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A simple index of innovation with complexity

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ABSTRACT

Patents are the main source of data on innovation. Since most of the innovative activity happens outside of the patenting system, and since patents –and innovations- have different quality, complexity, and impact on each market, unweighted sums of patents and proxies are an imperfect indicator of a country's innovative activity. I generate two very simple indices of innovation (one dependent on the size of a country, and another that normalizes country-size), based on weighting patents and exports by a complexity measure. Each index captures the technological complexity of innovations inside and outside the intellectual property rights system. I empirically analyze the rankings of these innovation indices, and contrast the results with technological development, GDP, and the existing mainstream innovation index.

Introduction

Along history, innovation metrics have evolved consistently from input measures of innovation, such as R&D expenditure, to output measures, such as patent counts, and then to composite indicators. The awareness of patents being a biased measure of innovation made composite indices and rankings popular, even though these indices rely heavily on patent counts that do not take into account the differences in inventive steps across patents. Moreover, most composite indices use a large number of proxies to account for different types of innovation, and how much innovation these proxies account for is, in many cases, doubtful.

Either as a simple counting indicator, or as part of a composite index, patents have become the standard measure for innovation in most disciplines. Indeed, patents are public and available information. There are, however, numerous concerns that patent counts may be a biased and imperfect measure of innovation. For example, simply adding patents without any measure of the quality of the invention (e.g. inventive step covered by a patent), inflates the measure of innovation for countries where most patents are just small inventive steps from previous inventions. Similarly, the unweighted sum of patents ignores the sophistication and complexity of each innovation, and just assumes that all patents have the same innovative content and impact.

Furthermore, most inventive activity happens outside of the patenting system (Moser, 2013). Keeping an innovation as a secret can be a dominant strategy over patenting when the cost of secrecy is lower than the potential loss of imitators "inventing around" once the innovation has been disclosed. There is empirical evidence suggesting that the complexity of the invention is an effective deterrent for imitators, as the cost of copying the new idea (e.g. reverse engineer) increases with complexity (Fernandez Donoso, 2014).

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How can we accurately measure innovation when most of it stays outside of the formal intellectual property rights system? How does one generate a measure of innovation that incorporates complexity or sophistication differences across inventions? This paper offers two simple, computable and comparable metrics to compare innovation across economies. These metrics have the virtue of reducing the bias of adding patents, without the need of looking for large sets of innovation proxies.

Using a very simple method, I generate a normalized index of innovation that incorporates differences in the complexity at the industry level for patents and exports. Though the index is improvable, the rankings of computing the index are consistent with intuitive results, such as the correlation with technological development.

This remainder of this paper is organized as follows. Next section discusses different measures of innovation used along history and their limitations. Section 3 explains the calculation of the indices. Section 4 shows the empirical results. Final section concludes.

2. Metrics of innovation

2.1. Overview of innovation metrics

The first generation of innovation measures, mostly based on input indicators, date from the late 1950s to mid 1960s (e.g. National Science Foundation surveys in the United States). Input measures (e.g. R&D expenditure, number of scientists, etc.) were typically used as proxies to innovation metrics. Countries compared their performance by comparing their R&D measures, ignoring the limitations of the definitions of these measures, and the endogenous role of governments in using these type of metrics to compare public policies to other countries (e.g. R&D in socialist economies and OECD in the 70s and 80s). Though the limitations of R&D measures are self-evident, their use has not been completely ruled out, as there are no available output measures of R&D in health or education sectors.

Many contributions intended to accurately measure those activities in R&D that do matter to innovation and technology change, and to develop international standards for R&D measurement. Among them, the Frascati Manual (2002) theoretically breaks up activities that should be excluded from R&D measurement by splitting them between novelty and routine. If a given activity "follows an established routine pattern," it should be excluded from R&D, while if it "departs from routine and breaks new ground, it should be qualified as R&D."

While this distinction between novelty and routine activities helps to construct an accurate measure of R&D, it does not provide a clear definition of innovation, or of how to measure it at the firm, industry, and country level. The reason for this lies in the fact that not all innovative activities are developed in laboratories or plants with full-time qualified research staff. Measures of R&D are a good statistic to infer professional R&D activity, but they fail to account for important inventions made by private inventors or entrepreneurs. Moreover, if this type of "informal" R&D was somehow negatively correlated with the technological complexity of the industry, then R&D measures would underestimate the amount of innovation input for many industries, and particularly for poor and middle-income countries, as their technological development is lower (Fieler, 2011).

The second generation measures (1970s–1980s) focused on innovation outputs, such as patent applications, publications, or licensing. Patenting a new product variety, input, or process requires paying a fixed cost, in exchange for the inventor to earn a legal monopoly right over its invention. If the monopoly profits over the time of the patent exceed the fixed cost of the patent, one would expect that all profitable innovations ought to be patented.

Consequently, the fact that since 1900 the share of individual patents have declined, while corporate patents have increased their share (Freeman & Soete, 2009), means that most innovative activity happens within the boundaries of specialized R&D laboratories and departments of firms, government, and academia. If the patenting story holds, something does not add. According to the 2008 U.S. Census R&D and Innovation Survey (NRDIS), for 85% of surveyed firms, trademarks are not important. Moreover, for 96% of surveyed firms utility patents are not important, and for 95% of them design patents are not important for business. Only by splitting the sample and selecting those firms that engage in formal R&D activity, these numbers decrease (though 67% consider design patents as not important, and 85% thinks of them as not or somewhat important).

In fact, patents have shown to be an imperfect proxy for innovation. First, not all innovations are patentable, as States have exclusions for some innovations. Second, the enforcement of the patent is private, which means that if the patent is imitated without the owner's consent, the owner must take action at nonzero cost, i.e. legal costs and uncertain outcome. If the outcome probabilities depend on the legal costs (e.g. more qualified and expensive lawyers), it is straightforward that smaller firms will patent less than large corporations will. Third, firms may engage in strategic patenting if the size of a patent portfolio increases bargaining power in patent disputes (Noel & Schankerman, 2013), or if it affects the ability of other firms to develop a similar patentable innovation (Stiglitz, 2014). Third, if there is a fixed cost of imitation, i.e. product complexity (Fernandez Donoso, 2014) or the timing of shorter product cycles (Bilir, 2013), there is no incentive to patent an innovation, since the cost of imitation for a potential rival exceeds the profits of imitating. Finally, only "successful" innovations are patentable, meaning that all trial and error are omitted from the measure.

These limitations of patent counts as an output statistic were at the origin of the development of innovation output indicators. Some of these indicators were based on innovation surveys, within the framework of the Oslo Manual (2002). The manual defines innovation as follows: "An innovation is the implementation of a new or significantly improved product (good or service), a new process, a new marketing method, or new organizational method in business practices, workplace organization, or external relations.Ëven though national innovation surveys are informative of micro-evidence on how firms perceive and fund their innovative activity, the data generated by these surveys is hardly useful for comparative purposes between countries. On one side, not every country administers these surveys on a yearly frequency -some have never surveyed their firms on their innovative activity-. Moreover, surveys differ in questions across countries, and respondents' idea of what constitutes an innovation varies across countries.

The third generation of indices are super-indices, also known as composite or multidimensional indices. These type of metrics combine different pillars of input and output measures of innovation. The weight of each component depends on the metric. Input measures include institutions, human capital, and market performance. For most of these indices, innovation output measures include formal intellectual property applications, such as patents and trademarks. In addition to intellectual property, output measures include a variety of other statistics, such as published academic papers, ISO 9001 certificates, or license receipts.

2.2. Limitations of current metrics

Most indices today are complex. This means that several statistics are summed using different weights, and then sorted to present country rankings of innovation. The are two important limitation of these indices: (i) the strong relation with formal intellectual property rights, and (ii) they do not take into account the complexity of each innovation, or the industry where the innovative activity is taking place.

Even though patents and innovation are not perfectly related in these type of indices, most of the output components of these indices rely on innovators formally registering their ideas. As an example, the output components of the Global Innovation Index (GII), the existing mainstream innovation metric, include domestic resident patents, trademark and utility models, PCT resident patents and utility models, and licensing receipts. Other measures of output in the GII are not necessarily pure innovation output: scientific papers −could be thought as innovation input rather than output-, computer software spending −also innovation input rather than output-, FDI outflows as percentage of GDP, Wikipedia entries, or YouTube uploads.

