A simple index of innovation with complexity

Jose Fernandez Donoso*

Universidad del Desarrollo

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 a bad indicator of a country's innovative activity. I generate a very simple index of innovation that weights patents and exports by a complexity measure. Country rankings using this measure are consistent with market size, GDP per capita, and technological development of each country.

1. Introduction

Patents have become the standard measure for innovation in most disciplines, mostly because it is 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.

* Facultad de Economía y Negocios. Universidad del Desarrollo. Av. Plaza 680, San Carlos de Apoquindo, Las Condes, Santiago, Chile. E-mail: jgfernandez@udd.cl.

Moreover, 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 risk of "inventing around" by imitators when the innovation is disclosed. There is empirical evidence suggesting that the complexity of the invention is actually a deterrent for imitators, as the cost of copying the new idea (e.g. reverse engineer) increases with complexity (Fernandez Donoso 2014).

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, and do not take into account the differences in inventive steps across patents. Moreover, these indices use a large number of proxies to account for different types of innovation, and how much innovation these proxies account for is questionable. For example, the Global Innovation Index (2013) counts Wikipedia entries as part of the innovation output sub-index.

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 a simple, computable and comparable metric to compare innovation across economies, without using large sets of proxies, such as Wikipedia entries, or number of LinkedIn profiles on the web.

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 or the total GDP of the country.

This paper is organized as follows. Next section discusses different measures of innovation used along history and their limitations. Section 3 analyzes the limitations of current innovation metrics, in particular available composite indicators. Section 4 develops an index of innovation with complexity. Final section concludes.

2. 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 US). Input measures such as R&D investment, S&T personnel, or university graduates in science were typically used as proxies to innovation metrics. Cross-countries R&D comparisons were based on such measures, ignoring the limitations of the definitions of such measures, and the evident 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). The limitations of such measures are self-evident, nonetheless have not been completely ruled out, as there are no available output measures of R&D in such sectors as health or education.

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 Frascani Manual (1981) theoretically breaks up activities that should be excluded from R&D measurement by splitting functions 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."* As example, collecting weather data should be excluded, while investigating new methods to analyze the data for forecast should be included in R&D measurement.

While this distinction between novelty and routine activities helps to construct an accurate measure of R&D, it does not provide a clear statement of what constitute an innovation, and 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 specialized laboratories or plants with full-time qualified 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, production engineers, or creative firm staff. 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, among others. Though patenting a new product variety, input, or process requires a fixed cost, depending on the legal system of the jurisdiction where the patent is granted, the inventor would 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 and 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 can be patented, 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 the big players. Third, firms may engage in strategic patenting if the size of a patent portfolio affects bargaining power in patent disputes (Noel and 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 can be patented, 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, many of them based on innovation surveys, within the framework of the Oslo manual (1992). 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." Even 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, while others 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 indexes are super indexes, 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.

3. 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. Whether the inclusion and the weight of each measure on the index is questionable, there 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) include domestic resident patents, trademark and utility models, PCT resident patents and utility models, 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, or FDI outflows as percentage of GDP.

Historical evidence suggests that most innovative activity does not take place inside the formal intellectual property rights system (Fernandez Donoso 2014). Moreover, recent findings suggest that innovations in some industries have shown similar patent rates in countries with very different intellectual property rights regimes (Moser 2013).

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 breastfeeding 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 and drastic innovative activity in highly complex industries.

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 additional learning costs (e.g. reverse engineer) when the innovation is kept in secret instead of made public through patents (Fernandez Donoso 2014).

4. A simple index of innovation with complexity

I propose an indicator that considers 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 should take 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 innovations taking place outside of the formal intellectual property rights system. Finally, the index should be simple and comparable between countries.

4.1. Data sources and calculation

4.1.1. 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 and Hausmann 2009; Hausmann, Hidalgo et al. 2012). 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 product or service.

