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Running head: SCIENTIFIC IMPACT OF NATIONS

Indicators of the Scientific Impact of Nations Revisited

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Abstract

An improved *Indicator of a Nation's Scientific Impact* (*INSI*), which, in addition to citation rates, takes into account how many research areas in which each nation has exceeded the entrance thresholds of the *Essential Science Indicators* (*ESI*; Clarivate Analytics), was proposed. This indicator provided a more realistic estimate of nations' scientific impact, which was better predicted from the societal factors that are related to the quality of scientific output. The strongest predictor of countries' scientific impact was good governance, while economic wealth and research and development expenditure played a relatively minor role in predicting research impact. We conclude that good governance is needed to create an environment, which can facilitate the translation of money invested into the production of high-impact scientific output.

Keywords: bibliometric analysis; Web of Science; Essential Science Indicators; scientific impact of nations

Indicators of the Scientific Impact of Nations Revisited

Two influential papers, published in *Nature* and *Science*, have popularized the idea that, just like economic wealth, the scientific impact of nations can be measured by a simple indicator which counts how many times papers from a country have been cited on average (King, 2004; May, 1997). These two prominent papers demonstrated that articles published by researchers from wealthy nations are more frequently cited than papers that were published by researchers from less economically advanced countries, thus, supporting the popular view that money can buy scientific excellence. Yet, this conclusion was based on a limited sample of countries: May (1997) analyzed only 15 and King (2004) 31 predominantly Western, Educated, Industrial, Rich, and Democratic (WEIRD) countries (cf. Henrich, Heine, & Norenzayan, 2010a, 2010b), which form a relatively small fraction of economically well developed nations. However, we know very little about whether and to what extent May's (1997) and King's (2004) findings can be generalized to other countries. Another reason for caution is that both studies looked at the relationship between economic and scientific wealth in isolation from other important societal factors which may influence the observed relationship. Although a typical bibliometric analysis prefers to focus on variables that are related to articles, authors, references, and citations (e.g., Xie et al., 2019), there is convincing evidence from many studies that both the quantity and quality of countries' research output are significantly influenced, not just by economic, but also social and cultural factors (Harzing & Giroud, 2014; Leydesdorff & Wagner, 2009; Mueller, 2016; Schofer, 2004; Tahamtan, Afshar, & Ahamdzadeh, 2016). The *Worldwide Governance Indicators* (WGI), for instance, which was developed by the World Bank to characterize practices and institutions through which authority is exercised in a country (Kaufmann, Kraay, & Mastruzzi, 2010), has been found to be an influential factor in driving scientific excellence (Jüri Allik, Lauk, & Realo, 2020; Gantman, 2012).

One of the most prominent bibliometric trends is a shift from impact scores based on average values of citations toward indicators reflecting the top of the citation distribution, such as the number of papers reaching the highest rank of citations (Albarran, Ortufno, & Ruiz-Castillo, 2011; Bornmann, 2014; van Leeuwen, Visser, Moed, Nederhof, & van Raan, 2003). In accordance with this general development, Allik and colleagues (J. Allik, 2013; Jüri Allik et al., 2020) proposed the *High Quality Science Index* (*HQSI*), which combines the mean citation rate per paper with the percentage of papers that has reached the top 1% level of citations in a given research area and an age cohort of published papers. Interestingly, they discovered that significant correlations between the *HQSI* and economic indicators—Gross National Income (GNI) and expenditure on research and development (GERD)—became insignificant when the indicator of good governance —WGI—was taken into account (Jüri Allik et al., 2020). Good governance, to explain very briefly, is when authority is transparently and responsibly exercised, government has the capacity to effectively formulate and implement sound policies, and when citizens are respected and social institutions are accountable to people, not to any one privileged group (Kaufmann et al., 2010). As shown by Allik and colleagues (2020), such well-governed countries, especially if they are relatively small and have no communist past, seem to be more efficient at translating economic wealth into high-quality science.

Although the mean citation rate appears to be a sufficiently reliable indicator of a nation's scientific impact (cf. Cole & Phelan, 1999; King, 2004; May, 1997; Prathap, 2017), sometimes rankings of nations based on citation rates alone may appear confusing. For example, very few experts would predict that it is researchers from Panama who publish papers that have the highest citation rate in the world (Jüri Allik et al., 2020; Erfanmanesh, Tahira, & Abrizah, 2017; Monge-Najera & Ho, 2015). Likewise, it was a rather unexpected finding to see Peru, Estonia, and the Republic of Georgia among the world's most scientifically advanced nations (Jüri Allik et al., 2020), while scientific super-powers such as the United States, Germany, and Japan had relatively modest scores on the *HQSI,* which were not in proportion to their gigantic spending on research and development. These anomalies seem to suggest that there may be some methodological problems in how the scientific impact of nations is measured by the *HQSI* (J. Allik, 2013; Jüri Allik et al., 2020).