As a rule, innovation indices, and in particular the output measures of innovation, do not take into account the complexity of the industry where the innovative activity is taking place. For example, a patent for a simple invention, such as a breast-feeding shirt to avoid cold stomach in the winter, has the same impact on the national innovation metric than devices and methods for transferring data through a human body. This limitation is important, as countries may show higher patenting rates because of strategic reasons (e.g. patent thickets), and with most innovative activity taking place in industries of low complexity, and yet be ranked as more innovative than countries with little patenting rates, but leading exports in sophisticated industries, and drastic innovative activity in highly complex technologies.

Furthermore, complexity and the decision of using formal IP are also connected. Indeed, complex inventions need less patent protection, as complexity itself generates additional costs for potential imitators. As inventions are more complex, there are increasing learning costs (e.g. reverse engineer) when the innovation is kept in secret instead of made public through patents (Fernandez Donoso, 2014).

Next section proposes two simple metrics that consider the predisposition of innovators to not using formal intellectual property rights and, in particular, to not using patents; according to the complexity of the industry where the innovative activity is taking place. More explicitly, the index of innovation takes into account three potential problems that current indices do not control. First, the index should account for complexity, either of the industry where the innovation is happening, or the innovation itself. Second, the index should account for the complexity of innovations taking place outside of the formal intellectual property rights system. Finally, the index should be simple and comparable between countries.

3. Data sources and calculation

3.1. Data sources

There is no unique definition of complexity. Complex systems consist of a large number of elements with no centralized control. In brief, a complex system is a "non-simple" system. In economics, complexity is related to the diversification and sophistication of large economic systems (Hidalgo & Hausmann 2009; Haumann et al., 2013). The production of a given country becomes more complex as the sophistication of the products it produces, and the number of country destinations of its exports are larger. This definition is useful to analyze large economic systems, such as countries, using holistic measures of production characteristics. However, it does not say much about the complexity of each technology, product or service.

Systems' theory literature has also contributed to create measures of complexity. The complexity of an invention, or the number of interdependent components (Fleming & Sorenson, 2001), can also influence the fragility of the system, a process is known as the 'complexity catastrophe' (Kauffman, 1993). Using patent citation rates, Fleming and Sorenson (2001) generate an index of interdependency of inventions to study technology as a complex adaptive system.

An extension of Hidalgo and Hausmann (2009) index was used to generate a knowledge complexity index, combining USPTO patent records to the technological structure of cities, and in particular to an index of relative technological advantage (Balland & Rigby, 2015). The intuition behind using a (revealed) relative technological advantage is that technologies that

Table 1
Data sources.

Variable	Source
Patent counts	European Patent Office (PATSTAT)
Complexity	Naghavi et al. (2015) using O*NET and US Census of Labor Statistics
Exports	United Nations COMTRADE
GDP, GDP per-capita, Population	The World Bank
Technology	Fieler (2011)

are more complex cannot be easily reproduced in other cities. Therefore, if a particular metropolitan area shows a very high relative patenting rate for a given technology, then knowledge complexity of that particular technology must be high in that area.

An ideal measure of industry level complexity would take into account both the number of inputs used to produce a specific product (Hidalgo & Hausmann, 2009; Nunn, 2007), as well as the complexity of the tasks involved to produce it (Naghavi, Spies, & Toubal, 2015). For illustration purposes, in this paper I use the normalized index of Naghavi et al. (2015) based on labor statistics. The index uses survey data for 809 occupations collected by the U.S. Bureau of Labor's Occupational Information Network (O*Net), and industry occupations from the U.S. Bureau of Labor Statistics' Occupational Employment Statistics (OED). As in Costinot, Oldenski, & Rauch (2011), it assumes that all countries have access to the same production technology. Table 1 shows the different sources to generate the index and the empirical analysis.

An important limitation when analyzing patents, and probably one of the reasons to simplify the measures of innovation to unweighted sum of patents, is the lack of a unique accepted correspondence between patent classifications and product classifications. There are currently different published attempts that take into account the fact that one patent may be useful in different industries (Lybbert & Zolas, 2014; Schmoch, Laville, Patel, & Frietsch, 2003). For illustration purposes, I use a very simple industry-technology concordance (Fernandez Donoso, 2014), based on the similarities of each title (e.g. patents for "tobacco; cigars; cigarettes; smokers' requisites" were matched to the industry "tobacco products").

To contrast how indices behave with other variables, I use GDP and GDP per-capita from the World Bank, and the country's technological development by Fieler (2011), a measure generated using Eaton and Kortum (2002) regression residuals.

An important issue to be addressed by any innovation index is the selection of an accurate variable to proxy for non-patented innovations (i.e. innovations outside the formal intellectual property rights system). Indeed, since most inventions remain outside the patenting system, no index will perfectly capture innovations kept in secret.

Innovations are sometimes kept in secret because of strategic reasons (Hall, Helmers, Rogers, & Sena, 2014). In other cases, intellectual property law does not allow to patent or use copyrights for some innovations (e.g. designs of mask geometry of integrated circuits). Since trade secrets, non-disclosure agreements, and other forms of intellectual property protection that do not use public registration, are not publicly available in datasets (i.e. unobservable), researchers need proxies to measure these innovations.

For simplicity, I use exports of each industry from the United Nations COMTRADE database, weighted by the complexity of each exporting industry, to proxy for non-patented innovation. Theoretical literature shows that productivity (i.e. process innovation) increases the extensive margin of exports (Melitz, 2003; Helpman, Melitz, & Yeaple, 2004), and that new product varieties with higher quality (i.e. product innovation) increase the intensive margin of exports (Hallak, 2006). Empirical literature has supported this positive correlation, and in particular, that innovation strongly correlates with exports performance: innovation affects positively the duration of exports (Chen, 2012), and the intensive and extensive margin of exports (Chen, 2013). Moreover, evidence suggests that exports can also lead to product innovation (Bratti and Felice, 2012), and that internationalization increases innovation through absorptive capacity (Filipeti, Frenz, & Ietto-Gillies, 2016). There is also evidence of trade increasing innovation, by inducing technical change, information technology and productivity (Bloom, Draca, & Van Reenen, 2016).

Though current literature finds strong evidence in favor of this correlation between innovation and sophisticated exports, there are several reasons to suspect that exports are not a perfect proxy for non-patented innovation. Nevertheless, since the objective of this paper is weighting innovations with the technological complexity of each technology or industry, the existence of variables with industry or technology classification is key for complexity weighting. Exports might correlate imperfectly with unobservable innovation, but it is a variable with the virtue of being registered by all countries using standardized industry-classifications. Future research looking for even better proxies for non-patented innovation should concentrate on variables with some industry or technology classification.

3.2. Index calculation

As an example of complexity weighting, I generate an index of innovation based only on innovation outputs. The innovation output sub-index of the Global Innovation Index is comprised of two pillars: knowledge and technology outputs (unweighted patents and utility models, and published articles in peer-reviewed journals), and creative outputs (trademarks and other proxies such as newspapers' circulation, printing output, or Wikipedia entries). In this example, I restrict the innovation output to two main variables: complex inventions with formal IP (patents), and production of complex goods.

For the complexity weights, I use the normalized complexity index by Naghavi et al. (2015). Then, I generate a complexity-weighted sum of patents and exports, and I normalize the two sums to a [0,1] scale using the min-max method. Finally, I compute the unweighted average of these two normalized measures. Hence, the innovation index of country j is computed using the following formula:

$$x_j = \frac{1}{2}\left(X_j + Y_j\right)$$

X_j is the innovation protected using formal intellectual property rights: $X_j = \frac{\left(\sum_i pat_i \times compl_i\right)_j - \left(\sum_i pat_i \times compl_i\right)_{\min}}{\left(\sum_i pat_i \times compl_i\right)_{\max} - \left(\sum_i pat_i \times compl_i\right)_{\min}}$ Y_j is the innovation not protected with formal intellectual property rights, which is estimated using the proxy:

$$Y_j = \frac{\left(\sum_i ex_i \times compl_i\right)_j - \left(\sum_i ex_i \times compl_i\right)_{\min}}{\left(\sum_i ex_i \times compl_i\right)_{\max} - \left(\sum_i ex_i \times compl_i\right)_{\min}}$$

The variables pat_i, ex_i, and $compl_i$ are the number of patents, the exports, and the complexity of industry i respectively. I also generate a size-independent (per-capita) index, which follows the same calculations but using patents per-capita and exports per-capita. To compare the impact of including complexity weights, I also generate unweighted aggregate and per-capita indices (i.e. mean of unweighted sum of patents and unweighted sum of exports).