An ideal measure of industry level complexity would take into account both the number of inputs used to produce a specific product (Hidalgo and Hausmann 2009; Nunn 2007), as well as the complexity of the tasks involved to produce it (Naghavi, Spies, and Toubal 2015). For illustration purposes, in this paper I use the normalized index of Naghavi, Spies and Toubal (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 et al. (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.

Table 1: Data sources

Variable	**Source**
Patent counts	European Patent Office (PATSTAT)
Complexity	Naghavi, Spies and Toubal (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)

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 (Schmoch et al. 2003; Lybbert and Zolas 2014). For illustration purposes, I use a very simple 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").

4.1.2. 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, Spies, and Toubal (2015).[1] 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:

$$x_j = mean(X_j, Y_j)$$

X_j is the innovation protected using formal intellectual property rights:

[1] See Appendix for details.

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

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.

As a robustness exercise, I also generate a per capita index, which follows the same calculations but using patents per capita and exports per capita. Nevertheless, the per capita index is not suitable to analyze the overall innovative output of each country.

4.2. Empirical analysis of complexity weighting

One of the main contributions of the index lies in the complexity weights. Hence, I generate different normalized indices to compare how the estimates change as 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. In Table A of appendix, the different metrics are presented normalized to a [0,1] scale.

The other contribution of the index is the clear separation between protected innovations with formal IP (i.e. patents), and innovations kept in secret. Table 2 shows the innovation output index for each classification normalized to a [0,1] scale, according to the calculation formula presented in the previous section.

Table 2: innovation output index with formal (X_j) and informal (Y_j) IP

Country	Formal	Informal	Country	Formal	Informal
Armenia	4.74E-06	0	Italy	0.0066606	0.0775297
Australia	0.0103615	0.0054173	Japan	0.1959514	0.4951155
Austria	0.0087704	0.0599078	Kazakhstan	0.0000942	1.08E-07
Belarus	0.0000564	3.31E-07	Korea (Rep.)	0.0576437	0.1674462
Belgium	0.0056954	0.0650892	Latvia	0.0001314	1.55E-06
Bosnia and H.	0.0000397	0	Lithuania	1.92E-06	1.18E-07
Brazil	0.0032269	0.0058579	Luxembourg	0.0010391	0.0001499
Bulgaria	0.0002813	0.0000706	Malaysia	0.0010438	0.0077557
Canada	0.024025	0.1946011	Mexico	0.0006415	0.0259101
Chile	0.0002633	0.0000153	Morocco	0.0001741	0.0000504
China	0.027021	0.8525027	Netherland	0.0249419	0.139479
Colombia	0.0000932	0.0012555	New Zealand	0.0015858	0.0002557
Croatia	0.0005157	5.45E-06	Normay	0.0049695	0.0034622
Czech R.	0.0021468	0.0161559	Philippines	0.0002063	0.0006029
Denmark	0.0065172	0.0127826	Poland	0.0023499	0.0096085
Dominican R.	0.0000222	0	Portugal	0.0008445	0.0003055
Ecuador	0.0002693	4.41E-07	Romania	0.0000682	0.0002259
Egypt	0.0002111	3.95E-06	Russia	0.0025504	0.0013939
Estonia	0.0002899	0.0000534	Serbia	0.0000998	2.53E-07
Finland	0.0222025	0.0085826	Singapore	0.0030787	0.0627076
France	0.1865624	0.1176811	Slovakia	0.0002293	0.0007119
Georgia	0.000056	0	Slovenia	0.000935	0.0003755
Germany	0.1123669	0.5094957	South Africa	0.0004551	0.0000963
Great Britain	0.1342331	0.1244922	Spain	0.0125182	0.0222298
Greece	0.0006367	0.0002094	Sweden	0.0109336	0.0286005
Hong Kong	0.0001835	0.0070793	Switzerland	0.0075828	0.0643409
Hungary	0.0034181	0.0086308	Thailand	0.0002762	0.003782
Iceland	0.0002736	4.71E-07	Tunisia	0.0000429	7.95E-10
India	0.0055247	0.0134767	Turkey	0.0025084	0.0006779
Indonesia	0.0000821	0.0001598	Ukraine	0.0004591	0.0002916
Ireland	0.0016241	0.0178048	United States	1	1
Israel	0.0103879	0.0132014			

