The Impact of a Nation's Research and Development Expenditure On Scientific Literacy

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Through pooled cross-sectional analysis of data from the OECD's triennial Programme for International Student Assessment (PISA), we estimate the effects of a nation's research and development expenditure on scientific literacy. Controlling for economic, educational, and demographic factors for over sixty countries between 1998 and 2015, we find that the amount of funds a nation allocates towards research and development has a positive and statistically significant association with scientific literacy. These results suggest that, along with established socioeconomic and educational determinants of scholastic achievement, the prioritization of research and development by a nation—beginning with policymakers—may function as a tacit cultural approval of science, and therefore may be auspicious to the quality and efficacy of science education.

I. Introduction

The Importance of Scientific Literacy

Scientific literacy is important to the individual and society as a whole for a few critical reasons. For one, it has long been accepted that knowledge and understanding of scientific topics is critical to being an informed citizen and voter (Miller, 1998). Public policy debates often regard controversial scientific topics such as climate change, science education curriculum, and public health initiatives, to name a few (ibid., 1998). In recent years, these debates have come to consider things such as artificial intelligence, biomedical engineering, and genetically modified organisms. Relatedly, public spending on science and the subsidization of scientific research is reevaluated each year when fiscal policy and federal budgeting come to forefront of policy making. Should an individual wish to understand these debates—as their outcomes undoubtedly affect one's decisions and decision making power when it comes to one's health, lifestyle, and consumption—and should an individual wish to play a part in shaping public policy—whether it be via public forum or through electing government representatives, as is done in any functioning democracy—at least a general knowledge and appreciation of science is necessary (National Academies of Sciences, Engineering, and Medicine, 2016).

What is more, scientific literacy is becoming more and more necessary as humankind advances technologically. As with reading and writing, an individual's ability to use and understand technology is now essential as technology is virtually inescapable in a developed, twenty-first century society. Similarly, science literacy is also critical to the employment prospects of future generations as advanced economies shift to science, technology, and engineering based production processes, demanding of a scientifically and technologically skilled workforce (ibid., 2016).

Finally, and perhaps most importantly, is the economic rationale for scientific literacy. Essentially, the economic rationale maintains that economic prosperity is largely engendered by innovations in science and technology, and for one to innovate scientifically or technologically, knowledge of science is imperative (ibid., 2016). Astrophysicist and science educator Dr. Neil deGrasse Tyson once summed this idea up by saying, "[to] breed a generation of people who do not know what science is, nor how it works," is to, "mortgage the future financial security of your nation [because] innovations in science and technology are the basis of tomorrow's economy" (Newsom, 2017). Historically, this argument is substantiated, as the data show that periods of economic growth generally follow from technological revolutions, for example, the Industrial Revolution and the advent of the Internet (Cameron, 1996; Rosenberg, 2006; Verspagen, 2005).

Thus, it has been established that scientific literacy is important for both the individual and society. It underpins democracy, enables successful functioning of an individual in a technologically advanced society, and engenders economic prosperity. So what might we do to promote it?

Research Idea and Goals

In line with Dr. Tyson's aforementioned notion, this study serves to examine the relationship between innovations in science and technology—that is to say, scientific and technological research and development—and scientific literacy, so as to uncover a possible, unconventional determinant of scientific literacy. We posit that, along with conventional socioeconomic, educational, cultural, and institutional factors, the prioritization of research and development by a nation—beginning with its policymakers—may function as a tacit cultural approval of science, or as Tyson would say, “a not-so-subtle message from the government that math [and science] matter,” and therefore may be auspicious to the quality and efficacy of science education. (Newsom, 2017).

In fact, a growing body of literature lends credence to such an idea. In one comprehensive cross national meta-analysis of surveys on public understanding of science, a small but positive and statistically significant correlation was found between attitudes towards science and general scientific knowledge (Allum et al., 2008). A study conducted in the United States specifically, found some evidence to suggest a correlation between Americans’ support for science funding and their knowledge of scientific topics, and such findings have also been replicated in Spain (Besley, 2016; Muñoz et al., 2012; Sanz-Menéndex et al., 2014). In light of these findings, we expect there to be a positive and meaningful relationship between research and development expenditure and scientific literacy.