One likely reason for the counterintuitive ranking of nations on the *HQSI* is its reliance on the number of highly cited or top articles, which may not adequately represent the whole range of papers produced by the researchers of each country (cf. Jüri Allik et al., 2020). When the *Essential Science Indicators* (*ESI*; Clarivate Analytics) database was created, all scientific output (except for the field of humanities) was divided into 22 research areas with very different publication and citation rates. (In principle, the *ESI* is an analytical tool that helps to identify top-performing research in the *Web of Science (WoS)* Core Collection.) This division, however, created a situation where it may be more advantageous for a country to avoid its papers being included in the *ESI* in certain research areas that are not so well developed and, therefore, could possibly decrease the country's mean citation rate. In other words, countries can achieve an overall higher citation rate per paper if they fail to collect the minimally required number of citations to pass *ESI* thresholds in those areas in which they are not competitive enough (cf. Jüri Allik et al., 2020). One modus to achieve this, for instance, is to publish papers in low-impact journals which have no or very little chance of being indexed in elite databases such as *Scopus* (Elsevier) or *WoS* (Clarivate Analytics) and, as a result, to qualify for the *ESI.* Thus, a prominent position in a nation's ranking on the *HQSI* can be achieved not only by a high citation rate of papers in most or all 22 research areas but also by a relatively high citation rate in very few research areas which pass the *ESI* threshold.

The Aim of the Present Study

The main aim of the study is to improve the *HQSI* (J. Allik, 2013; Lauk & Allik, 2018) by taking into account the number of research areas in which each country has succeeded in collecting the minimally required number of citations to pass the *ESI* threshold. Failure to reach the required number of citations in a certain area may indicate that the number of published papers in that area and/or their impact was not sufficient to enter the *ESI* database and, as a result, could have reduced the country's mean citation rate if these excluded papers had been considered. In other words, the main idea of this study is to supplement citation indicators with a count of the number of research areas in which a country has exceeded the database entrance threshold. Every failure to reach the *ESI* was penalized because papers that remained below the entrance threshold would have degraded citation indicators. In order to distinguish this new revised indicator from the previous *HQSI*, we would like to name it the *Indicator of a Nation's Scientific Impact* (*INSI*). In this paper, we will demonstrate that the new indicator is a more accurate estimator of the scientific merits and societal factors that are involved in determining the scientific output and impact of nations.

Method

Data were retrieved from the latest available release of the *Essential Science Indicators* (*ESI*; Clarivate Analytics, updated on March 14, 2019; https://clarivate.com/products/essential-science-indicators/) at the time of writing this paper, which covered an 11-year long period from 1 January 2008 to 31 December 2018 (see also J. Allik, 2013; Jüri Allik et al., 2020).

In order to be included in the *ESI*, journals, papers, institutions, and authors need to exceed the minimum number of citations obtained by ranking journals, researchers, and papers in a respective research field in descending order by citation count and then selecting the top fraction or percentage of papers. For authors and institutions, the threshold is set as the top 1%, and the top 50% is established for countries and journals, in an 11-year period. The main purpose of the division into separate fields is to balance publication and citation frequencies in different research areas.

Among the 153 countries/territories that passed the *ESI* threshold in at least one research field were several that published only a small number of papers. For example, researchers from Dominica, Vatican, Bermuda, and Seychelles published less than 300 papers during the last 11 years. In our analyses, we only included countries that published more than 4,000 papers during the 11-year period. Although somewhat arbitrary, this number was chosen based on our previous studies (cf. Jüri Allik, 2003, 2008; J. Allik, 2013; Jüri Allik, 2015; Lauk & Allik, 2018). Applying this criterion, 53 countries or territories (36.6%) were left out of further analysis. There were six countries in which scientists published over 3,000 (but less than 4,000) papers, namely Zambia, Burkina Faso, Uzbekistan, Sudan, Macedonia, and Zimbabwe; including these did not alter the results significantly. The final sample consisted of 97 countries.

The *ESI* entrance thresholds for a country or territory were quite different dependent on the research area. For example, in the field of clinical medicine it required 10,177 citations for all papers published by researchers of a given country in the journals classified into this category to be included in the *ESI*. At the same time, the *ESI* entrance threshold in economics and business was 282, and in mathematics 414, citations. Although these thresholds may not seem very high, they guarantee that the upper half of the most cited countries/territories will be included in each research area.

The tradition of keeping separate records for England, Northern Ireland, Scotland, and Wales in the *ESI*, and not for the United Kingdom as a whole, also created a slight problem for our analysis. Because our country-level indicators were only available for the United Kingdom and not for its four constituent countries, we had no other choice but to aggregate the constituents' bibliometric data. However, a simple aggregation of the bibliometric data for England, Northern Ireland, Scotland, and Wales may lead to a biased estimate, caused by the fact that, if a paper has co-authors from two or more constituent countries of the United Kingdom, it is attributed to each of those countries. In other words, the same article could be counted two, three, or even four times, if its co-authors are affiliated with institutions from more than one constituent country of the United Kingdom. For the mean citation rate, we computed an aggregate weighted by the total number of citations received by each constituent.