I expect formal and informal IP innovation outputs to be positively and imperfectly correlated, as innovative countries are expected to perform well in both measures, but not perfectly correlated as countries may specialize in innovations less likely to be patented. The correlation between X_j and Y_j is 0.75, indicating that patented inventions are imperfectly correlated with the unprotected innovation output proxy.

With respect to the effect of the complexity weights, Table 3 shows the correlation matrix between indices.

Table 3: Indices correlations

	Innovation	Innovation per capita	Innovation unweighted	Innovation per capita unweighted	Global Innovation Index
Innovation	1				
Innovation per capita	0.4555*** 0.0002	1			
Innovation unweighted	0.6584*** 0.0000	0.2710* 0.0317	1		
Innovation per capita unweighted	0.1046 0.4145	0.3142* 0.0121	0.0728 0.5707	1	
Global Innovation Index	0.3130* 0.0125	0.7891*** 0.0000	0.1583 0.2154	0.4781*** 0.0001	1

* p<.05; ** p<.01; *** p<.001

The correlation between the weighted and the unweighted indices is 0.66, and between innovation and innovation per capita (both weighted) is 0.46. The index has positive but imperfect correlation with the unweighted version, and the weighted but per capita version. The correlation with the Global Innovation Index is even weaker. The innovation per capita unweighted is statistically uncorrelated with the complexity weighted innovation index.

Another approach for interpretation is looking at the consistency of different index rankings. Countries generating innovative outputs highly valued should score better than other countries in the ranking. Table 4 illustrates the rankings with and without complexity for the 63 computed countries, as well as the per capita complexity weighted, and the Global Innovation Index rankings of 2013.

Table 4: Innovation (with complexity), Global Innovation Index, Innovation per capita (with complexity) and unweighted innovation rankings

Country	Innovation	GII	Innov. per capita	Unweighted Innov.
United States	1	5	3	1
China	2	33	30	15
Japan	3	22	9	6
Germany	4	15	7	4
France	5	20	6	7
Great Britain	6	3	10	3
Korea (Rep.)	7	18	13	9
Canada	8	11	11	10
Netherland	9	4	4	16
Italy	10	27	24	19
Switzerland	11	1	5	14
Belgium	12	21	12	27
Austria	13	23	8	21
Singapore	14	8	1	11
Sweden	15	2	14	26
Spain	16	25	26	22
Finland	17	6	2	25
Mexico	18	48	36	37
Israel	19	14	17	17
Ireland	20	10	18	36
Denmark	21	9	16	24
India	22	51	52	60
Czech R.	23	26	21	32
Australia	24	19	23	18
Hungary	25	29	22	29
Poland	26	40	31	44
Brazil	27	49	41	33
Malaysia	28	30	32	55
Normay	29	16	19	28

Hong Kong	30	7	28	13
Thailand	31	43	42	23
Russia	32	47	43	48
Turkey	33	52	40	35
New Zealand	34	17	27	46
Colombia	35	46	50	2
Slovenia	36	28	25	41
Luxembourg	37	12	15	31
Portugal	38	32	34	42
Slovakia	39	34	35	45
Greece	40	42	38	50
Philippines	41	61	59	49
Ukraine	42	54	49	8
South Africa	43	44	51	30
Croatia	44	35	33	43
Bulgaria	45	37	39	56
Estonia	46	24	29	20
Romania	47	39	63	5
Chile	48	38	45	57
Iceland	49	13	20	54
Ecuador	50	58	44	63
Indonesia	51	60	62	12
Morocco	52	62	55	52
Egypt	53	63	61	53
Latvia	54	31	37	34
Serbia	55	41	47	40
Kazakhstan	56	59	54	38
Belarus	57	56	53	61
Georgia	58	55	46	51
Tunisia	59	53	57	39
Bosnia and H.	60	50	48	59
Dominican R.	61	57	60	62
Armenia	62	45	56	58
Lithuania	63	36	58	47