II. Literature Review

In determining the proper controls to implement, we largely draw from the existing literature regarding the determinants of traditional reading literacy and language development, as research on the determinants of scientific literacy specifically, is sparse. Reading literacy is said to be largely dependent upon multifarious factors belonging to perceptual, cognitive, conceptual, linguistic, and social categories (Johnston, 2010).

Arguably most influential though are the social factors, as language development and literacy acquisition are largely regarded as a social practice (Compton-Lilly, 2008).

This critical social category can be broken down into subcategories encompassing demographic, home, and educational factors. The few quantitative analyses of these factors have looked at the impact of demographic factors such as gender, average years of schooling for adults, geographic region, and life expectancy at birth; home/familial factors such as parental involvement in students' schooling and the number of books in the home; and educational factors such as student-teacher ratios and school enrollment rates. Other factors that have been considered include economic indicators such as per capita income and national educational expenditure, as well as miscellaneous factors such as access to technology. One widely cited study found the main determinants of reading literacy to be: 1) primary school enrollment rates, 2) average years of schooling for adults, and 3) life expectancy at birth (Vernor, 2005). This study also provided some evidence supporting the idea that income does have an effect on reading literacy (ibid., 2005).

As previously mentioned, the existing literature regarding the determinants of scientific literacy specifically, is wanting. However, one of the few existing studies demonstrated that income had a positive relationship with scientific literacy rates in Hong Kong, and that the variation in scientific literacy between schools in Hong Kong could be mostly explained by school enrollment size as well as the socioeconomic composition of a school's student population (Sun et al., 2012). Similarly, in an investigation of the determinants of scientific literacy in Turkey, exposure and access to technology has been found to explain some of the variance in scientific literacy (Delen et al., 2011).

The Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA)—of which we derive the data for the dependent variable considered within in the models to follow—also shows strong positive correlation of primary school students' performance in science with per capita gross domestic product, government expenditure on students, and parents' educational attainment (OECD, 2016).

In summation, while there is a dearth of literature discussing the topic of the determinants of literacy, especially that of scientific literacy, there do exist a number of established controls, which may be worthwhile for future models to build off of. These controls include: 1) economic factors, such as per capita income and government expenditure on education, 2) demographic/institutional factors, such as adult educational attainment, life expectancy at birth, school socioeconomic composition, and access to technology, and 3) educational factors, such as primary school enrollment rates and school enrollment size.

III. Data

Introduction

The data used in this study and in developing the models found in Section IV were predominantly accessed through online databases from The World Bank, which provides free and open access to thousands of economic and financial indicators for over 150 countries. The data regarding corruption come from Transparency International, which monitors, surveys, and reports on corruption and its effects around the world. Data regarding our dependent variable (*PISA*) comes from the Organisation for Economic Co-operation and Development's triennial Programme for International Student Assessment, as published between 2000 and 2015. Summary statistics for all variables are presented on page 23 in Table 1.

Scientific Literacy

The OECD's Programme for International Student Assessment (PISA) broadly defines scientific literacy as, "the ability to engage with science related issues, and with the ideas of science, as a reflective citizen" (OECD, 2016). The PISA scores captured in the data used in our models reflect the mean overall scientific performance score of 15-year-old students, both male and female, for 67 countries. Mean overall scientific performance indicates the average ability of a nation's students to, "explain phenomena scientifically, to evaluate and design scientific enquiry, and to interpret data and evidence scientifically" (ibid, 2016). Thus, it is a useful proxy for measuring and assessing levels of scientific literacy, cross-nationally.

Research and Development

The World Bank Group defines research and development as:

> Current and capital expenditures [sic] (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development" (The World Bank, 2017).

The data are represented as a percentage of national gross domestic product (GDP), and come from the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.

GDP Per Capita

Our models use the natural log of gross domestic product (GDP) per capita based on purchasing power parity (PPP) in current international dollars. GDP per capita is commonly used as a proxy indicator of economic prosperity, and is useful for making a relative comparison of the average citizen's wealth and standard of living between countries with different population sizes. The indicator's basis on purchasing power parity (PPP) in current international dollars means that, "an international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States" (The World Bank, 2017a).