Measures

Indicator of a Nation's Scientific Impact (*INSI*). As already mentioned, the *High Quality Science Index* (HQSI; J. Allik, 2013) was a combination of two highly correlated indicators of scientific excellence – the mean citation rate and the percentage of articles that reaches the top 1% citation rate. To improve the previous measure, the *INSI* has a third component, which is the number of research areas in which a country/territory has entered the *ESI* database. On average, a country or territory is represented in the *ESI* in about 13 disciplines (http://archive.sciencewatch.com/about/met/). In the final sample of 97 countries, the mean number of areas in which they were represented in the *ESI* was slightly higher, 19.5, which was expected because about 57% of countries were successful in entering the *ESI* database in all 22 research areas. Table 1 column #5 demonstrates the number of research areas in which a country or territory has passed the entrance threshold. Before these three components were combined into the single measure *INSI*, it was necessary to decide what weights these three components have. Although equal weights for all three components seemed the most natural option, we nevertheless probed different combinations of weights, looking for the one which maximizes the percentage of explained variance that the selected societal predictor variables can provide. As it turned out, the best result was obtained when the mean citation rate, the percentage of articles that reaches the top 1% citation rate, and the number of represented research areas all had equal weights of 1/3, summed into an indicator of the scientific impact.

Predictor Variables

Our choice of potential contextual drivers that may influence the relationship between the economic wealth and scientific excellence of countries was primarily guided by the findings of previous research (Jüri Allik et al., 2020).

Gross National Income (GNI). GNI per capita is conceptually similar to the Gross Domestic Product (GDP) measure of living standard, but they are calculated slightly differently (Update Team, 2018). GNI is one of three components from which the Human Development Index (HDI; http://hdr.undp.org/en/content/human-development-index-hdi) is calculated.

Research and development expenditure (GERD). The latest available data for research and development expenditure as a percentage of GDP (GERD) were provided by the World Bank: https://data.worldbank.org/indicator/gb.xpd.rsdv.gd.zs. The missing data for Taiwan, South Korea, Malawi, Lebanon, Bangladesh, and Cameroon were filled by the most likely estimates, usually provided by these countries themselves.

Inequality (GINI). The GINI coefficient is the most commonly used measure of economic inequality. A GINI coefficient of 0 expresses perfect equality, where all incomes are the same. A GINI coefficient of 1 expresses theoretically maximal inequality, where only one person has all the income or consumption, and all others have none. We obtained the most recent GINI estimates from the World Bank (https://data.worldbank.org/indicator/si.pov.gini).

Country population size. Population size by country was retrieved from the United Nations Population Division database: https://www.worldometers.info/world-population/population-by-country/. Because differences in populations are huge, a common logarithm with a base of 10 was used to represent the data.

Worldwide Governance Indicators (WGI; http://info.worldbank.org/governance/wgi/#home). In our previous study, we identified WGI as the strongest predictor of high quality science as measured with the *HQSI*, with a correlation $r = .59$ between these two variables (Jüri Allik et al., 2020). The WGI measures the quality of governance, which is how authority in a country is exercised, how governments are selected, monitored and replaced, the capacity of the government to effectively formulate and implement sound policies, and the respect of citizens and the state for the institutions that govern the economic and social interactions among them (Kaufmann et al., 2010). The summary WGI is computed based on six indicators of good governance: voice and accountability, absence of violence, government effectiveness, regulatory quality, rule of law, and the absence of corruption. Cronbach alpha of the WGI in our sample 97 countries was .96.

English-speaking countries. There is evidence that countries with English as an official language are scientifically more productive than other countries (Gantman, 2012; Mueller, 2016; van Leeuwen, Moed, Tijssen, Visser, & van Raan, 2001). The data about countries where English is an official language (either de jure or de facto) were taken from http://worldpopulationreview.com/countries/english-speaking-countries/. These were Australia, Canada, India, Ireland, Kenya, Malawi, New Zealand, Nigeria, Singapore, South Africa, Tanzania, UK, and USA.

Communist past and/or presence. It has been noticed that (post-)communist countries still lag behind their Western counterparts in the quality of their scientific output (Jurajda, Kozubek, Munich, & Skoda, 2017; Kozak, Bornmann, & Leydesdorff, 2015; Must, 2006; Pajic, 2015; Vinkler, 2008). This was the reason to include a country having a communist history or presence (these being Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, China, Croatia, Cuba, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Latvia, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, Ukraine, and Vietnam) as a predictor variable.

Results

Table 1 presents a ranking of the 97 nations based on their *INSI* score (column #6). Compared with the previous ranking based on the *HQSI* (cf. J. Allik, 2013; Jüri Allik et al., 2020), the ranking of countries based on the *INSI* looks intuitively more accurate. For example, Panama lost its status as the country with the highest science impact because of a failure to reach the *ESI* in 9 out of the 22 research areas. Due to this, Panama dropped from first place to the 3rd position. The drop of Georgia from the 3rd to the 10th place was also due to a failure to reach the *ESI* in numerous (11) research areas. However, the recession that Armenia experienced was the largest: a failure in 15 research areas dropped Armenia from 18th to 72nd position in the ranking. It is important to note that smaller and economically less developed countries may have problems maintaining a sufficient number researchers to produce papers in all areas to reach the top half of all countries by the number of citations their papers were able to collect.

In a recent study by Allik and colleagues (2020), it was observed that the best predictor of high-quality science as measured by *HQSI* was not economic wealth or research and development expenditure but the quality of governance measured by the World Governance Indicators or WGI, $r = .59$, $N = 97$, $p < .001$. In the present study, the observed correlation between the *INSI* and the WGI increased by about 0.1 points, now $r = .69$ ($N = 97$, $p < .001$). Figure 1 demonstrates a two-dimensional plot between these two variables. If in the previously reported relationship between WGI and *HQSI* countries such as Panama, Georgia, and Peru looked like outliers (Jüri Allik et al., 2020; Figure 1), their positions are closer to the regression line when plotting the relationship between the *INSI* and WGI.