As complexity weighted innovation is not a per capita index, there should be a strong correlation between the market size, or total GDP, and the capacity to generate innovation outputs. The correlation between these two variables is 0.97. This importance of size is not trivial. Using the Global Innovation Index methodology, Switzerland or Sweden score higher than the United States, suggesting that these countries generate more innovative outputs than the U.S. The result is at least controversial. Moreover, China scores extremely low (ranked 35, below Latvia, Malta, or Slovenia), which seems unlikely for the country of companies such as Alibaba, Lenovo, or Huawei. Table 5 shows the results of a simple linear regression between the innovation index and total GDP. Innovation is statistically significant at level 0.001, and the r-squared shows that innovation adjusts very smoothly to country GDP.

Table 5: Innovation index and GDP regression

	GDP
Innovation Index	1.37e+13***
Constant	2.519e+11***
N	63
R2	0.9438

* p<.05; ** p<.01; *** p<.001

Another important correlation is the level of technology development and the innovation output of a country. To test for this correlation, in Table 3 I use Fieler's (2011) index of country technological development, which is basically a residual of Eaton and Kortum's (2002) bilateral trade gravity regression. The correlation of these two variables is 0.72, and the linear regression coefficient is presented in Table 6.

Table 6: Innovation index and technological development

	Technology
Innovation Index	0.916***
Constant	-0.00237
N	63
R2	0.5233

* p<.05; ** p<.01; *** p<.001

This relation does not imply causality between the two variables. Nevertheless, it is suggestive that, even at this very simple stage of a composite index of innovation with only components weighted by complexity, the data generated is consistent with very intuitive results.

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 still rely heavily on patent counts. In this paper, I proposed a simple method to reduce the bias of counting patents.

By weighting patent counts, and other non-patent measure of innovation, with the complexity of the product, invention, or index, complex inventions gain a higher weight. Countries with more complex or sophisticated exports and patents rank better in the innovation ranking, and this result is consistent with how more innovative countries should correlate with GDP or technological development.

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

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Appendix

Complexity Index: Naghavi, Spies, and Toubal (2015)