Education Expenditure

Data for educational expenditure used in this study comes from the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics, and is defined by the World Bank as, "general government [local, regional, and central] expenditure on education [sic] (current, capital, and transfers)" including, "expenditure funded by transfers from international sources to government," and is expressed as a percentage of real GDP (The World Bank, 2017b). This factor is useful for comparing educational expenditure between countries over time relative to the size of their economies, and thus may be used as a proxy for quantity of education provided within a country.

Internet Access

Data on Internet access come from the International Telecommunication Union's World Telecommunication/ICT Development Report, and were accessed through The World Bank's online database. The specific indicator used in this study measures the percentage of a country's citizens that use the Internet. Internet users are defined as, "individuals who have used the Internet (from any location) in the last 3 months," either "via a computer, mobile phone, personal digital assistant, games machine, digital TV etc" (The World Bank, 2017c).

Life Expectancy at Birth

The World Bank defines life expectancy at birth as an indicator of "the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life" (The World Bank, 2017d). The data is aggregated from various census reports including: 1) The United Nations Population Division's World Population Prospects, 2) Census reports and other statistical publications from national statistical offices, 3) Eurostat: Demographic Statistics, 4) The United Nations Statistical Division's "Population and Vital Statistics Report", 5) The U.S. Census Bureau, and 6) The Secretariat of the Pacific Community: Statistics and Demography Programme. This indicator is useful for understanding the general health status of a country's population.

Net Primary Enrollment Rate

The data for the net primary enrollment rate come from the UNESCO Institute for Statistics, as reported by The World Bank. This indicator represents the ratio of the number of students in the theoretical age group at the primary education level that are enrolled in school to the total population in that age group (The World Bank, 2017e). The net primary school enrollment rate is commonly used as an indicator of the capacity and quality of a nation's education system.

Student-Teacher Ratio

The data for the student-teacher ratio again come from the UNESCO Institute for Statistics and are reported by The World Bank. The indicator measures the average number of pupils per teacher at the primary school level, and is commonly used as a proxy for quality of education (The World Bank, 2017f).

Corruption Perceptions Index (CPI)

The Corruption Perceptions Index (CPI) is, “a composite index, a combination of surveys and assessments of corruption, collected by a variety of reputable institutions,” that ranks countries based on, “how corrupt a country’s public sector is perceived to be,” by its citizens (Transparency International, 2017). We use the natural log of CPI in the models to follow as a proxy indicator and control for institutional and political stability.

International Migrant Stock

The World Bank defines international migrant stock as, “the number of people born in a country other than that in which they live,” including refugees (The World Bank, 2017g). The data is aggregated from population censuses and the United Nations Populations Division “Trends in Total Migrant Stock: 2008 Revision” report. This indicator is a useful proxy for ethnic and cultural homogeneity of a population.

Data Limitations

The panel used is unbalanced as data for all variables, for all sixty-seven countries, in all six periods, were unobtainable. The only variables with observations for all sixty-seven countries in all six periods are GDP per capita and life expectancy at birth. All other variables, including our dependent variable, have missing observations, which ultimately resulted in smaller sample sizes for our models to run on. Thus, our analysis represents that of pooled cross-sections rather than that of a conventional panel.

Furthermore, being that data for our dependent variable (*PISA*) are published triennially, data for our independent variables were aggregated as three-year averages based on the value of that variable during the observed PISA year plus its values for the two years leading up to the observed PISA year. For example, the observation for *GDP* in 2015 for Albania is an average of Albania's GDP per capita in 2013, 2014, and 2015. For cross-sections with missing observations, the reported average is based not on a three-year average, but a two-year or one-year average depending on if one or two observations are missing. This is captured by,

$$\frac{1}{n}\sum_{i=t-2}^{n} x_i$$

in the models presented in Section IV, where t equals the observation year, i corresponds to the year two years prior t, and n represents the number of observations (up to three).