4. Empirical analysis of complexity weighting

4.1. Weighting, size-dependent and size-independent metrics

As an empirical exercise, I propose two different measures of innovation: (i) a complexity-weighted index of innovation per-capita, or size-independent innovation index; and (ii) a complexity-weighted index of innovation, or size-dependent innovation index. The distinction is similar to GDP and GDP per-capita measures.

Since countries are very different in size (e.g. geographic, GDP, population), using an index that measures and compares their overall innovative performance is not a suitable approach to analyze the innovative output generated by individuals under different contexts (countries). A country of size 1/10th of another country, but generating half the innovative output of the large country is certainly more innovative than the large country. That is, if both countries were the same size, the first would produce five times more innovation than the second country would. By normalizing countries by population, the size-independent index of innovation is suitable to compare the innovation output of individuals from each country of the sample.

On the other hand, an index taking into account the overall innovative output of the economy is suitable to measure and compare how economies' innovation generate a global impact. Indeed, large economies, like China, may not perform high in per-capita innovation, but Chinese companies such as Alibaba or Huawei are important players in global innovative output. A size-dependent measure of innovation, in which countries are not normalized by size, is an appropriate measure to capture countries' production of global innovation.

Since the main contribution of these indices lies in the complexity weights, I generate four different normalized indices (weighted innovation, weighted innovation per-capita, unweighted innovation, and unweighted innovation per-capita) to compare how the estimates change when the weights are introduced in the index. I use 2010 patents' data, and 2011 exports data, which makes the results comparable to the 2013 Global Innovation Index (GII 2013).[1] Table 2 shows the correlations between the four innovation indices and the GII (2013).

The correlation of size-independent and size-dependent with their unweighted versions are 0.308 and 0.657. Hence, the introduction of complexity weights does generate correlated indices with the unweighted metrics, as expected, though the correlations are lower that the correlation between the (weighted) size-independent index and the GII (2013), which has a very different variable structure and composition.

[1] Table A1 of Appendix A shows the normalized metrics.

Table 2
Innovation indices correlations.

	Weighted Innovation	Weighted Innovation p/c	Unweighted Innov.	Unweighted Innovation p/c	GII (2013)
Weighted Innovation	1				
Weighted Innovation p/c	0.453	1			
Unweighted Innovation	0.657	0.266	1		
Unweighted Innovation p/c	0.105	0.308	0.072	1	
GII (2013)	0.319	0.789	0.156	0.465	1

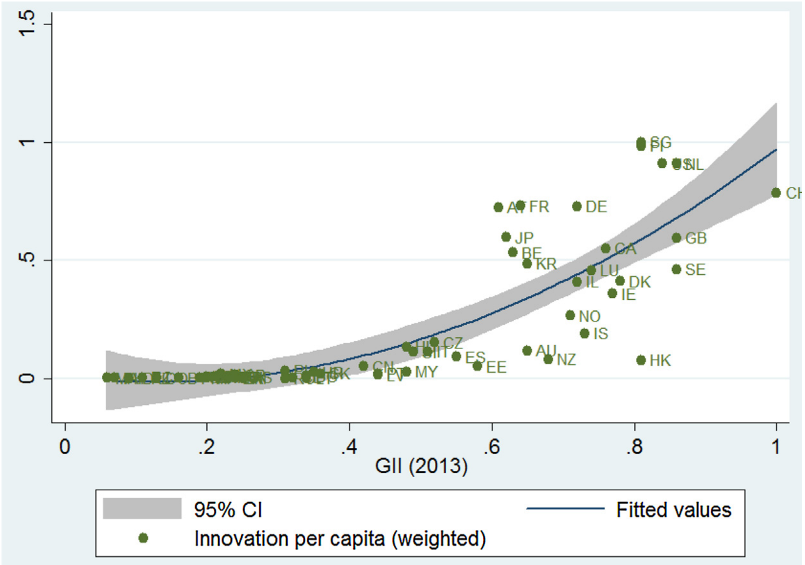

Fig. 1. Innovation per-capita and Global Innovation Index (2013).

Table 3
Innovation per-capita index correlations with other economic measures.

	Innovation p/c	GII (2013)	Technology	GDP p/c	GDP
Innovation p/c	1				
GII (2013)	0.787	1			
Technology	0.352	0.238	1		
GDP p/c	0.687	0.817	0.291	1	
GDP	0.373	0.240	0.740	0.155	1

4.2. Size-independent innovation

The first empirical exercise generates a measure that enables to sorting the innovation output of countries, but normalizing the size (i.e. population) of economies. As shown in Table 2, the per-capita (weighted) innovation index is very much in line with the mainstream innovation index (correlation with GII is 0.789). This correlation does not imply an equivalency between both measures, though it is indicative of both indices measuring similar “size-independent” innovation output capacities. By looking at how the index behaves (Fig. 1), countries like Singapore, the Netherlands, Germany, France, Belgium, or Japan rank higher when innovation is measured using the per-capita (complexity-weighted) index than if they were measured using GII (2013). These countries generate more complex patents and exports, but the sum of unweighted components included in the GII (2013) computation is lower than for other countries. Hong-Kong, New Zealand, Iceland, Australia, or Norway, on the other hand, are among the countries that rank lower when the proposed index is used to measure their innovation output.

In general, the weighted innovation per-capita index does not show surprising correlation signs with other economic measures (Table 3). Innovation per-capita is positively correlated with technological development, GDP per-capita, and GDP. In terms of magnitudes, the index correlates lower with GDP per-capita than GII (2013), but higher with GDP and technological development.

This higher correlation with GDP may be indicative of a size effect affecting complex innovations more than other innovations. Indeed, magnitudes suggest that the complexity-weighting approach to measure innovation per-capita captures more the impact of economic size on the per-capita innovative output. Namely, larger economies (higher GDP) usually have larger R&D expenditures, clusters, and spillovers; hence, fostering complex innovations even at per-capita level.

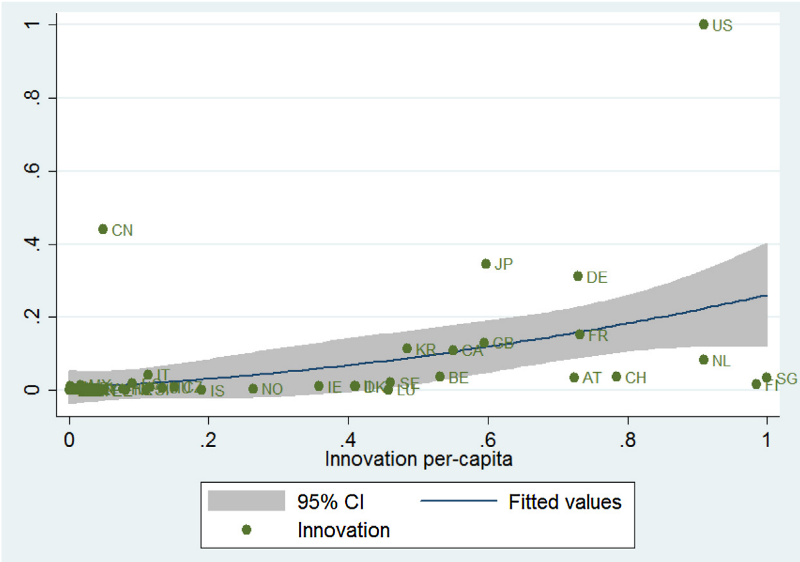

Fig. 2. Innovation and Innovation per-capita.

Table 4
Innovation index correlations with other economic measures.

	Innovation	GII (2013)	Technology	GDP p/c	GDP
Innovation	1				
GII (2013)	0.304	1			
Technology	0.723	0.238	1		
GDP p/c	0.184	0.817	0.291	1	
GDP	0.971	0.240	0.740	0.155	1

4.3. *Size-dependent innovation*

Innovation per-capita is a suitable measure of how much innovation individuals generate in different countries, but it fails to explain how in large economies with low per-capita innovative performance, big innovative players emerge. Moreover, a size-independent innovation metric fails to capture which economies are contributing more to global innovative output.

Both metrics, size-dependent and size-independent innovation, are positively correlated (Table 2). Though the U.S. scores high in both metrics, countries like China, Japan, and Germany have a much higher performance overall than per-capita (Fig. 2). The case of China is particularly striking, showing a low per-capita innovative output (ranks 30 out of 63 economies), but very high in overall innovation output given the size of the economy (2nd in size-dependent innovation).

