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PISA Science Score: A Good Indicator of Competence in S & T?

Abstract

In this study, the data from the Programme for International Student Assessment (PISA) are used to investigate whether the PISA science test score is a good indicator of competence in science and technology. The researcher uses a number of scientific and technical journal articles per million people as a measure instrument to represent the competence of science and technology. A regression model analysis suggests that the PISA science scores would significantly predict competence in S & T, even when controlling the number of researchers in R&D per million people and the R&D expenditure (% of GDP). Moreover, it shows that R&D expenditure (% of GDP) is another important determinant of the competence in S & T. Multicollinearity is also found between the R&D expenditure (% of GDP) and the number of researchers in R&D per million people. The policy implication is clear.

Keywords: *PISA, science education, indicator, competence in science and technology*

Introduction

The Programme for International Student Assessment (PISA) 2012 was conducted from April to May 2012, the corresponding results will be published at the end of 2013. What can the PISA really tell us? As commonly known, grades are the main indicator of ability and performance that can have long-term consequences for pupil achievement and thereby on future employment perspectives (Papay et al., 2011). Those with greater problem-solving and communication abilities should perform better than their less skilled counterparts. Thus, it has been taken for granted that PISA achievement is a good measure of the quality of human capital, and that science scores are an important indicator of national competence in the competence of science and technology. Developed economies have to concentrate on research and development (R&D) activities in order to maintain their leading position in the world. Due to the relatively poor performance of US students in the tests administered by the PISA, there is a widespread sense of crisis that the US leadership in science and technology is in jeopardy (Viadero 2008; Emeagwali 2010; Yu et al., 2012). Since the number of scientific and technical journal articles (per million people), which shows the activities involved in research and development, can better represent the competence of science and technology (Chen and Luoh 2010), it was used to investigate the relationships between the PISA science test scores and competence in science and technology, and to find out whether there is a strong link between them. Is it a good indicator for policy-makers to evaluate the competence in science and technology (S&T)? The link was tested between the PISA 2009 science test scores and competence in S&T while other variables, such as Research and Development researchers (per million people) and research and development expenditure (% of GDP), which are important to competence in S&T, were also included in the regression model.

Data

Science test score data from the PISA 2009 is available on OECD, http:// www.pisa.oecd.org. In the PISA 2009, about 475,000 students from over 17,000 schools in 65 countries/regions took part in a two-hour test (OECD 2012). World population is available from the United Nations' statistical databases (United Nations 2012). The number of Scientific and Technical journal articles is obtained from the World Development Index constructed by the World Bank (World Bank 2012a). The number of research and development (R&D) researchers per million people and the R&D expenditure (% of GDP) are also obtainable from the World Development Index constructed by the World Bank (World Bank 2012b, 2012c). All the data is shown in the appendix.

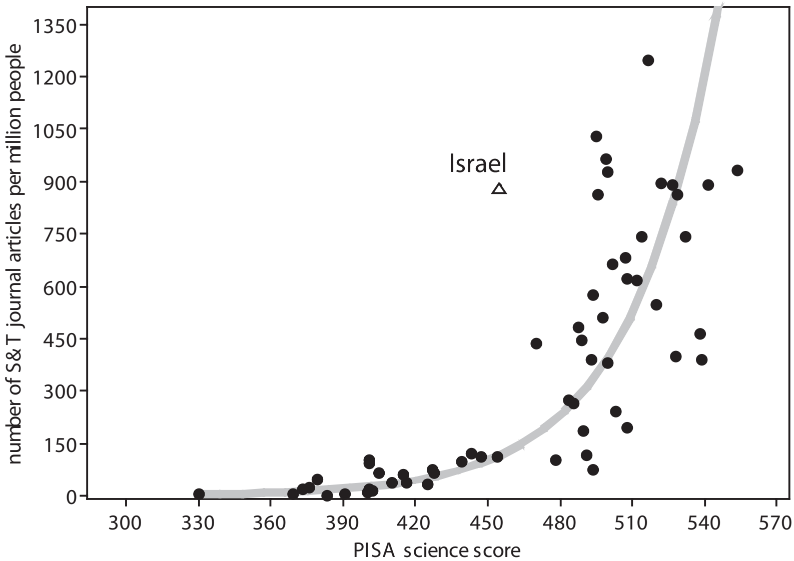
Analysis of the relationship between PISA and competence in S&T

In the PISA 2009, about 475,000 students from over 17,000 schools in 65 countries/regions took part in a two-hour test. Because of the unavailability of Hong Kong-China's, Macau-China's, Shanghai-China's, Chinese Taipei (Taiwan)'s, Liechtenstein's and Dubai's article or population data, 59 countries are taken into account.