IV. Empirical Methodology

The Model

We employ eight Ordinary Least Squares (OLS) models, beginning with a simple regression testing only research and development and its square against scientific literacy. We then progressively add GDP per capita, public expenditure on education, internet access, life expectancy at birth, the net primary school enrollment rate, the student-teacher ratio, and then finally the Corruption Perceptions Index and immigrant population percentage. Thus, the eighth and most comprehensive model may be expressed mathematically as,

$$
\begin{aligned}
ln(PISA)_{dt} = \beta_0 \; &+ \; \beta_1 \left[\frac{1}{n}\sum_{i=t-2}^{n} RD_i\right]_d + \; \beta_2 \left[\frac{1}{n}\sum_{i=t-2}^{n} RD_i^2\right]_d + \; \beta_3 \left[\frac{1}{n}\sum_{i=t-2}^{n} ln(GDP)_i\right]_d \\
&+ \; \beta_4 \left[\frac{1}{n}\sum_{i=t-2}^{n} EDUCSPEND_i\right]_d + \; \beta_5 \left[\frac{1}{n}\sum_{i=t-2}^{n} INTERNET_i\right]_d + \; \beta_6 \left[\frac{1}{n}\sum_{i=t-2}^{n} LIFEX_i\right]_d \\
&+ \; \beta_7 \left[\frac{1}{n}\sum_{i=t-2}^{n} PRIMENROL_i\right]_d + \; \beta_8 \left[\frac{1}{n}\sum_{i=t-2}^{n} STUTEACH_i\right]_d \\
&+ \; \beta_9 \left[\frac{1}{n}\sum_{i=t-2}^{n} ln(CORRUPT)_i\right]_d + \; \beta_{10} \left[\frac{1}{n}\sum_{i=t-2}^{n} IMMIGRANT_i\right]_d + \; u_{dt}
\end{aligned}
$$

where *d* designates the country, *t* corresponds to the year, and *u* is the error term.

All eight OLS models have period fixed effects implemented as dummies for year, as well as cross-section random effects in place. While the Hausman Tests for the models we employ are inconclusive, due possibly to the use of logarithmically and quadratically transformed data, regression analyses of level data and their corresponding Hausman Tests indicate the presence of cross-section random effects in all eight models.

Hypotheses

We expect the coefficients for our main regressor of interest, namely, research and development expenditure, to be positive in line with our hypothesis that national research and development expenditure positively impacts public perception and acceptance of science and therefore would positively correlate with science educational attainment and literacy. However, we expect the beta for RD^2 to be negative, capturing the diminishing marginal impact of research and development expenditure on scientific literacy, that is apparent in Table 3 on page 25.

For *lnGDP*, *EDUCSPEND*, *INTERNET*, and *LIFEX*, we expect the coefficients to be positive because income, education spending, internet access, and life expectancy have each been demonstrated to correlate positively with literacy rates in previous studies (OECD, 2016; Delen et al., 2011; Vernor, 2005). Also in line with aforementioned previous research, we expect the coefficeints for *PRIMENROL* and *STUTEACH* to be negative, as it has been demonstrated that higher enrollment rates and larger school populations may lead to less attention and involvement of teachers per student, and thus diminish the quality and/or quantity of an individual students' education (Sun et al., 2012; Vernor, 2005).

For *lnCORRUPT*, we suspect that there would be a positive relationship, where higher scores on the index—corresponding to lower levels of perceived corruption—should signify greater institutional stability, which undoubtedly is conducive to educational success. Lastly, for *IMMIGRANT* we predict there to be a positive impact in expectation that a more heterogeneous population may lead to greater competition within schools between students of different ethnic backgrounds, all competing to be the best.

V. Results

**Summary results for all models are presented on page 24 in Table 2.*

Model I

Model I is the simple regression that tests the relationship solely between *lnPISA*, research and development expenditure and its square. Across 287 observations, we find that for a one percent increase in national research and development expenditure as a percentage of GDP, the mean overall science performance PISA score increases 5.74 percent, on average. This finding is statistically significant at 1%, but accounts for little—just over seven percent of the variation in PISA across the sample. We also find, albeit at the 10% significance level, evidence of diminishing marginal returns, demonstrated by the negative coefficient for RD^2.

Model II

Model II adds the natural log of real GDP per capita, which is our proxy indicator for wealth. Across 287 observations, we find that when controlling for a country's wealth, a one percent increase in research and development expenditure is associated with a 4.2 percent increase in scientific literacy. This finding is statistically significant at the 5% level. The coefficient for *lnGDP* is also positive and statistically significant at the 1% level, demonstrating that a one percent increase in real GDP per capita is associated with a 0.05 percent increase in *PISA*. The beta for the square of research and development is found to be statistically insignificant. Together, research and development, its square, and the natural log of GDP per capita accounted for just over fifteen percent of the variance in *PISA*.