Because the predictors that were selected for this study contained categorical variables—English as one of the official languages and having a communist past or present—we were not able to use an ordinary multiple regression to analyze potential predictors of a country's scientific impact. We used the General Linear Models approach, which is an extension of the multiple regression and allows the inclusion of categorical variables. Table 2 demonstrates the results, in which *INSI* was predicted from seven continuous and two categorical variables. We used a method in which the sums of squares are invariant to the order in which effects are entered into the model. A general linear model predicted 61.50% of *INSI* variance: $R = .78$, $F(9,79) = 13.48$, $p < .001$. The contributions of individual predictors can be estimated based on their partial eta-squared (η^2) statistics. Although several country-level predictors had statistically significant independent correlations with *INSI*, in any situation where predictors competed with each other, only two predictors remained significant in the prediction of *INSI*. Good governance or WGI accounted for approximately 10% and a communist past or present about the same 10% of the total variance in the *INSI*.

Discussion

GDP, like its more modern version GNI, is a measure of the economic success of nations that has been declared one of the great inventions of the 20th Century (Landefeld, 2000). Although this may be an exaggeration, this statistical construction has nevertheless played a pivotal role in guiding economic and social policies in all modern nations (Coyle, 2014). In the same way, politicians, administrators, and other interested parties need a good measure of the scientific impact of nations. The *ESI* was created as a response to a need to identify emerging science trends as well as influential individuals, institutions, and countries in different fields of research. Based on the insight that the associations between ideas form the essence of science (Garfield, 1955), it was quite natural to consider the mean citation rate as an appropriate measure for a nation's scientific impact or wealth (cf. King, 2004; May, 1997).

Nevertheless, sometimes citation indicators, as noted above, may led to spurious country rankings, which are not easy to reconcile with scientific prestige as publicly perceived (Jüri Allik et al., 2020). Without diminishing Panama's achievement in science, a good explanation is still needed for how such a high position was achieved. If in the previous study we simply recognized the problem (Jüri Allik et al., 2020), then in this paper we take the next step: demonstrating how to cope with the inaccuracy that a failure to meet the entrance criterion in some research areas brings about.

As a result, all indicators have been computed based on the most cited layer of scientific papers, which may give a distorted picture of what could otherwise be obtained by using all scientific papers published by researchers in each country. Neglecting the bottom-layer of cited papers creates a possibility for bias in which a generally high citation rate can be boosted by excluding those papers that could decrease the average citation rate. Because *ESI* thresholds are defined by the total number of citations, small and scientifically weaker nations may experience difficulties reaching these targets, which is not the case for the leading nations. For example, about 10,000 *ESI* papers published by Icelandic researchers were expected to collect the same amount of citations as about 4.1 million papers authored by researchers affiliated with US research institutions. Although Iceland conquered the *ESI* entrance thresholds in all 22 research areas, many other nations, especially smaller ones, failed to pass the ESI threshold in several fields. For example, Azerbaijan was successful in only 6, and Armenia together with Bosnia and Herzegovina in 7, research areas out of the 22 into which science is divided by the *ESI*.

The proposed indicator of a nation's scientific impact—*INSI*—was created to compensate for the absence of less cited papers which would have lowered the average citation rate if they had been included. This corrected indicator produced a ranking of nations which is less controversial than that based on citations rates alone. It also increased the predictability from the societal factors that seem to support scientific excellence. For example, in this new ranking, Georgia and Peru were slightly pushed down, being penalized for every research area in which they failed to enter the database. Only Estonia's 6th place may be seen as a deviation from previous demonstrations that post-communist countries lag behind those who succeeded in avoiding the misfortune of communist rule (Jurajda et al., 2017; Kozak et al., 2015; Pajic, 2015; Vinkler, 2008). Although Estonia's current position was already predictable from the observed growth rate several years ago, there is no exhaustive explanation as to why this growth is more rapid compared with the country's two neighbors, Latvia and Lithuania, which had identical starting positions two decades ago (Jüri Allik, 2003, 2008, 2011; Lauk & Allik, 2018). Nevertheless, as a confirmation of previous studies, a country's communist history seems to be a factor that holds back scientific progress, even thirty years after the collapse of the Soviet Union.

It seemed self-evident that if more money is invested into science, this will have a return in terms of increased numbers of highly cited papers (Cimini, Gabrielli, & Labini, 2014; King, 2004; May, 1997; Mueller, 2016; Prathap, 2017; Rousseau & Rousseau, 1998). It may seem completely predictable that with more money a larger number of papers can be published, and these will attract a larger number of citations. However, this may not be entirely true because, as preceding studies already showed, economic wealth and research and development expenditure do not predict nations' scientific output when the impact of governance quality is also taken into consideration. This finding does not imply, of course, that high-impact science can be produced without resources invested into infrastructure and respectable salaries for scientists. It needs to be remembered that the *ESI* already excluded a large group of scientifically less advanced nations in addition to our own additional criterion to drop those countries not producing at least 4,000 papers during the last 11 years. Most of these omitted countries are economically underdeveloped, which could disguise a link between money and scientific performance. For example, none of the countries from the low-income group (GNI per capita less than $1,100) was able to fulfill the established inclusion criteria. It is unrealistic to expect that a country struggling with basic needs could produce a large number of cutting-edge scientific publications.