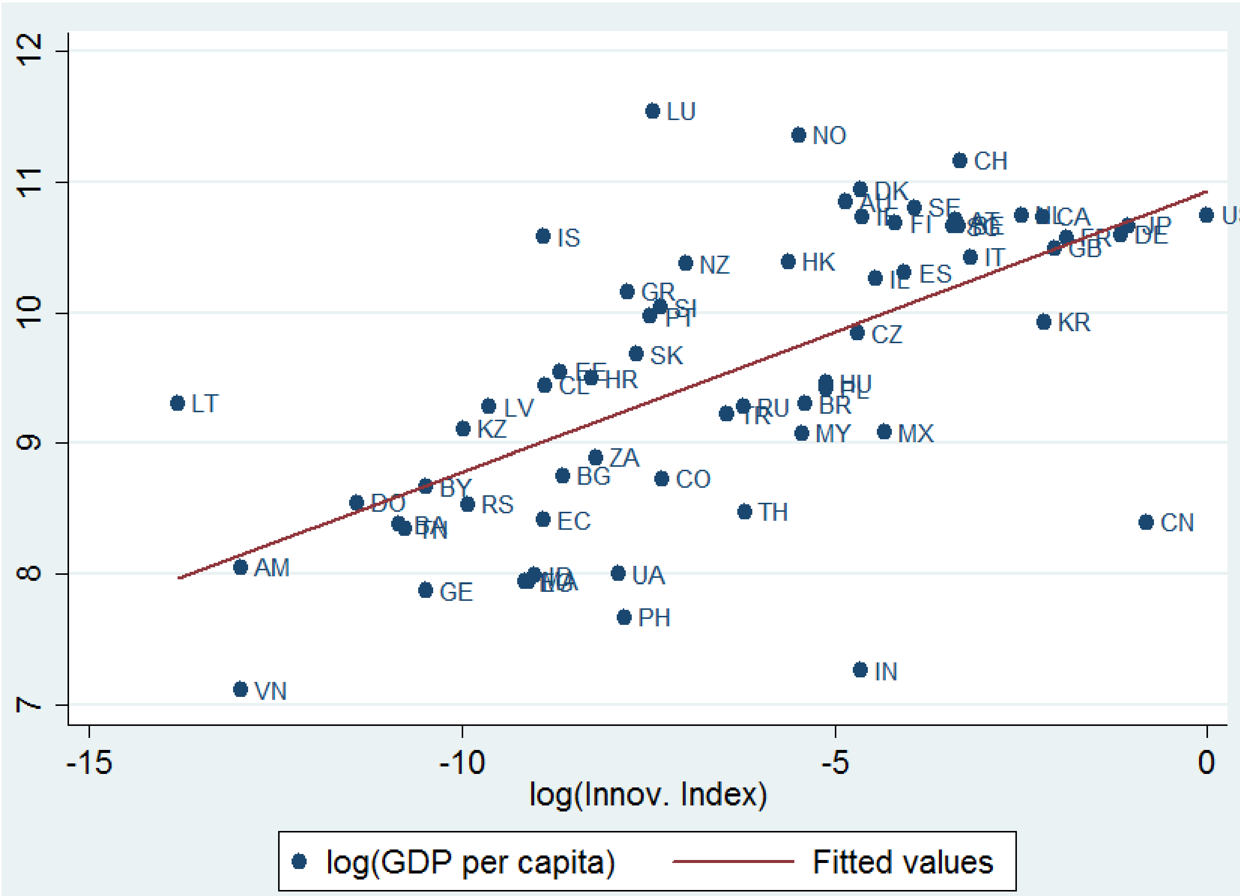
O*Net provides information on the importance and level of complex solving skills for 809 eight digit SOC occupations. Each occupation o embodies a complexity of $i_o^{\alpha} + l_o^{\beta}$, where α and β are the contributions of two complexity components: importance $i \in [1,5]$, and level $l \in [1,7]$. The different scales of complexity components are normalized to a [0,1] scale using the min-max method. Complexity is then merged with employment information from the U.S. Census of Labor Statistics' Occupational Employment Statistics (OES). The data contains the number of employees by occupation in every three digit SIC classification. The occupational intensity, b_o^k of each industry k is given by $b_o^k = L_o^k / \sum_o L^k$, where L_o^k is the employment level of occupation o in industry k.