Model III

Model III tests *lnPISA* against research and development, its square, the natural log of GDP per capita, and government education expenditure, which is our proxy for quantity of education. When holding research and development expenditure, its square, as well as the natural log of GDP per capita fixed, we find the effect of government education expenditure on *lnPISA* to be statistically insignificant at all confidence levels. On the other hand, *RD* and *lnGDP* are statistically significant at 5%, and RD^2 is statistically significant at 10%. Holding all else fixed, we find that for a one percent increase in our main regressor (*RD*) there is an associated 5.84 percent increase in *PISA*, on average. On the whole, the model accounts for more than fifteen percent of the variance in *PISA*.

Model IV

Model IV adds internet access, our proxy indicator of access to technology. We find that when controlling for quantity of education (*EDUCSPEND*), wealth (*lnGDP*), and access to technology (*INTERNET*), a one percent increase in research and development expenditure as a percent of GDP is correlated with a 5.61 percent increase in scientific literacy, on average. Said finding is statistically at the 95% confidence level. Evidence of diminishing returns is also found (at the 90% confidence level) as demonstrated by the negative beta for RD^2. Also at the 90% confidence level, we find that for a one percent increase in GDP per capita, scientific literacy increases 0.04 percent, on average. The effect of access to internet under this model is found to be statistically insignificant at all confidence levels. Model IV accounts for about 20 percent of the variance in *PISA*.

Model V

Model V adds the control for health status within a population, as approximated by the indicator for infant life expectancy. We find that, at the 95% confidence level, when holding research and development expenditure and its square, the natural log of GDP per capita, education expenditure, and internet access fixed, a one year increase in infant life expectancy is associated with a 0.7 percent increase in scientific literacy, on average. Research and development expenditure on the other hand is statistically significant at 10%, where a one percent increase in *RD* correlates with a 4.8 percent increase in *PISA*, on average. Diminishing returns may also be in effect under Model V. Education expenditure, access to internet, and *lnGDP* are all demonstrated to be statistically insignificant. Together, the regressors of Model V account for over twenty-one percent of the variance in scientific literacy.

Model VI

In Model VI, we add the regressor for the net primary school enrollment rate, which is an indicator of educational quality. Model VI demonstrates with 99% confidence that a one percent increase in the net primary school enrolment rate is associated with a 0.4 percent decrease in scientific literacy, on average. It also shows that with 95% confidence, a one percent increase in research and development expenditure is associated with a 6.73 percent increase in scientific literacy, on average. Infant life expectancy is also demonstrated to be statistically significant at this level, but *lnGDP*, *EDUCSPEND*, and *INTERNET* are each found to be statistically insignificant. This model accounts for over a quarter of the variation in scientific literacy.

Model VII

Model VII adds the regressor for the student-teacher ratio, which is an additional proxy indicator of educational quality, though, its impact on scientific literacy is found to be statistically insignificant. Under this model, research and development expenditure remains statistically significant at the 5% level, where for a one percent increase in *RD*, scientific literacy increases 7.58 percent, on average. Also demonstrated at this confidence level are diminishing marginal returns of research and development expenditure to *PISA*, which is captured by the negative beta for RD^2. The beta for the net primary school enrollment rate remains statistically significant, as does that of infant life expectancy, while the betas for *lnGDP*, education expenditure, and internet access remain statistically insignificant. Model VII as a whole accounts for about a quarter of the variation in *PISA*.

Model VIII

Lastly, Model VIII adds the institutional controls for corruption and immigration. While the coefficient for corruption is found to be statistically insignificant, a one percent increase in the immigrant population relative to the total population is associated with a 0.25 percent decrease in scientific literacy, on average, at the 99% confidence level. Research and development expenditure remains statistically significant at the 95% confidence level, with its beta demonstrating that a one percent increase in *RD* corresponds to a 7.1 percent increase in *PISA*. RD^2 is also statistically significant at 5%, as is infant life expectancy. Access to internet becomes statistically significant at 10% under this model, and the net primary enrollment rate remains statistically significant at 1%. Model VIII, which is our most comprehensive model, accounts for about 30% of the variance in scientific literacy.