Figure 1 shows a plot of the PISA science test scores and S&T journal articles per million people for the 59 countries. R^2 as a measure of the proportion of variance explained is 0.772, which shows a good evaluation indicator for the competence in S&T. The line shown in Figure 1 is the line of best fit for the data points. That is, if we are to predict the number of S&T journal articles per million people using PISA science score, the value on this line provides an estimate of the predicted number of articles as a function of PISA science score. Consequently, countries shown below the line have the observed article numbers lower than the fitting model predicts. That is, those countries performed relatively poorer in the competence in S&T. When we take a close look, it is found that the article number increase is not significant while the scores are below about 450, but the rate of increase in the number of articles rises sharply after about 485. It can be seen that, generally, Middle East and South Eastern Asia and the Latin American countries are fitted nearly perfectly; most of those countries' PISA science scores are below 450. Western countries performed a little better than predicted. Eastern European countries (such as the Russian Federation, Estonia, Hungary, Poland, the Slovak Republic, Lithuania and Latvia) and East Asia countries (such as Japan and Korea) generally performed a little poorer than predicted. The results are consistent with previous studies (Hutchison and Schagen 2007; Wu 2009). The outlier (symbol Δ) data point "Israel" is obvious.

This observation prompted an investigation into other possible factors impacting on S&T competence. Israel's performance on the PISA score was lower, but their research and development expenditure is the highest in the world at 4.3% (data from the World Development Index constructed by the World Bank). This may be the reason why Israel has such a strong competence in S&T. Similarly, Nordic countries' (Iceland, Norway, Denmark, Sweden, and Finland) numbers of R&D researchers per million people are among the top countries in the world (data from the World Development Index constructed by the World Bank) and their research and development expenditure (% of GDP) is also the highest in the world. Perhaps both factors contribute to the Nordic countries' higher S&T competence.

Figure 1. PISA science score and S&T journal articles per million people, red line



The number of S&T journal articles per million people in Switzerland is the highest in the world. This may be due to the combination of three important factors: higher research and development (R&D) expenditure, more R&D researchers, and a higher quality of human capital.

Hence, we must consider two other factors which also influence the S&T competence: the number of R&D researchers per million people and R&D expenditure (% of GDP). It is worth learning whether there is still a strong link between PISA science scores and S&T competence while adding the other two important factors.

Regression Model

Standard regression model is considered as follows:

$$\log(\mathrm{ar}tical) = \beta_0 + \beta_1 score + u \quad (1)$$
$$\log(\mathrm{ar}tical) = \beta_0 + \beta_1 score + \beta_2 reseacher + u \quad (2)$$
$$\log(\mathrm{ar}tical) = \beta_0 + \beta_1 score + \beta_2 reseacher + \beta_3 \mathrm{exp}enditure + u \quad (3)$$
$$\log(\mathrm{ar}tical) = \beta_0 + \beta_1 score + \beta_2 \mathrm{exp}enditure + u \quad (4)$$

Where article, score, researcher, expenditure and u are numbers of S&T journal articles per million people, PISA science test scores, R&D researchers (per million people), research and development expenditure (% of GDP) and the random error term, respectively.

Here, research and development researchers (per capita) and research and development expenditure (% of GDP) are included in the regression model, since both of them are also very important factors for the competence of science and technology.

Results

Due to the unavailability of data on the number of R&D researchers per million people and the R&D expenditure (% of GDP) in some countries in the year 2009, 28 countries were analyzed. However, this is enough to explain the correlation. A simple bivariate regression analysis in column (1) of Table 1 shows that the slope coefficient of the regression line is statistically significant at the significance level of 1%. The result suggests the PISA science score is an important determinant of the S&T competence.

Table 1. PISA science score and S&T competence

	(1)	(2)	(3)	(4)
LHS: log (Article)				
PISA science test scores	0.00997 [0.0020]**	0.00577 [0.0021]*	0.004994 [0.0019]*	0.005125 [0.0018]**
R&D researcher (per million)		0.00011 [0.000034]*	0.000013 [0.000048]	
R&D expenditure (% of GDP)			0.21912 [0.0847]*	0.23685 [0.0521]**
Constant	-2.4063 [0.9462]*	-0.68368 [0.9625]	-0.340695 [0.8787]	-0.392925 [0.8409]
Observations	28	28	28	28
R-squared	0.5110	0.6579	0.7325	0.7317
Robust standard errors in parentheses, * significant at 5%, ** significant at 1%				

When the number of R&D researchers per million people is added to the analysis, we can see clearly that the correlation between PISA science scores and the number of scientific and technical journal articles (per million people) remains significant (cf., column (2) of Table 1). It is worth noting that in this model, both factors contribute significantly to the explanation of the number of scientific and technical journal articles (per million people). In column (3) of Table 1, the R & D expenditure (% of GDP) is added to the regression model. The significant impact of PISA science scores remains, but the number of R&D researchers per million people is no longer related to competence. Moreover, if the R & D expenditure (% of GDP) is retained as the only additional measure of the number of scientific and technical journal articles (per million people), the results in column (4) suggest that R & D expenditure is another variable that contributes to national S &T competence. This factor and the PISA science score are both significant at 1%. The results in columns (2)-(4) suggest that although the number of R&D researchers per million people and the R&D expenditure (% of GDP) are important determinants of the number of scientific and technical journal articles, they seem to be similar variables. Hence, the correlation coefficient between the two variables was examined, it was 0.859 and suggested that the multicollinearity was a problem. Correlation coefficients between explanatory variables are shown in Table 2. This is the reason why the account of model 3 is similar to model 4. One plausible explanation is a larger proportion of R&D expenditure cost on the researchers.