Our results demonstrated, however, that if economically more or less prosperous countries invest money into their science then there is no guarantee that every additionally invested dollar (or euro or other currency) automatically returns a measurable increase in the quality of scientific output. This study is evidence that money alone cannot produce high-quality science; it is also necessary to have a supportive environment. It seems that one of the factors from which science benefits most is good governance. To repeat what good governance means, it is when state authority is exercised deliberately and meticulously. This includes the absence of violence and corruption, and a respect for the rule of law and citizens. This also presumes an ability to formulate and implement sound policies from which the whole of society benefits, not only a privileged minority (Andrews, Hay, & Myers, 2010; Erkkilä & Piironen, 2014; Kaufmann et al., 2010; Langbein & Knack, 2010; Pinar, 2015). Although we still do not know the exact underlying mechanisms of the relationship, it seems likely that bad governance, which often leads to conflicts, corruption, and favoritism, apparently impedes scientists from writing and publishing highly cited papers. There are many plausible scenarios for how good governance supports, and poor governance undermines, producing outstanding scientific results. Just as an example, because corruption is an indicator of poor governance, one specific form of it—nepotism—can be an obstacle to achieving scientific excellence. It is generally agreed that, for outstanding results in science, nations need to promote equal opportunities in academic careers, minimizing nepotism. For example, in a recent study, it was shown that the country author-kinship trend was elevated for countries like Greece, India, Italy, Poland, and Russia. On the contrary, nations with the highest scientific wealth, such as Netherlands, Switzerland, and Sweden, demonstrated the opposite: a lower rate of kinship among authors of scientific papers (Prosperi et al., 2016). While nepotism in Italian academia is not perhaps entirely surprising (Allesina, 2011), even Swedish practices in science may not be totally free from modest signs of nepotism (Sandstrom & Hallsten, 2008). In addition to the individual level of nepotism, there is national (Jaffe, 2011), and even ethnic, nepotism (Rushton, 1991) in science. It was observed, for instance, that countries such as USA, China, and Iran show exceptionally high country self-citation rates in all fields of science (Jaffe, 2011).

Besides corruption-nepotism, there are other scenarios which may inspire or hold back scientists from maximal expression of their scientific potential. Good governance also includes the protection of intellectual property rights, the equal treatment of foreigners and minorities before the law, and low rates of social conflict, to say nothing about not having personal taxation systems that might discourage people from working or seeking advancement in their careers (Kaufmann et al., 2010). Thus, it may not always be money that inspires scientists in writing papers their colleagues will find worthy of citing.

Conclusions

In sum, we believe that we have been successful in proposing an improved measure of the scientific impact of nations. The proposed indicator—*INSI*—takes into account, in addition to citation rates, how many areas in which researchers a given country have succeeded in entering the essential science database *ESI*. According to this novel measure of scientific impact, the most advanced science in the world is practiced in Iceland, Switzerland, the Netherlands, and Denmark. The world's scientific giants, producing the largest number of papers, USA, Germany, and China, have more resources to publish papers but these are not necessarily attracting the largest number of citations. Although it is widely believed that money can buy scientific excellence, our analysis of a representative sample of 97 nations shows that economic wealth and expenditure on research and development are not directly transformed into high-impact scientific papers. One of the factors facilitating high-quality science seems to be good governance. Thus, nations that have been successful in countering negative aspects of society such as corruption, lawlessness, discrimination, and favoritism, are also those that have scientists who are slightly more inspired to write and publish high-impact papers.

Author's Notes

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Table 1

Ninety-seven countries which published more than 4,000 ESI papers between 2008 and 2018 ranked according to the Indicator of a Nation's Scientific Impact (INSI; column #6*).*

Rank	**Country**	**Code**	**No of Papers**	**No of Citations**	**Citations/ Papers**	**Top-1% Papers**	**No of Areas**	***INSI***	**WGI**
			#1	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**
1	Iceland	ISL	10,573	260,926	24.7	3.2	22	1.89	1.51
2	Switzerland	CHE	298,321	6,617,690	22.2	2.8	22	1.51	1.77
3	Panama	PAN	4,127	100,797	24.4	3.8	13	1.44	0.13
4	Netherlands	NLD	402,147	8,514,132	21.2	2.5	22	1.31	1.68
5	Denmark	DNK	173,372	3,515,751	20.3	2.6	22	1.26	1.64
6	Estonia	EST	17,972	327,620	18.2	2.7	22	1.17	1.19
7	Singapore	SGP	126,288	2,444,211	19.4	2.6	21	1.12	1.62
8	United Kingdom	GBR	1,260,025	24,508,628	19.5	2.3	22	1.06	1.37
9	Belgium	BEL	221,551	4,244,377	19.2	2.3	22	1.04	1.18
10	Georgia	GEO	5,785	116,333	20.1	3.8	11	0.95	0.43
11	Ireland	IRL	84,133	1,547,625	18.4	2.2	22	0.95	1.36
12	Peru	PER	10,317	171,202	16.6	2.8	20	0.94	-0.11
13	Austria	AUT	153,777	2,736,940	17.8	2.2	22	0.89	1.44
14	Sweden	SWE	268,864	5,033,444	18.7	2.1	22	0.89	1.71
15	United States	USA	4,147,742	78,222,660	18.9	1.8	22	0.80	1.26
16	Norway	NOR	130,465	2,245,694	17.2	2.1	22	0.78	1.82
17	Finland	FIN	130,431	2,298,650	17.6	1.9	22	0.75	1.77
18	Canada	CAN	688,974	12,164,970	17.7	1.9	22	0.73	1.68
19	Australia	AUS	583,480	9,613,694	16.5	2.0	22	0.69	1.54
20	Germany	DEU	1,103,959	19,504,309	17.7	1.8	22	0.67	1.49