This metric of overall innovation output is positively correlated to the technological development of countries (Table 4), and the correlation to GDP is very high (correlation 0.97). However striking, this high correlation is not surprising in terms of the economic forces that drive innovative output. The measure of GDP is not included in the construction of the innovation output metric, but GDP is a metric of the total income of economies, and hence, the amount of resources available to produce innovation. Equivalently, GDP is also the total amount of resources that economic activity generate, which is highly dependent on innovation output. Hence, the economies that generate more innovative products and processes are expected to earn higher income.

Nevertheless, GDP should not be used instead of size-dependent innovation output, as it should lead to bias due to low-complexity economic activity. For example, India and Brazil have the third and ninth largest GDP in the world respectively, but their innovation output rank only the 22nd and 27th out of the 63 countries measured in this paper. Moreover, the Netherlands and Turkey have similar GDPs (17th and 18th economies respectively), but the Netherlands is the 10th country bringing more innovation to the world according to this index, while Turkey only ranks 33rd in the sample.

On the other hand, the correlation between the innovation index and GDP increases as the sample is reduced to larger economies, and the correlation decreases the sample considers smaller countries only. If the sample is caped to countries with GDP lower than 4.0e + 11 dollars (40 countries with lower GDP), the correlation drops to 0.489. If the sample is capped to countries with GDP higher than 1.4e + 11 (41 countries with higher GDP), correlation increases to 0.973 (from 0.971 with all countries). This is, GDP seems to be a good proxy for larger economies, but may lead to errors for middle-size and smaller countries.

5. Conclusion

Although patents are still the most popular measure of innovation, there have been important improvements to tackle the shortcomings of counting patents. Still, most composite indicators rely heavily on patent counts. In this paper, I propose a simple method to reduce the bias of counting patents.

As an empirical exercise, I generate two indices of innovation based on complexity weights. Though the indices are correlated with current mainstream innovation metrics, the computation of these indices is simpler, as they need less proxies of innovation output (some of these proxies of dubious relation with innovation). Using two innovative output measures has also the advantage of measuring both the total innovation of a country (currently unavailable), as well as a country-size normalized measure of innovation. Empirically, the size-independent (weighted) measure of innovation shows higher correlation to technological development than the current (unweighted) mainstream measure of innovation.

Weighting intellectual property and exports by technological complexity is a progress with respect to current unweighted measures, but does not overcome all the challenges of measuring innovation. The indices of this paper use technologically complex exports to account for all non-patented innovations, leaving non-tradable goods and services outside of the index. Future research should bring forwards better methods to measure non-patented innovation, and account for differences in quality.

The main message of this paper is simple: instead of adding large sets of proxies with doubtful relation to innovation, composite indices should weight their innovation metrics with an appropriate metric of the quality of the innovation.

Appendix A. Indices metrics and rankings

See Table A2–A3

Table A1
Indices scores.

Country	Innovation	Innovation per-capita	Innovation (no complexity)	Innovation per-capita (no complexity)	GII score (normalized)
Armenia	0.00e + 00	1.25e – 03	0.00e + 00	1.22e – 02	2.40e – 01
Austria	3.43e – 02	7.24e – 01	8.57e – 03	7.34e – 02	6.10e – 01
Australia	7.89e – 03	1.16e – 01	1.11e – 02	3.77e – 02	6.50e – 01
Bosnia and H.	2.00e – 05	2.88e – 03	0.00e + 00	9.39e – 03	2.00e – 01
Belgium	3.54e – 02	5.32e – 01	4.58e – 03	2.99e – 02	6.30e – 01
Bulgaria	1.80e – 04	8.88e – 03	0.00e + 00	4.78e – 03	3.40e – 01
Brazil	4.54e – 03	5.61e – 03	2.84e – 03	1.27e – 03	2.10e – 01
Belarus	3.00e – 05	1.54e – 03	0.00e + 00	3.79e – 03	1.60e – 01
Canada	1.09e – 01	5.51e – 01	2.78e – 02	5.20e – 02	7.60e – 01
Switzerland	3.60e – 02	7.85e – 01	1.90e – 02	6.48e – 02	1.00e + 00
Chile	1.40e – 04	3.45e – 03	0.00e + 00	2.08e – 03	3.20e – 01
China	4.40e – 01	4.92e – 02	1.77e – 02	9.40e – 04	4.20e – 01
Colombia	6.70e – 04	2.39e – 03	5.01e – 01	2.31e – 03	2.30e – 01
Czech R.	9.15e – 03	1.52e – 01	2.84e – 03	2.41e – 02	5.20e – 01
Germany	3.11e – 01	7.29e – 01	1.18e – 01	9.83e – 02	7.20e – 01
Denmark	9.65e – 03	4.10e – 01	6.14e – 03	9.14e – 02	7.80e – 01
Dominican R.	1.00e – 05	7.40e – 04	0.00e + 00	3.59e – 03	1.30e – 01
Ecuador	1.30e – 04	3.96e – 03	0.00e + 00	2.38e – 03	1.10e – 01
Estonia	1.70e – 04	5.04e – 02	9.23e – 03	4.32e – 01	5.80e – 01
Egypt	1.10e – 04	6.10e – 04	4.70e – 04	9.00e – 04	–
Spain	1.74e – 02	9.13e – 02	8.11e – 03	1.41e – 02	5.50e – 01
Finland	1.54e – 02	9.85e – 01	5.68e – 03	8.78e – 02	8.10e – 01
France	1.52e – 01	7.32e – 01	6.12e – 02	6.46e – 02	6.40e – 01
Great Britain	1.29e – 01	5.95e – 01	1.44e – 01	1.17e – 01	8.60e – 01
Georgia	3.00e – 05	3.26e – 03	4.70e – 04	1.62e – 02	1.90e – 01
Greece	4.20e – 04	1.34e – 02	4.70e – 04	6.38e – 03	2.40e – 01
Hong Kong	3.63e – 03	7.70e – 02	2.07e – 02	1.65e – 01	8.10e – 01
Croatia	2.60e – 04	2.53e – 02	9.50e – 04	2.46e – 02	3.50e – 01
Hungary	6.02e – 03	1.33e – 01	3.31e – 03	2.89e – 02	4.80e – 01
Indonesia	1.20e – 04	1.30e – 04	2.18e – 02	2.70e – 04	9.00e – 02
Ireland	9.71e – 03	3.58e – 01	2.05e – 03	4.04e – 02	7.70e – 01
Israel	1.18e – 02	4.09e – 01	1.33e – 02	1.23e – 01	7.20e – 01
India	9.50e – 03	1.76e – 03	–	–	2.00e – 01
Iceland	1.40e – 04	1.90e – 01	–	1.14e – 01	7.30e – 01
Italy	4.21e – 02	1.14e – 01	1.11e – 02	1.02e – 02	5.10e – 01
Japan	3.46e – 01	5.98e – 01	6.61e – 02	3.92e – 02	6.20e – 01
Korea (Rep.)	1.13e – 01	4.85e – 01	3.13e – 02	4.76e – 02	6.50e – 01
Kazakhstan	5.00e – 05	1.38e – 03	1.46e – 03	8.84e – 03	1.10e – 01
Lithuania	0.00e + 00	9.50e – 04	5.40e – 04	2.20e – 02	3.40e – 01

Table A1 (*Continued*)

Country	Innovation	Innovation per-capita	Innovation (no complexity)	Innovation per-capita (no complexity)	GII score (normalized)
Luxembourg	5.90e – 04	4.58e – 01	2.85e – 03	5.00e – 01	7.40e – 01
Latvia	7.00e – 05	1.36e – 02	2.45e – 03	9.70e – 02	4.40e – 01
Morocco	1.10e – 04	1.33e – 03	4.70e – 04	2.22e – 03	6.00e – 02
Mexico	1.33e – 02	1.67e – 02	1.57e – 03	1.20e – 03	2.20e – 01
Malaysia	4.40e – 03	2.72e – 02	0.00e + 00	1.25e – 03	4.80e – 01
Netherland	8.22e – 02	9.09e – 01	1.37e – 02	6.10e – 02	8.60e – 01
Normay	4.22e – 03	2.64e – 01	4.52e – 03	7.40e – 02	7.10e – 01
New Zealand	9.20e – 04	8.12e – 02	5.40e – 04	1.66e – 02	6.80e – 01
Philippines	4.00e – 04	9.50e – 04	4.70e – 04	7.50e – 04	7.00e – 02
Poland	5.98e – 03	3.08e – 02	9.50e – 04	2.82e – 03	3.10e – 01
Portugal	5.80e – 04	1.90e – 02	9.50e – 04	1.02e – 02	4.40e – 01
Romania	1.50e – 04	0.00e + 00	8.62e – 02	0.00e + 00	3.10e – 01
Serbia	5.00e – 05	3.26e – 03	9.70e – 04	1.49e – 02	2.50e – 01
Russia	1.97e – 03	4.48e – 03	4.80e – 04	4.80e – 04	2.30e – 01
Sweden	1.98e – 02	4.61e – 01	4.97e – 03	4.25e – 02	8.60e – 01
Singapore	3.29e – 02	1.00e + 00	2.43e – 02	4.28e – 02	8.10e – 01
Slovenia	6.60e – 04	1.10e – 01	9.50e – 04	5.30e – 02	4.90e – 01
Slovakia	4.70e – 04	1.86e – 02	6.60e – 04	1.33e – 02	3.60e – 01
Thailand	2.03e – 03	4.94e – 03	7.08e – 03	1.06e – 03	2.40e – 01
Tunisia	2.00e – 05	1.11e – 03	1.42e – 03	1.37e – 02	1.90e – 01
Turkey	1.59e – 03	8.02e – 03	2.37e – 03	2.98e – 03	2.00e – 01
Ukraine	3.80e – 04	2.61e – 03	4.08e – 02	1.55e – 03	1.90e – 01
United States	1.00e + 00	9.09e – 01	5.55e – 01	1.24e – 01	8.40e – 01
South Africa	2.80e – 04	2.11e – 03	2.97e – 03	1.42e – 03	2.40e – 01

