute to that conclusion that PISA scores are positively associated with some important employment sectors which are important for the growth of the overall economy across countries.

Limitations

There are several limitations to this study. First, the study merely included thirty-three countries, and there are many countries that were left unexplored. Second, only the employment sectors of agriculture, industry, service, and R&D were investigated, and the study could definitely be improved if other employment sectors were studied also. Finally, though regression analysis models were run, this study could not show how PISA scores could actually affect economic growth, and hence GDP *per capita*, through employment in different sectors. This study could conclude only that there are significant relationships among those variables.

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