21	Hong Kong, SAR of China	HKG	133,644	2,142,965	16.0	2.0	22	0.67	1.45
22	Philippines	PHL	12,181	177,665	14.6	2.3	21	0.63	-0.35
23	Israel	ISR	145,692	2,428,537	16.7	1.7	22	0.58	0.72
24	France	FRA	768,715	13,076,680	17.0	1.7	22	0.56	1.09
25	New Zealand	NZL	95,495	1,512,585	15.8	1.8	22	0.55	1.86
26	Luxembourg	LUX	9,606	145,980	15.2	2.2	20	0.51	1.66
27	Sri Lanka	LKA	7,483	104,816	14.0	2.3	20	0.50	-0.13
28	Italy	ITA	672,758	10,847,769	16.1	1.5	22	0.44	0.50
29	Cyprus	CYP	11,152	160,211	14.4	2.3	19	0.44	0.88
30	Saudi Arabia	SAU	101,357	1,149,304	11.3	2.3	22	0.43	-0.26
31	Greece	GRC	118,864	1,787,043	15.0	1.6	22	0.40	0.18
32	Spain	ESP	582,464	8,899,247	15.3	1.5	22	0.35	0.80
33	Hungary	HUN	71,757	982,182	13.7	1.6	22	0.27	0.49
34	Kenya	KEN	16,431	265,530	16.2	2.1	16	0.24	-0.53
35	Portugal	PRT	135,633	1,924,930	14.2	1.4	22	0.24	1.09
36	South Africa	ZAF	118,564	1,453,864	12.3	1.6	22	0.15	0.14
37	Qatar	QAT	13,259	151,550	11.4	2.3	18	0.12	0.33
38	Costa Rica	CRI	5,807	89,041	15.3	1.8	17	0.10	0.54
39	Lebanon	LBN	12,477	146,519	11.7	1.7	21	0.09	-0.80
40	Colombia	COL	40,154	437,306	10.9	1.5	22	0.04	-0.19
41	Slovenia	SVN	40,924	495,297	12.1	1.3	22	0.02	0.91
42	Chile	CHL	74,891	894,977	12.0	1.3	22	0.01	0.94
43	Czech Republic	CZE	122,339	1,489,116	12.2	1.3	22	0.00	0.99
44	Uruguay	URY	9,488	132,242	13.9	1.2	20	-0.04	0.86
45	Bulgaria	BGR	25,672	282,123	11.0	1.3	22	-0.07	0.24
46	Argentina	ARG	92,542	1,103,425	11.9	1.1	22	-0.12	0.01
47	Japan	JPN	863,585	11,157,632	12.9	0.9	22	-0.13	1.37
48	Uganda	UGA	9,455	152,450	16.1	1.6	14	-0.17	-0.55

49	China	CHN	2,442,207	26,050,826	10.7	1.1	22	-0.17	-0.34
50	Indonesia	IDN	18,950	205,960	10.9	1.3	21	-0.18	-0.17
51	United Arab Emirates	ARE	19,772	196,543	9.9	1.3	22	-0.18	0.65
52	Ecuador	ECU	8,032	83,003	10.3	1.8	18	-0.18	-0.48
53	Malawi	MWI	4,212	66,694	15.8	2.1	11	-0.19	-0.46
54	Tanzania	TZA	8,787	128,779	14.7	1.6	15	-0.20	-0.50
55	Croatia	HRV	38,543	398,928	10.4	1.1	22	-0.20	0.46
56	Thailand	THA	74,635	819,883	11.0	1.0	22	-0.23	-0.27
57	Malaysia	MYS	98,303	911,994	9.3	1.2	22	-0.25	0.29
58	Vietnam	VNM	27,409	248,974	9.1	1.2	22	-0.25	-0.33
59	Slovakia	SVK	36,323	367,911	10.1	1.0	22	-0.27	0.71
60	South Korea	KOR	553,720	6,191,163	11.2	0.9	22	-0.27	0.81
61	Bangladesh	BGD	16,993	176,069	10.4	1.3	20	-0.29	-0.82
62	Venezuela	VEN	11,595	118,238	10.2	1.0	22	-0.30	-1.56
63	Taiwan	TWN	283,256	3,228,426	11.4	0.7	22	-0.32	1.11
64	Ghana	GHA	8,956	110,527	12.3	1.5	16	-0.33	0.06
65	Mexico	MEX	134,301	1,319,716	9.8	0.9	22	-0.35	-0.34
66	Lithuania	LTU	23,231	209,968	9.0	1.2	21	-0.37	0.91
67	Latvia	LVA	7,026	77,088	11.0	1.6	16	-0.38	0.80
68	Pakistan	PAK	79,055	633,041	8.0	1.1	22	-0.38	-0.96
69	Oman	OMN	6,641	68,391	10.3	1.4	18	-0.39	0.16
70	Poland	POL	264,867	2,485,806	9.4	0.9	22	-0.40	0.67
71	Morocco	MAR	19,038	175,591	9.2	1.1	21	-0.41	-0.29
72	Armenia	ARM	7,878	110,085	14.0	2.5	7	-0.45	-0.30
73	Romania	ROM	80,421	640,417	8.0	0.9	22	-0.49	0.21
74	Cameroon	CMR	8,185	83,149	10.2	1.2	18	-0.49	-1.00
75	India	IND	598,277	5,593,281	9.4	0.7	22	-0.51	-0.14
76	Serbia	SRB	51,922	432,970	8.3	1.0	21	-0.52	-0.02