Table A2
Indices rankings.

Country	Innovation	Innov. per-capita	Unweighted Innov.	Unweighted Innov. p/c	GII
United States	1	3	1	4	5
China	2	30	15	57	33
Japan	3	9	6	23	22
Germany	4	7	4	8	15
France	5	6	7	15	20
Great Britain	6	10	3	6	3
Korea (Rep.)	7	13	9	19	18
Canada	8	11	10	18	11
Netherland	9	4	16	16	4
Italy	10	24	19	38	27
Switzerland	11	5	14	14	1
Belgium	12	12	27	25	21
Austria	13	8	21	13	23
Singapore	14	1	11	20	8
Sweden	15	14	26	21	2
Spain	16	26	22	33	25
Finland	17	2	25	11	6
Mexico	18	36	37	55	48
Israel	19	17	17	5	14
Ireland	20	18	36	22	10
Denmark	21	16	24	10	9
India	22	52	60	63	51
Czech R.	23	21	32	28	26
Australia	24	23	18	24	19
Hungary	25	22	29	26	29
Poland	26	31	44	46	40
Brazil	27	41	33	53	49
Malaysia	28	32	55	54	30
Normay	29	19	28	12	16
Hong Kong	30	28	13	3	7
Thailand	31	42	23	56	43
Russia	32	43	48	60	47
Turkey	33	40	35	45	52
New Zealand	34	27	46	30	17
Colombia	35	50	2	48	46
Slovenia	36	25	41	17	28
Luxembourg	37	15	31	1	12
Portugal	38	34	42	37	32
Slovakia	39	35	45	35	34
Greece	40	38	50	41	42

Table A2 (*Continued*)

Country	Innovation	Innov. per-capita	Unweighted Innov.	Unweighted Innov. p/c	GII
Philippines	41	59	49	59	61
Ukraine	42	49	8	51	54
South Africa	43	51	30	52	44
Croatia	44	33	43	27	35
Bulgaria	45	39	56	42	37
Estonia	46	29	20	2	24
Romania	47	63	5	62	39
Chile	48	45	57	50	38
Iceland	49	20	54	7	13
Ecuador	50	44	63	47	58
Indonesia	51	62	12	61	60
Morocco	52	55	52	49	62
Egypt	53	61	53	58	63
Latvia	54	37	34	9	31
Serbia	55	47	40	32	41
Kazakhstan	56	54	38	40	59
Belarus	57	53	61	43	56
Georgia	58	46	51	31	55
Tunisia	59	57	39	34	53
Bosnia and H.	60	48	59	39	50
Dominican R.	61	60	62	44	57
Armenia	62	56	58	36	45
Lithuania	63	58	47	29	36

Table A3
Formal and informal IP innovation metrics.

Country	Formal	Informal	Country	Formal	Informal
Armenia	4.74e – 06	0	Italy	6.66e – 03	7.75e – 02
Australia	1.04e – 02	5.42e – 03	Japan	1.96e – 01	4.95e – 01
Austria	8.77e – 03	5.99e – 02	Kazakhstan	9.42e – 05	1.08e – 07
Belarus	5.64e – 05	3.31e – 07	Korea (Rep.)	5.76e – 02	1.67e – 01
Belgium	5.69e – 03	6.51e – 02	Latvia	1.31e – 04	1.55e – 06
Bosnia and H.	3.97e – 05	0	Lithuania	1.92e – 06	1.18e – 07
Brazil	3.23e – 03	5.86e – 03	Luxembourg	1.04e – 03	1.50e – 04
Bulgaria	2.81e – 04	7.06e – 05	Malaysia	1.04e – 03	7.76e – 03
Canada	2.40e – 02	1.95e – 01	Mexico	6.42e – 04	2.59e – 02
Chile	2.63e – 04	1.53e – 05	Morocco	1.74e – 04	5.04e – 05
China	2.70e – 02	8.53e – 01	Netherland	2.49e – 02	1.39e – 01
Colombia	9.32e – 05	1.26e – 03	New Zealand	1.59e – 03	2.56e – 04
Croatia	5.16e – 04	5.45e – 06	Normay	4.97e – 03	3.46e – 03
Czech R.	2.15e – 03	1.62e – 02	Philippines	2.06e – 04	6.03e – 04
Denmark	6.42e – 03	1.28e – 02	Poland	2.35e – 03	9.61e – 03
Dominican R.	2.22e – 05	0	Portugal	8.45e – 04	3.06e – 04
Ecuador	2.69e – 04	4.41e – 07	Romania	6.82e – 05	2.26e – 04
Egypt	2.11e – 04	3.95e – 06	Russia	2.55e – 03	1.39e – 03
Estonia	2.90e – 04	5.34e – 05	Serbia	9.98e – 05	2.53e – 07
Finland	2.22e – 02	8.58e – 03	Singapore	3.08e – 03	6.27e – 02
France	1.87e – 01	1.18e – 01	Slovakia	2.29e – 04	7.12e – 04
Georgia	5.60e – 05	0	Slovenia	9.35e – 04	3.76e – 04
Germany	1.12e – 01	5.09e – 01	South Africa	4.55e – 04	9.63e – 05
Great Britain	1.34e – 01	1.24e – 01	Spain	1.25e – 02	2.22e – 02
Greece	6.37e – 04	2.09e – 04	Sweden	1.09e – 02	2.86e – 02
Hong Kong	1.84e – 04	7.08e – 03	Switzerland	7.58e – 03	6.43e – 02
Hungary	3.41e – 03	8.63e – 03	Thailand	2.76e – 04	3.78e – 03
Iceland	2.74e – 04	4.71e – 07	Tunisia	4.29e – 05	7.95e – 10
India	5.52e – 03	1.35e – 02	Turkey	2.51e – 03	6.78e – 04
Indonesia	8.21e – 05	1.60e – 04	Ukraine	4.59e – 04	2.92e – 04
Ireland	1.62e – 03	1.78e – 02	United States	1	1
Israel	1.04e – 02	1.32e – 02			

Appendix B. Correlation plots

See Fig. B1–B6

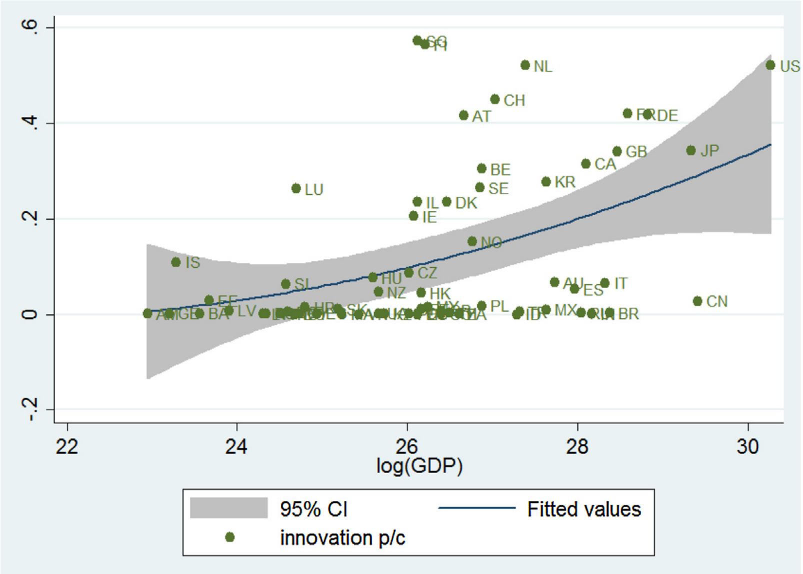

Fig. B1. Size-independent innovation and GDP (log) plot.