Table 2. Correlation coefficient

	researcher	expenditure
expenditure	0.859	
score	0.617	0.594

Conclusion and Policy Recommendations

In this study, the researcher investigated whether the PISA science score is a good indicator of the competence in S&T. The results of the regression model suggest that national PISA science scores would significantly predict competence in S & T, even when controlling the number of R&D researchers per million people and the R&D expenditure (% of GDP). However, it is important to point out that the link between the R&D expenditure (% of GDP) or the number of R&D researchers per million people and the competence in S & T is as strong as the PISA science score. At the same time, we can see the multicollinearity between the R&D expenditure (% of GDP) and the number of R&D researchers per million people. One plausible explanation is a larger proportion of R&D expenditure on researchers.

The policy implication from this study is clear: in the era of knowledgeable economy, we must pay attention to the educational test score, because it represents the quality of human capital. At the same time, increasing the R&D expenditure to attract and recruit more R&D researchers and technicians is also a very important factor.

It is another important indicator of the competence in science and technology. This may be the reason why Israel's performance on PISA science tests was lower, but competence in S&T is stronger. Switzerland is a very good example, it takes both factors into account, thus getting No. 1 in the performance on the competence in S&T.

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Data Appendix

Table 2. PISA 2009 science score and other data

Country Name	Article	Population (millions)	Score	Researcher	Expenditure
Albania	8	3.2	391		
Argentina	3655.2	40.3	401		
Australia	18923.3	21.3	527		
Austria	4832.2	8.4	494	4122.13	2.75
Azerbaijan	150.9	8.8	373		0.26
Belgium	7217.6	10.6	507	3490.72	1.96
Brazil	12306.3	193.7	405		
Bulgaria	735.4	7.5	439	1586.71	0.53
Canada	29016.9	33.6	529		1.95
Chile	1867.8	17	447		
Colombia	608.4	45.7	402		0.16
Croatia	1164.1	4.4	486	1571.35	0.83
Czech Republic	3946.2	10.4	500	2754.79	1.53
Denmark	5306.1	5.5	499	6390.35	3.02
Estonia	518.1	1.3	528	3210.28	1.44
Finland	4949.1	5.3	554	7647.36	3.96
France	31748.3	62.3	498		2.23
Germany	45002.8	82.2	520	3780.09	2.82
Greece	4881	11.2	470		
Hungary	2397.2	10	503	2005.95	1.15
Iceland	259.1	0.3	496		
Indonesia	262	230	383	89.61	0.08
Ireland	2798.5	4.5	508	3372.53	1.77
Israel	6304.2	7.2	455		4.27

Country Name	Article	Population (millions)	Score	Researcher	Expenditure
Italy	26755.3	59.9	489	1690.01	1.27
Japan	49627	127.2	539		
Jordan	382.6	6.3	415		
Kazakhstan	98.7	15.6	400		0.23
Korea, Rep.	22270.8	48.3	538		
Kyrgyz Republic	15.4	5.5	330		0.16
Latvia	161.6	2.2	494	1601.23	0.46
Lithuania	387.6	3.3	491	2541.08	0.84
Luxembourg	136.8	0.5	484	4824.8	1.68
Mexico	4127.7	109.6	416		
Montenegro	10.6	0.6	401		
Netherlands	14866	16.6	522	2817.58	1.84
New Zealand	3187.8	4.3	532		
Norway	4440	4.8	500	5503.72	1.8
Panama	72.6	3.5	376		0.21
Peru	158.6	29.2	369		
Poland	7355.4	38.1	508	1597.55	0.68
Portugal	4156.5	10.7	493	4307.84	1.66
Qatar	64.2	1.4	379		
Romania	1366.6	21.3	428	894.78	0.48
Russian Federation	14016.2	140.9	478	3091.36	1.25
Serbia	1172.6	9.9	443	1060.14	0.89
Singapore	4186.8	4.7	542		
Slovak Republic	1000.4	5.4	490	2437.65	0.48
Slovenia	1234.2	2	512	3678.78	1.86
Spain	21542.6	44.9	488	2931.83	1.38
Sweden	9477.8	9.2	495	5017.55	3.62
Switzerland	9469.2	7.6	517		
Thailand	2032.7	67.8	425		
Trinidad and Tobago	47.7	1.3	410		
Tunisia	1022.4	10.3	401		1.1
Turkey	8300.9	74.8	454	803.92	0.85
United Kingdom	45648.8	61.6	514	3946.94	1.87
United States	208600.8	314.7	502		
Uruguay	246.2	3.4	427		