77	Brazil	BRA	437,052	3,932,914	9.0	0.7	22	-0.53	-0.20
78	Nigeria	NGA	26,479	202,868	7.7	0.9	22	-0.54	-1.01
79	Egypt	EGY	93,672	795,111	8.5	0.7	22	-0.54	-0.87
80	Macao, SAR of China	MAC	6,398	51,785	8.1	2.0	14	-0.58	1.00
81	Ethiopia	ETH	11,303	107,923	9.6	1.1	18	-0.58	-0.97
82	Iran	IRN	281,559	2,271,928	8.1	0.7	22	-0.59	-0.85
83	Jordan	JOR	14,462	124,959	8.6	1.0	19	-0.65	-0.09
84	Turkey	TUR	282,288	2,157,826	7.6	0.6	22	-0.68	-0.47
85	Nepal	NPL	5,918	67,939	11.5	1.4	13	-0.69	-0.65
86	Ukraine	UKR	52,940	393,906	7.4	0.7	21	-0.70	-0.69
87	Kuwait	KWT	8,204	70,674	8.6	1.0	18	-0.71	-0.18
88	Russia	RUS	347,015	2,401,279	6.9	0.6	22	-0.74	-0.67
89	Cuba	CUB	8,915	86,277	9.7	0.8	16	-0.88	-0.43
90	Tunisia	TUN	36,956	282,727	7.7	0.4	20	-0.91	-0.23
91	Algeria	DZA	26,510	185,975	7.0	0.8	17	-1.02	-0.85
92	Belarus	BLR	12,229	124,512	10.2	1.7	8	-1.07	-0.58
93	Azerbaijan	AZE	5,481	54,359	9.9	2.0	6	-1.12	-0.70
94	Senegal	SEN	4,155	44,851	10.8	1.2	9	-1.19	-0.07
95	Iraq	IRQ	9,377	60,452	6.5	1.0	12	-1.36	-1.48
96	Bosnia and Herzegovina	BIH	4,882	32,667	6.7	1.0	7	-1.75	-0.32
97	Kazakhstan	KAZ	6,716	37,345	5.6	0.8	8	-1.87	-0.38

Note. No of papers = Number of papers included in the *ESI*; No of Citations = Number of citations; Citations/Papers = Number of citations per paper; Top-1% Papers = Percentage of papers reaching the top-1% or higher citation rate; No of Areas = Number of areas in which a nation has exceeded the *ESI* citation threshold; *INSI* = Indicator of the Scientific Wealth of a Nation; WGI = Worldwide Governance Indicators (Kaufmann et al., 2010); SAR = Special Administrative Region.

Table 2

General linear model prediction of *INSI* score from macro-level predictors: $R = .78$, $R^2 = .61$, $F(9,79) = 13.48$, $p < .001$. The last two columns show the Pearson correlation with these predictors.