VI. Discussion

Policy Implications

This study was conducted to uncover the relationship between a nation's research and development activities and the scientific literacy observed within that nation's population. When controlling for relevant economic, institutional, and educational factors, we find research and development expenditure to positively impact scientific literacy. These findings are statistically significant across all eight of our models (albeit, at different confidence levels). Under these models, a one percent increase in national research and development expenditure—that is to say, the aggregate of public and private contributions to research and development endeavors relative to national GDP—is associated with increased PISA mean overall scientific literacy scores between about four and eight percent, depending on the controls that are implemented.

In light of these findings, it may be argued that, should a nation wish to increase the scientific literacy of its population—which, of course, has multifarious benefits for both the individual and the society, including increased civic engagement in the political process, as well as increased economic prosperity—it may be a worthwhile endeavor to increase national research and development activities (National Academies of Sciences, Engineering, and Medicine, 2016; Miller, 1998; Cameron, 1996). This process largely begins with policymakers, as they have the power to appropriate and allocate federal funding however they see fit.

While our study does not determine any causality, simply, correlation, we believe that the amount budgeted for scientific enterprises by policymakers may serve as an indicator to the general public of the importance and value of science, which then influences and pervades the public's attitude towards science. Positive perception of science is demonstrated to have a positive effect on a population's knowledge and understanding of science (Allum et al., 2008; Besley, 2016; Muñoz et al., 2012). Thus, the relationship may in fact be causal. However, more work in uncovering this and substantiating such a notion needs to be done.

It must also be stated that there seems to be diminishing marginal returns in effect when it comes to increasing scientific literacy strictly via research and development expenditure. This can be seen graphically on page 25 in Table 3, and is demonstrated by the negative coefficients for the regressors of the square of research and development in Table 2 on page 24. These findings suggest that research and development spending may only affect scientific literacy to a certain degree, and that it alone cannot tremendously determine or predict scientific literacy.

What is more, our findings demonstrate that many of the conventional determinants of educational success, namely, the student-teacher ratio and government spending on education—that is to say, the quantity and quality of education—as well as access to internet, may not play as big of a role in developing scientific literacy as they do in helping to cultivate traditional, reading literacy. The coefficients for these three controls across every model were statistically insignificant at the 95% confidence level. This also seems to be the case for wealth, specifically real per capita GDP, as well as rates of perceived corruption.

On the other hand, the net primary school enrollment rate, the percentage of a nation's population that is foreign born, and life expectancy at birth may indeed be important determinants of scientific literacy, as the coefficients for these three indicators, across all relevant models, are statistically significant at the 95% confidence level. For infant life expectancy, as hypothesized, the impact is positive, indicating that increased levels of health status correspond with increased levels of scientific literacy. The impact for both the net primary school enrollment rate and the percentage of a nation's population that is foreign born though is negative, suggesting inverse correlation, where higher rates of each correspond with lower levels of scientific literacy.

The U.S. In Perspective

Of the sixty-seven countries considered in this study with *PISA* observations for 2015, the United States ranked twenty-third, with a score of 496. The top five scoring countries were Singapore, Japan, Estonia, Finland, and Macao, which scored 556, 538, 534, 531, and 529, respectively. The bottom five scoring countries includes the

Dominican Republic, Algeria, Lebanon, Tunisia, and Peru, which scored 332, 376, 386, 386, and 367, respectively. These scores can be found in Table 4 on page 26.

Of the sixty countries with *RD* observations for 2015, the United States ranked ninth, spending an average 2.76 percent of national GDP on research and development activities between 2013 and 2015. The top five research and development spenders were Israel, Korea, Japan, Sweden, and Finland, which spent on average 4.23, 4.22, 3.33, 3.24, and 3.12 percent, respectively, during that same period. The bottom five spenders were Trinidad and Tobago, Indonesia, Macao, Peru, and Kazakhstan, which spent on average, 0.07, 0.08, 0.09, 0.10, and 0.17 percent, respectively. These scores can be found in Table 5 on page 27.

While research and development spending alone is not and cannot be an exact predictor of *PISA* as previously established, our models demonstrate that theoretically, if the United States were to become the world's leader in research and development spending—by at least matching Israel's spending of 4.23 percent of GDP, thus increasing research and development spending by 1.74 percent of GDP—then it would experience a PISA mean overall scientific literacy score between about 515 and 536. All else constant, this would bump the United States' international ranking up from twenty-third to somewhere between tenth and third. This extrapolation is compelling, and more work on this topic should be undertaken, so as to corroberate it.