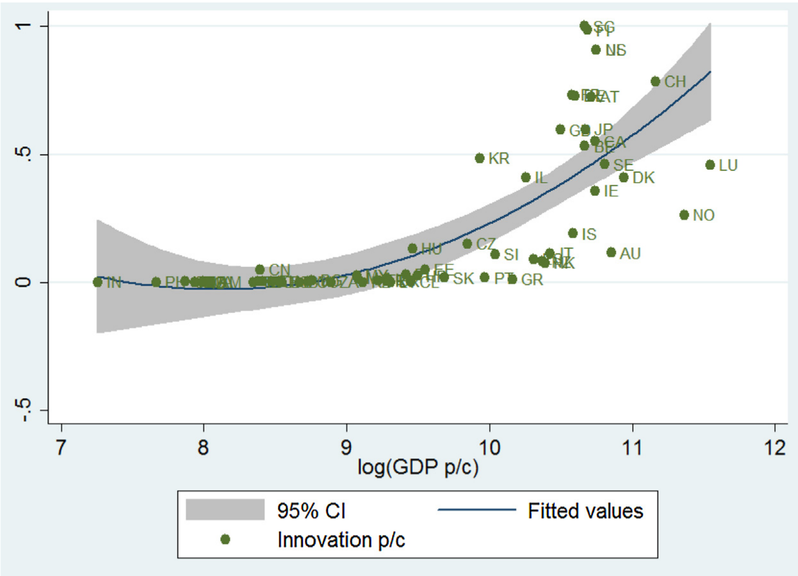

Fig. B2. Size-independent innovation and GDP per capita (log) plot.

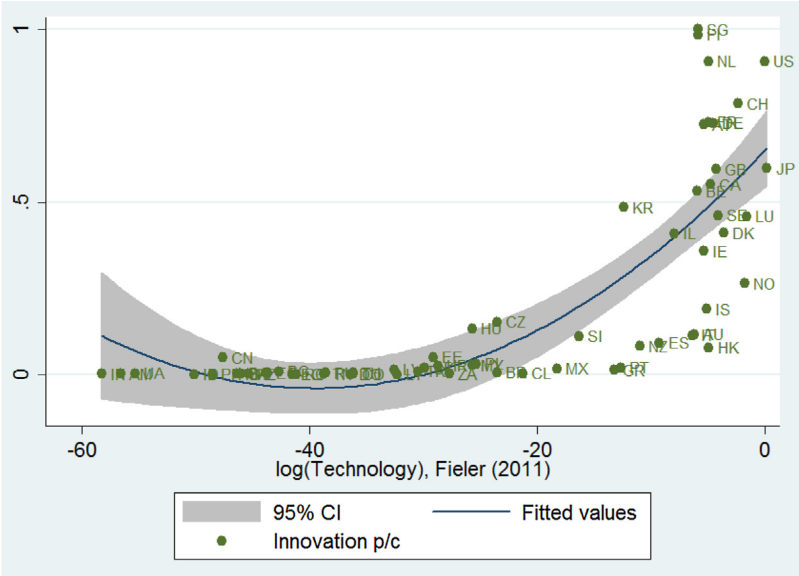

Fig. B3. Size-independent innovation and technology (Fieler, 2011).

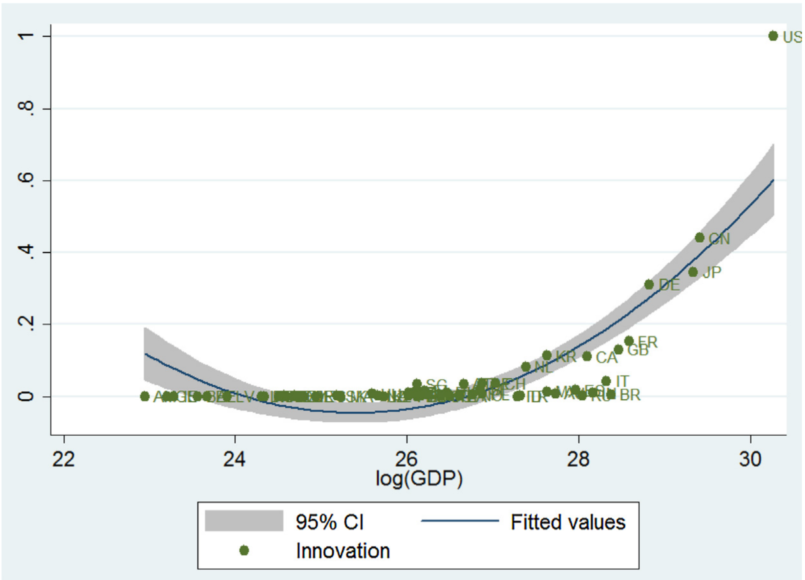

Fig. B4. Size-dependent innovation and GDP (log) plot.

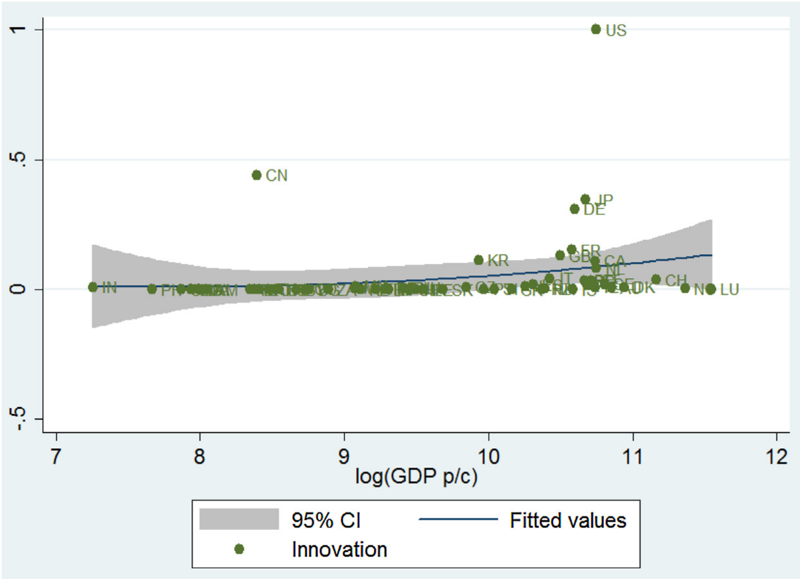

Fig. B5. Size-dependent innovation and GDP per-capita (log) plot.

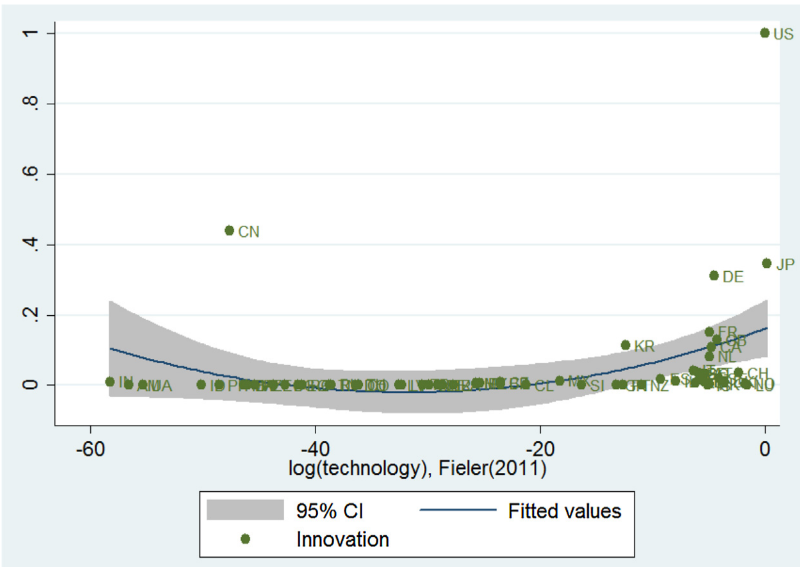

Fig. B6. Size-dependent innovation and technology (Fieler, 2011).