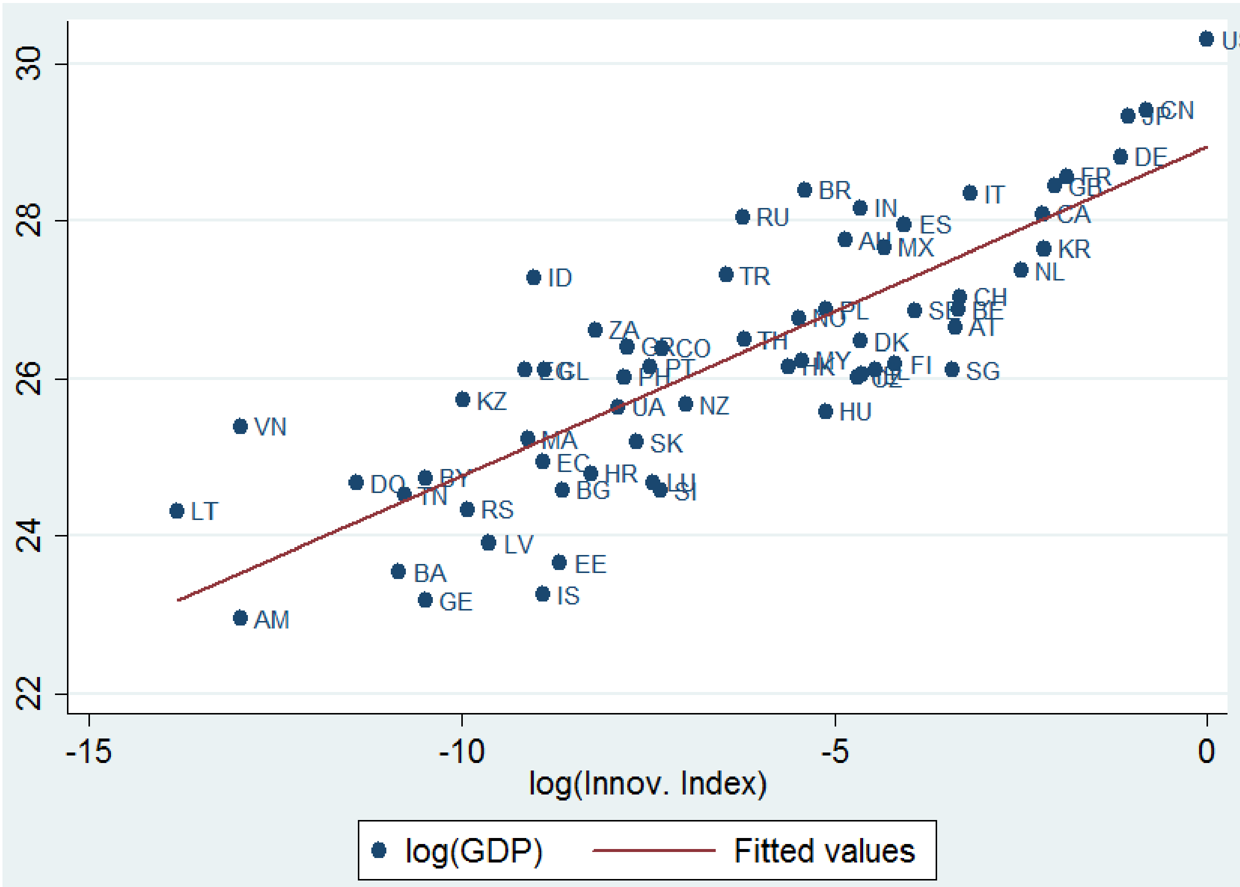
Table A: Indices scores

Country	Innovation	Innovation per capita	Innovation (no complexity)	Innovation per capita (no complexity)	GII score (normalized)
Armenia	0.00000	0.00125	0.00000	0.01219	0.24
Austria	0.03434	0.72434	0.00857	0.07335	0.61
Australia	0.00789	0.11629	0.01109	0.03772	0.65
Bosnia and H.	0.00002	0.00288	0.00000	0.00939	0.20
Belgium	0.03539	0.53192	0.00458	0.02988	0.63
Bulgaria	0.00018	0.00888	0.00000	0.00478	0.34
Brazil	0.00454	0.00561	0.00284	0.00127	0.21
Belarus	0.00003	0.00154	0.00000	0.00379	0.16
Canada	0.10931	0.55074	0.02777	0.05197	0.76
Switzerland	0.03596	0.78467	0.01900	0.06476	1.00
Chile	0.00014	0.00345	0.00000	0.00208	0.32
China	0.43976	0.04923	0.01766	0.00094	0.42
Colombia	0.00067	0.00239	0.50095	0.00231	0.23
Czech R.	0.00915	0.15161	0.00284	0.02407	0.52
Germany	0.31093	0.72899	0.11779	0.09828	0.72
Denmark	0.00965	0.41038	0.00614	0.09136	0.78
Dominican R.	0.00001	0.00074	0.00000	0.00359	0.13
Ecuador	0.00013	0.00396	0.00000	0.00238	0.11
Estonia	0.00017	0.05037	0.00923	0.43231	0.58
Egypt	0.00011	0.00061	0.00047	0.00090	-
Spain	0.01737	0.09131	0.00811	0.01412	0.55
Finland	0.01539	0.98477	0.00568	0.08775	0.81
France	0.15212	0.73159	0.06119	0.06457	0.64
Great Britain	0.12936	0.59487	0.14359	0.11686	0.86
Georgia	0.00003	0.00326	0.00047	0.01624	0.19
Greece	0.00042	0.01340	0.00047	0.00638	0.24
Hong Kong	0.00363	0.07702	0.02073	0.16495	0.81
Croatia	0.00026	0.02527	0.00095	0.02456	0.35
Hungary	0.00602	0.13313	0.00331	0.02894	0.48