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Summary Statistics

Table I

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Obs.
PISA	476.28	491.00	563.32	332.00	49.06	306
RD	1.27	1.00	4.29	0.04	1.01	350
GDP	26699.10	23226.04	128266.10	1795.63	20712.41	402
EDUCSPEND	4.75	4.79	8.68	1.82	1.39	348
INTERNET	43.83	42.82	97.64	0.09	27.95	400
LIFEX	76.45	77.00	84.03	65.19	4.18	402
PRIMENROL	95.27	96.25	99.98	80.82	3.97	338
STUTEACH	16.97	16.79	33.51	8.15	5.16	343
CORRUPT	57.02	54.00	99.33	18.00	22.13	387
IMMIGRANT	13.03	8.13	88.40	0.06	16.54	399

Results Summary

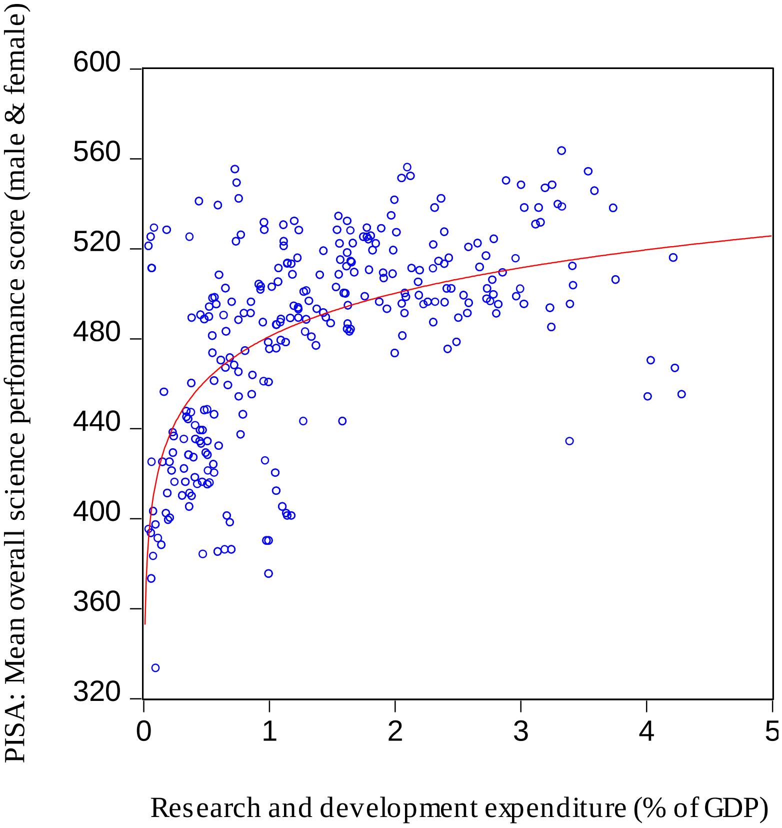
Table II

Variable	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII	Model VIII
Research and development expenditure (% of GDP)	0.057* (2.846)	0.042** (1.968)	0.058** (2.433)	0.056** (2.315)	0.048*** (1.934)	0.067** (2.434)	0.076** (2.385)	0.071** (2.388)
R&D expenditure (% of GDP) squared	-0.009*** (2.846)	-0.006 (-1.144)	-0.008*** (-1.687)	-0.008*** (-1.762)	-0.008*** (-1.719)	-0.012*** (-1.946)	-0.014** (-1.976)	-0.014** (-2.016)
Real GDP per capita, PPP, current Intl. $ (natural log)		0.048* (3.036)	0.043** (2.373)	0.036*** (1.793)	0.018 (0.842)	0.018 (0.765)	0.005 (0.213)	0.039 (1.533)
Total Govt. expenditure on education (% of GDP)			-0.004 (-0.843)	-0.005 (-0.959)	-0.006 (-1.213)	-0.008 (-1.594)	-0.009 (-1.607)	-0.009 (-1.648)
Internet access (% of population)				0.001 (1.447)	0.0005 (1.133)	0.001 (1.379)	0.001 (1.435)	0.001*** (01.667)
Life expectancy at birth (in years)					0.008** (1.986)	0.008** (2.083)	0.008** (2.035)	0.010** (2.369)
Net primary school enrollment rate (% of pop)						-0.004* (-2.968)	-0.004** (-2.507)	-0.005* (-3.238)
Student to teacher ratio, at primary school level							-0.002 (-0.825)	-0.002 (-0.905)
Corruption Perceptions Index (natural log)								-0.033 (-1.102)
International migrant stock (% of population)								-0.003* (-2.663)
Observations	287	287	260	260	260	221	192	190
Adjusted R^2	0.0763	0.1513	0.1554	0.1923	0.2173	0.2549	0.2424	0.2886
F-Stat (p-value)	4.375 (0.000)	7.374 (0.000)	6.296 (0.000)	7.165 (0.000)	7.537 (0.000)	7.271 (0.000)	5.699 (0.000)	6.112 (0.000)