Appendix C. Patent Classification used for index calculation

CPC	CPC Description
A21	BAKING; EDIBLE DOUGHS
A22	BUTCHERING; MEAT TREATMENT; PROCESSING POULTRY OR FISH
A23	FOODS OR FOODSTUFFS; THEIR TREATMENT, NOT COVERED BY OTHER CLASSES
A24	TOBACCO; CIGARS; CIGARETTES; SMOKERS' REQUISITES
A41	WEARING APPAREL
A42	HEADWEAR
A43	FOOTWEAR
A44	HABERDASHERY; JEWELLERY
A45	HAND OR TRAVELLING ARTICLES
A46	BRUSHWARE

A47	FURNITURE
A63	SPORTS; GAMES; AMUSEMENTS
B01	PHYSICAL OR CHEMICAL PROCESSES OR APPARATUS IN GENERAL
B02	CRUSHING, PULVERISING, OR DISINTEGRATING; PREPARATORY TREATMENT OF GRAIN FOR MILLING
B03	SEPARATION OF SOLID MATERIALS USING LIQUIDS OR USING PNEUMATIC TABLES OR JIGS;MAGNETIC OR ELECTROSTATIC SEPARATION OF SOLID MATERIALS FROM SOLID MATERIALS OR FLUIDS; SEPARATION BY HIGH-VOLTAGE ELECTRIC FIELDS (separating isotopesB01D59/00; crushing or disintegrating B02C; centrifuges or vortex apparatus for carrying out physical processes B04)
B04	CENTRIFUGAL APPARATUS OR MACHINES FOR CARRYING-OUT PHYSICAL OR CHEMICAL PROCESSES (using centrifugal force for the separation of particles from liquids or gases, in general B01D, e.g. B01D21/26, B01D43/00, B01D45/12)
B05	SPRAYING OR ATOMISING IN GENERAL; APPLYING LIQUIDS OR OTHER FLUENT MATERIALS TO SURFACES, IN GENERAL (domestic cleaning A47L; cleaning in general by methods essentially involving the use or presence of liquid B08B3/00; sand-blasting B24C; coating of articles during shaping of substances in a plastic state B29C39/10, B29C39/18, B29C41/20, B29C41/30,B29C43/18, B29C43/28, B29C45/14, B29C47/02; for further classification of forming layered products, see B32B; printing, copying B41; conveying articles or workpieces through baths of liquid B65G, e.g. B65G49/02; handling webs or filaments in general B65H; surface treatment of glass by coating C03C17/00, C03C25/10; coating or impregnation of mortars, concrete, stone or ceramics C04B41/45; paints, varnishes, lacquers C09D; enamelling of metals, applying a vitreous layer to metals, chemical cleaning or de-greasing of metallic objects C23; electroplatingC25D; treating of textile materials by liquids, gases or vapours D06B; laundering D06F; treating roads E01C; apparatus or processes for the preparation or treatment of photosensitive materials G03; apparatus or processes, restricted to a purpose fully provided for in a single other class, see the relevant class covering the purpose)
B06	GENERATING OR TRANSMITTING MECHANICAL VIBRATIONS IN GENERAL
B07	SEPARATING SOLIDS FROM SOLIDS; SORTING (separation in general B01D; wet separating processes, sorting by processes using fluent material in the same way as liquid B03; using liquids B03B, D; sorting by magnetic or electrostatic separation of solid materials from solid materials or fluids, separation by high voltage electric fields B03C; centrifuges or vortex apparatus for carrying out physical processes B04; sorting peculiar to particular materials or articles and provided for in other classes, see the relevant classes)
B21	MECHANICAL METAL-WORKING WITHOUT ESSENTIALLY REMOVING MATERIAL; PUNCHING METAL (casting, powder metallurgy B22; shearing B23D; working of metal by the action of a high concentration of electric current B23H; soldering, welding, flame-cutting B23 K; other working of metal B23P; punching sheet material in general B26F; processes for changing of physical properties of metals C21D, C22F; electroforming C25D1/00)
B22	CASTING; POWDER METALLURGY
B23	MACHINE TOOLS; METAL-WORKING NOT OTHERWISE PROVIDED FOR (punching, perforating, making articles by processing sheet metal, tubes, or profiles B21D; wire-working B21F; making pins, needles, or nails B21G; making chains B21L; grinding B24)
B24	GRINDING; POLISHING
B25	HAND TOOLS; PORTABLE POWER-DRIVEN TOOLS; MANIPULATORS
B26	HAND CUTTING TOOLS; CUTTING; SEVERING
B27	WORKING OR PRESERVING WOOD OR SIMILAR MATERIAL; NAILING OR STAPLING MACHINES IN GENERAL
B28	WORKING CEMENT, CLAY, OR STONE
B29	WORKING OF PLASTICS; WORKING OF SUBSTANCES IN A PLASTIC STATE, IN GENERAL(processing doughs A21C; working chocolate A23G; casting of metals B22; working cement, clay B28; chemical aspects, see Section C, particularly C08; working glass C03B; candle making C11C5/02; making soap C11D13/00; manufacture of artificial filaments, threads, fibres, bristles or ribbons D01D, F; manufacture of articles from cellulosic fibrous suspensions or from papier-mâchè D21J)
B30	PRESSES
B31	MAKING PAPER ARTICLES; WORKING PAPER
B41	PRINTING; LINING MACHINES; TYPEWRITERS; STAMPS (reproduction or duplication of pictures or patterns by scanning and converting into electrical signals H04N)
B42	BOOKBINDING; ALBUMS; FILES; SPECIAL PRINTED MATTER
B43	WRITING OR DRAWING IMPLEMENTS; BUREAU ACCESSORIES
B44	DECORATIVE ARTS
B60	VEHICLES IN GENERAL
B61	RAILWAYS
B62	LAND VEHICLES FOR TRAVELLING OTHERWISE THAN ON RAILS
B63	SHIPS OR OTHER WATERBORNE VESSELS; RELATED EQUIPMENT
B64	AIRCRAFT; AVIATION; COSMONAUTICS
B81	MICRO-STRUCTURAL TECHNOLOGY
B82	NANO-TECHNOLOGY
C01	INORGANIC CHEMISTRY (processing powders of inorganic compounds preparatory to the manufacturing of ceramic products C04B35/00; fermentation or enzyme-using processes for the preparation of elements or inorganic compounds except carbon dioxide C12P3/00; obtaining metal compounds from mixtures, e.g. ores, which are intermediate compounds in a metallurgical process for obtaining a free metal C21B, C22B; production of non-metallic elements or inorganic compounds by electrolysis or electrophoresis C25B)
C02	TREATMENT OF WATER, WASTE WATER, SEWAGE, OR SLUDGE (settling tanks, filtering, e.g. sand filters or screening devices, B01D)
C03	GLASS; MINERAL OR SLAG WOOL ({organic glasses C08; metallic glasses, amorphous metalsB22F, C22C})
C04	CEMENTS; CONCRETE; ARTIFICIAL STONE; CERAMICS; REFRACTORIES (alloys based on refractory metals C22C)
C05	FERTILISERS; MANUFACTURE THEREOF (processes or devices for granulating materials, in general B01J2/00; soil-conditioning or soil-stabilising materials C09K17/00)