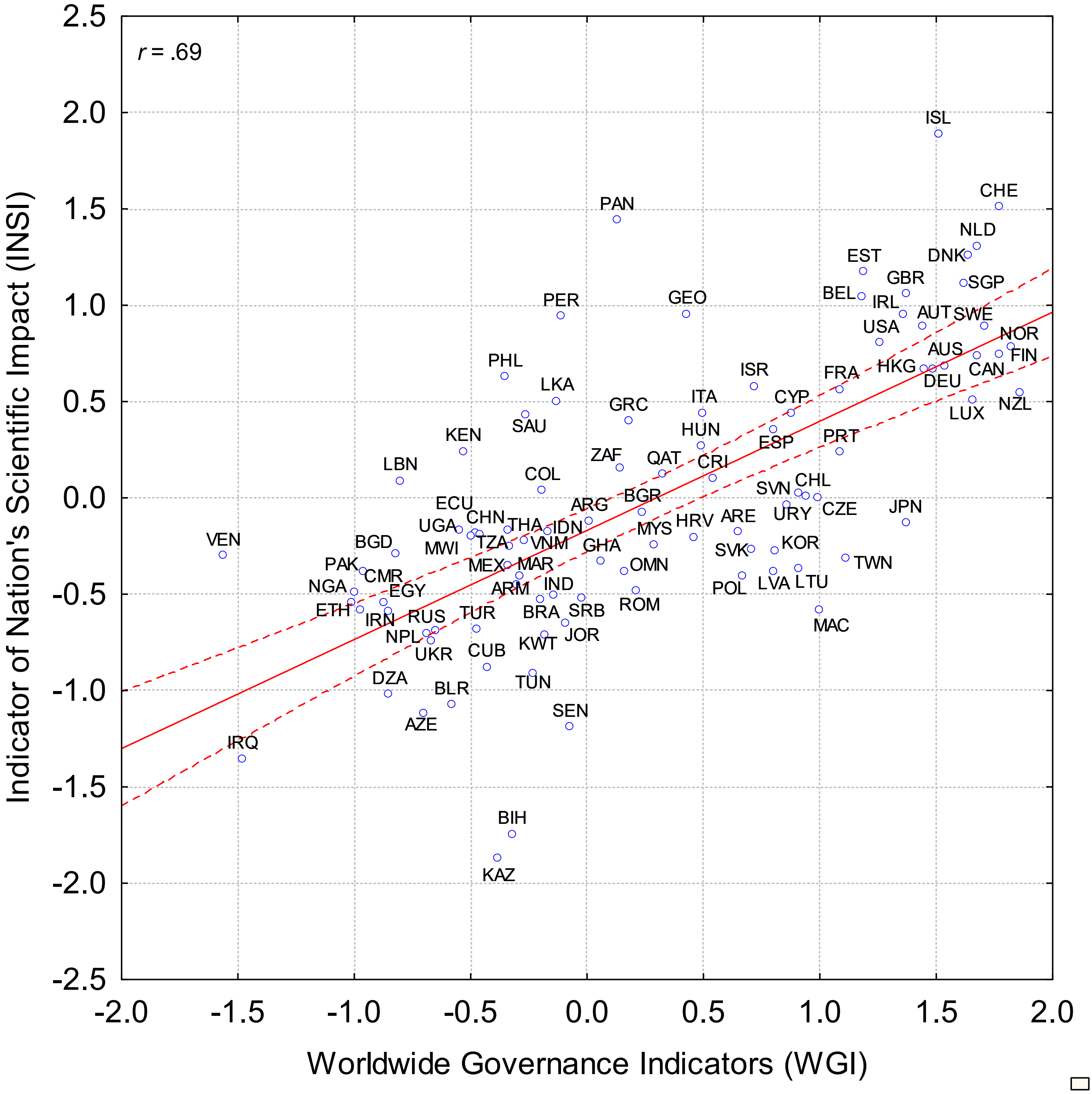
	General Linear Model				Correlation	
	Partial eta-squared (η^2)	*F*	*p*	Power (α=.05)	*r*	*p*
Intercept	.004	0.59	.590	.293		
Population ($\log_{10}$)	.009	–1.35	.388	.138	**–.24**	**.018**
English	.130	0.69	.408	.130	**.21**	**.045**
Communist Country	**.103**	**–9.05**	**.004**	**.844**	**–.31**	**.002**
Life Expectancy	.002	0.34	.562	.089	**.50**	**<.001**
Schooling Years	.033	2.72	.103	.370	**.48**	**<.001**
GNI	.000	0.00	.999	.050	**.44**	**<.001**
Inequality (GINI)	.016	1.93	.168	.279	.00	.972
GERD	.007	0.53	.468	.111	**.50**	**<.001**
WGI	**.101**	**8.83**	**.004**	**.835**	**.69**	**<.001**

Notes: Population ($\log_{10}$) = United Nations Population Division estimates (*United Nations Population Division* estimates); English = English as an official language; Communist country = Current or former communist country; Life Expectancy = Life expectancy at birth (HDI, 2018); Schooling Years = The mean years of schooling for adults aged 25 years and more and expected years of schooling for children of school-entering age (HDI, 2018); GNI = Gross National Income (HDI, 2018); Inequality (GINI) = The mean GINI value given by the World Bank (https://data.worldbank.org/indicator/si.pov.gini); GERD = Research and development expenditure as a percentage of GDP (https://data.worldbank.org/indicator/gb.xpd.rsdv.gd.zs); WGI = Worldwide Governance Indicators (Kaufmann et al., 2010). Significant ($p < .05$) predictors of the *INSI* in GLM and correlations are indicated in bold.

Figure Captions

Figure 1. Correlation plot between the Worldwide Governance Indicators (WGI) and the Indicator of a Nation's Scientific Impact (*INSI*): $r = .67$, $N = 97$, $p < .001$. Countries are referred to according to their officially assigned the ISO 3166-1 alpha-3 codes listed also in Table 1, column “Code”.

Figure 1


r = .69
Indicator of Nation's Scientific Impact (INSI)
Worldwide Governance Indicators (WGI)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
ISL
CHE
PAN
NLD
EST
DNK
GBR
SGP
PER
GEO
BEL
IRL
AUT
SWE
USA
NOR
AUS
FIN
PHL
ISR
FRA
HKG
CAN
DEU
LKA
ITA
CYP
NZL
LUX
GRC
SAU
HUN
ESP
PRT
KEN
ZAF
QAT
CRI
LBN
COL
CHL
SVN
ECU
BGR
ARG
URY
CZE
JPN
CHN
THA
IDN
HRV
ARE
UGA
MYS
MWI
TZA
VNM
GHA
VEN
BGD
SVK
KOR
PAK
MEX
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OMN
TWN
CMR
LVA
LTU
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EGY
ARM
IND
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IRN
RUS
TUR
BRA
SRB
MAC
NPL
JOR
UKR
CUB
KWT
DZA
TUN
BLR
SEN
AZE
IRQ
BIH
KAZ