Note: All models have country random effects and year dummies; t-statistics are in parenthesis; *, **, and *** represent 1%, 5%, and 10% significance, respectively.

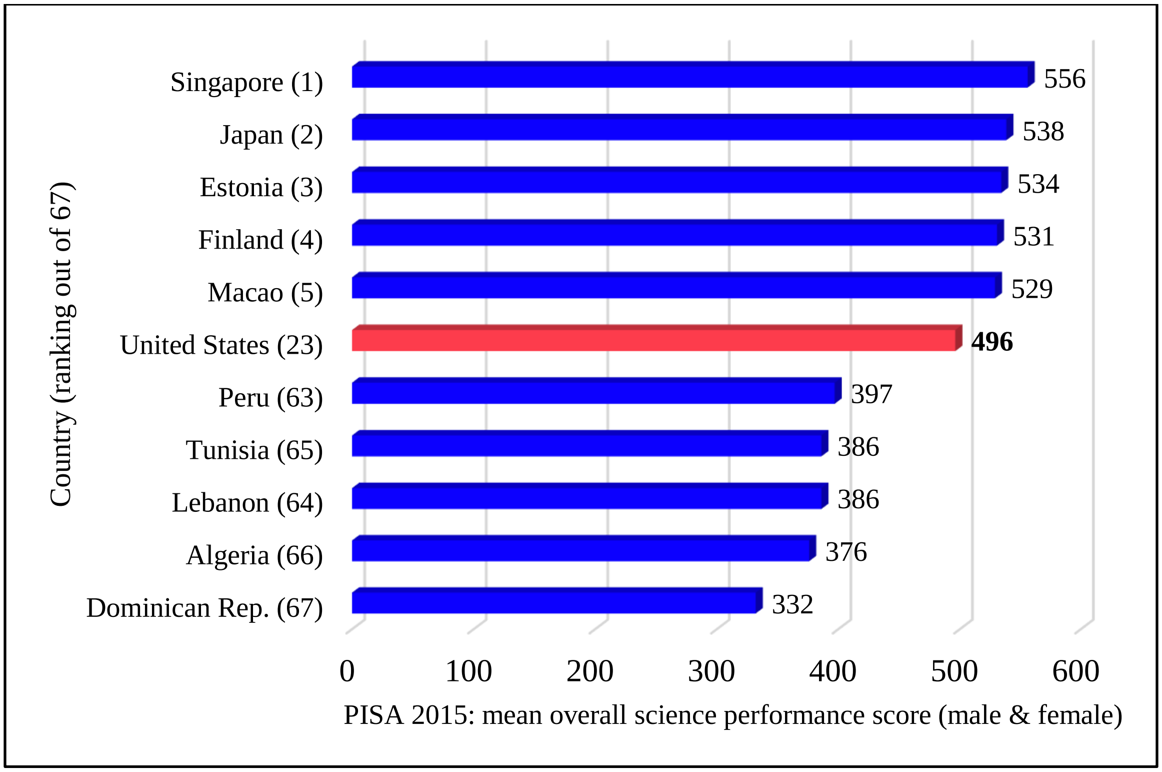
Scatter Plot of PISA and R&D

Table III



PISA 2015: Top & Bottom Five Countries Relative to the U.S.

Table IV



R&D 2015: Top & Bottom Five Countries Relative to the U.S.

Table V