C06	EXPLOSIVES; MATCHES
C07	ORGANIC CHEMISTRY (such compounds as the oxides, sulfides, or oxysulfides of carbon, cyanogen, phosgene, hydrocyanic acid or salts thereof C01; products obtained from layered base-exchange silicates by ion-exchange with organic compounds such as ammonium, phosphonium or sulfonium compounds or by intercalation of organic compounds C01B33/44; macromolecular compounds C08; dyes C09; fermentation products C12; fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture C12P; production of organic compounds by electrolysis or electrophoresis C25B3/00, C25B7/00)
C08	ORGANIC MACROMOLECULAR COMPOUNDS; THEIR PREPARATION OR CHEMICAL WORKING-UP; COMPOSITIONS BASED THEREON (manufacture or treatment of artificial threads, fibres, bristles or ribbons D01)
C09	DYES; PAINTS; POLISHES; NATURAL RESINS; ADHESIVES; MISCELLANEOUS COMPOSITIONS;MISCELLANEOUS APPLICATIONS OF MATERIALS
C10	PETROLEUM, GAS OR COKE INDUSTRIES; TECHNICAL GASES CONTAINING CARBON MONOXIDE; FUELS; LUBRICANTS; PEAT
C11	ANIMAL AND VEGETABLE OILS, FATS, FATTY SUBSTANCES AND WAXES; FATTY ACIDS THEREFROM; DETERGENTS; CANDLES (edible oil or fat compositions A23)
C12	BIOCHEMISTRY; BEER; SPIRITS; WINE; VINEGAR; MICROBIOLOGY; ENZYMOLOGY; MUTATION OR GENETIC ENGINEERING
C13	SUGAR INDUSTRY (polysaccharides, e.g. starch, derivatives thereof C08B; malt C12C)
C14	SKINS; HIDES; PELTS; LEATHER
C21	METALLURGY OF IRON
C22	METALLURGY (of iron C21); FERROUS OR NON-FERROUS ALLOYS; TREATMENT OF ALLOYS OR NON-FERROUS METALS (production of metals by electrolysis or electrophoresis C25)
C23	COATING METALLIC MATERIAL; COATING MATERIAL WITH METALLIC MATERIAL (by metallising textiles D06M11/83; decorating textiles by locally metallising D06Q1/04); CHEMICAL SURFACE TREATMENT; DIFFUSION TREATMENT OF METALLIC MATERIAL; COATING BY VACUUM EVAPORATION, BY SPUTTERING, BY ION IMPLANTATION OR BY CHEMICAL VAPOUR DEPOSITION, IN GENERAL (for specific applications, see the relevant places, e.g. for manufacturing resistors H01C17/06); INHIBITING CORROSION OF METALLIC MATERIAL OR INCRUSTATION IN GENERAL (treating metal surfaces or coating of metals by electrolysis or electrophoresis C25D, C25F)
C25	ELECTROLYTIC OR ELECTROPHORETIC PROCESSES; APPARATUS THEREFOR (electrodialysis, electro-osmosis, separation of liquids by electricity B01D; {separation of isotopes by electrochemical methods B01D59/38}; working of metal by the action of a high concentration of electric current B23H; treatment of water, waste water or sewage by electrochemical methodsC02F1/46; surface treatment of metallic material or coating involving at least one process provided for in class C23 and at least one process covered by this class C23C28/00,C23F17/00; anodic or cathodic protection C23F; single-crystal growth C30B; metallising textilesD06M11/83; decorating textiles by locally metallising D06Q1/04; electrochemical methods: of analysis G01N; electrochemical measuring, indicating or recording devices G01R; electrolytic circuit elements, e.g. capacitors, H01G; electrochemical current or voltage generators H01 M)
C30	CRYSTAL GROWTH (separation by crystallisation in general B01D9/00)
C40	COMBINATORIAL CHEMISTRY
D01	NATURAL OR ARTIFICIAL THREADS OR FIBRES; SPINNING (metal threads B21; fibres or filaments of softened glass, minerals, or slag C03B37/00; yarns D02)
D02	YARNS; MECHANICAL FINISHING OF YARNS OR ROPES; WARPING OR BEAMING
D03	WEAVING
D04	BRAIDING; LACE-MAKING; KNITTING; TRIMMINGS; NON-WOVEN FABRICS
D05	SEWING; EMBROIDERING; TUFTING
D06	TREATMENT OF TEXTILES OR THE LIKE; LAUNDERING; FLEXIBLE MATERIALS NOT OTHERWISE PROVIDED FOR
D07	ROPES; CABLES OTHER THAN ELECTRIC
D10	INDEXING SCHEME ASSOCIATED WITH SUBLASSES OF SECTION D, RELATING TO TEXTILES
D21	PAPER-MAKING; PRODUCTION OF CELLULOSE
E03	WATER SUPPLY; SEWERAGE
E21	EARTH DRILLING; MINING
F01	MACHINES OR ENGINES IN GENERAL (combustion engines F02; machines for liquids F03, F04);ENGINE PLANTS IN GENERAL; STEAM ENGINES
F02	COMBUSTION ENGINES (cyclically operating valves therefor, lubricating, exhausting, or silencing engines F01); HOT-GAS OR COMBUSTION-PRODUCT ENGINE PLANTS
F03	MACHINES OR ENGINES FOR LIQUIDS (for liquid and gases F01; positive-displacement machines for liquids F04); WIND, SPRING WEIGHT AND MISCELLANEOUS MOTORS;PRODUCING MECHANICAL POWER; OR A REACTIVE PROPULSIVE THRUST, NOT OTHERWISE PROVIDED FOR
F04	POSITIVE DISPLACEMENT MACHINES FOR LIQUIDS; PUMPS FOR LIQUIDS OR ELASTIC FLUIDS(portable fire-extinguishers with manually-operated pumps A62C11/00, with power-driven pumps A62C25/00; charging or scavenging combustion engines by pumps F02B; engines fuel-injection pumps F02 M; ion pumps H01J41/00; electro-dynamic pumps H02K44/02)
F15	FLUID-PRESSURE ACTUATORS; HYDRAULICS OR PNEUMATICS IN GENERAL
F16	ENGINEERING ELEMENTS AND UNITS; GENERAL MEASURES FOR PRODUCING AND MAINTAINING EFFECTIVE FUNCTIONING OF MACHINES OR INSTALLATIONS; THERMAL INSULATION IN GENERAL
F17	STORING OF DISTRIBUTING GASES OR LIQUIDS (water supply E03B)
F21	LIGHTING (electric aspects or elements, see Section H, e.g. electric light sources H01J, H01 K,H05B)
F22	STEAM GENERATION (chemical or physical apparatus for generating gases B01J; chemical generation of gas, e.g. under pressure, Section C; removal of combustion products or residues, e.g. cleaning of the combustion contaminated surfaces of tubes of boilers, F23J; generating combustion products of high pressure or high velocity F23R; water heaters not for steam generation F24H, F28; cleaning of internal or external surfaces of heat-transfer conduits, e.g. water tubes of boilers, F28G)

F23	COMBUSTION APPARATUS; COMBUSTION PROCESSES
F24	HEATING; RANGES; VENTILATING (protecting plants by heating in gardens, orchards, or forestsA01G13/06; baking ovens and apparatus A21B; cooking devices other than ranges A47J; forging B21J, B21 K; specially adapted for vehicles, see the relevant subclasses of B60 to B64; combustion apparatus in general F23; drying F26B; ovens in general F27; electric heating elements and arrangements H05B)
F25	REFRIGERATION OR COOLING; COMBINED HEATING AND REFRIGERATION SYSTEMS; HEAT PUMP SYSTEMS; MANUFACTURE OR STORAGE OF ICE; LIQUEFACTION SOLIDIFICATION OF GASES
F26	DRYING
F27	FURNACES; KILNS; OVENS; RETORTS (specially adapted for a purpose covered by a single other class and specifically mentioned in that class, see the class in question, e.g. bakery ovensA21B, glass melting furnaces C03B, coke or gas-making apparatus C10B, C10J, apparatus for cracking hydrocarbons C10G, blast furnaces C21B, converters for making steel C21C, furnaces for heat treatment of metal C21D; furnaces for electroslag or arc remelting of metalsC22B9/00; enamelling ovens C23D; combustion apparatus F23; electric heating H05B)
F28	HEAT EXCHANGE IN GENERAL
F41	WEAPONS
F42	AMMUNITION; BLASTING
G01	MEASURING (counting G06 M); TESTING
G02	OPTICS (making optical elements or apparatus B24B, B29D11/00, C03, or other appropriate subclasses or classes; materials per se, see the relevant places, e.g. C03B, C03C)
G03	PHOTOGRAPHY; CINEMATOGRAPHY; ELECTROGRAPHY; HOLOGRAPHY (reproduction of pictures or patterns by scanning and converting into electrical signals H04N)
G04	HOROLOGY
G05	CONTROLLING; REGULATING (specially adapted to a particular field of use, see the relevant place for that field, e.g. A62C37/00, B03B13/00, B23Q)
G06	COMPUTING; CALCULATING; COUNTING (score computers for games A63B71/06, A63D15/20,A63F1/18; combinations of writing implements with computing devices B43K29/08)
G07	CHECKING-DEVICES
G08	SIGNALLING (indicating or display devices per se G09F; transmission of pictures H04N)
G09	EDUCATION; CRYPTOGRAPHY; DISPLAY; ADVERTISING; SEALS
G10	MUSICAL INSTRUMENTS; ACOUSTICS
G11	INFORMATION STORAGE
G12	INSTRUMENT DETAILS
G21	NUCLEAR PHYSICS; NUCLEAR ENGINEERING
H01	BASIC ELECTRIC ELEMENTS
H02	GENERATION; CONVERSION OR DISTRIBUTION OF ELECTRIC POWER
H03	BASIC ELECTRONIC CIRCUITRY
H04	ELECTRIC COMMUNICATION TECHNIQUE
H05	ELECTRIC TECHNIQUES NOT OTHERWISE PROVIDED FOR

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