Indonesia	0.00012	0.00013	0.02181	0.00027	0.09
Ireland	0.00971	0.35787	0.00205	0.04044	0.77
Israel	0.01179	0.40938	0.01329	0.12347	0.72
India	0.00950	0.00176	-	-	0.20
Iceland	0.00014	0.18973	-	0.11383	0.73
Italy	0.04210	0.11370	0.01105	0.01015	0.51
Japan	0.34553	0.59782	0.06605	0.03918	0.62
Korea (Rep.)	0.11255	0.48480	0.03125	0.04761	0.65

Kazakhstan	0.00005	0.00138	0.00146	0.00884	0.11
Lithuania	0.00000	0.00095	0.00054	0.02201	0.34
Luxembourg	0.00059	0.45766	0.00285	0.50000	0.74
Latvia	0.00007	0.01361	0.00245	0.09701	0.44
Morocco	0.00011	0.00133	0.00047	0.00222	0.06
Mexico	0.01328	0.01668	0.00157	0.00120	0.22
Malaysia	0.00440	0.02723	0.00000	0.00125	0.48
Netherland	0.08221	0.90862	0.01365	0.06100	0.86
Normay	0.00422	0.26447	0.00452	0.07404	0.71
New Zealand	0.00092	0.08117	0.00054	0.01655	0.68
Philippines	0.00040	0.00095	0.00047	0.00075	0.07
Poland	0.00598	0.03079	0.00095	0.00282	0.31
Portugal	0.00058	0.01899	0.00095	0.01018	0.44
Romania	0.00015	0.00000	0.08623	0.00000	0.31
Serbia	0.00005	0.00326	0.00097	0.01487	0.25
Russia	0.00197	0.00448	0.00048	0.00048	0.23
Sweden	0.01977	0.46093	0.00497	0.04245	0.86
Singapore	0.03289	1.00000	0.02432	0.04277	0.81
Slovenia	0.00066	0.11032	0.00095	0.05300	0.49
Slovakia	0.00047	0.01864	0.00066	0.01331	0.36
Thailand	0.00203	0.00494	0.00708	0.00106	0.24
Tunisia	0.00002	0.00111	0.00142	0.01370	0.19
Turkey	0.00159	0.00802	0.00237	0.00298	0.20
Ukraine	0.00038	0.00261	0.04076	0.00155	0.19
United States	1.00000	0.90863	0.55452	0.12395	0.84
South Africa	0.00028	0.00211	0.00297	0.00142	0.24

Innovation Index Plots





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28
26
24
22
-15
-10
-5
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log(Innov. Index)
log(GDP)
Fitted values
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CN
JP
DE
FR
GB
IT
CA
KR
NL
BR
IN
RU
ES
AU
MX
ID
TR
CH
PL
NO
SE
BE
AT
ZA
GR
CO
TH
DK
MY
HK
FI
SG
PT
PH
EG
CL
KZ
UA
NZ
HU
VN
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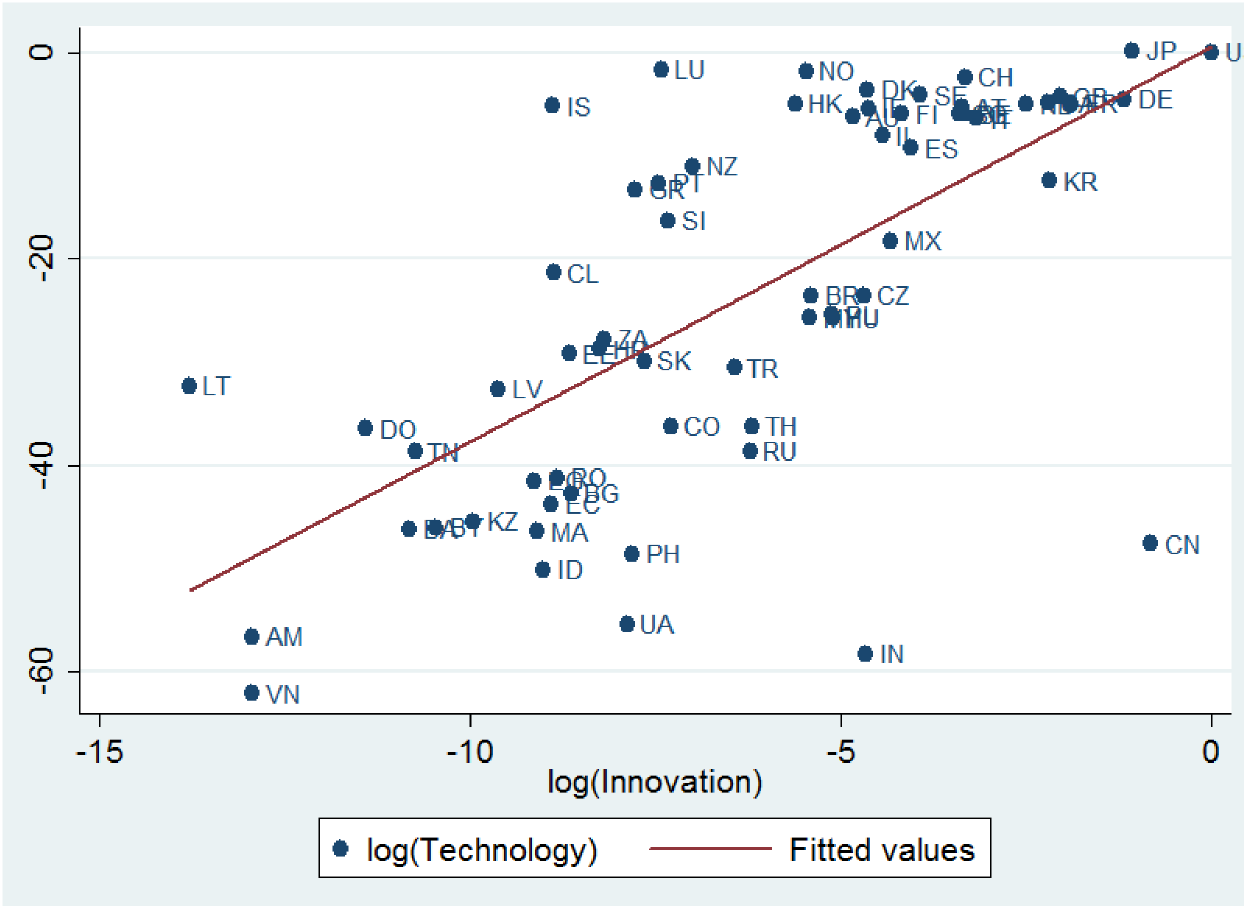
EE
BA
GE
IS
AM



log(Innovation)
log(Technology)
Fitted values
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US
LU
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CH
IS
DK
SE
HK
FI
DE
NZ
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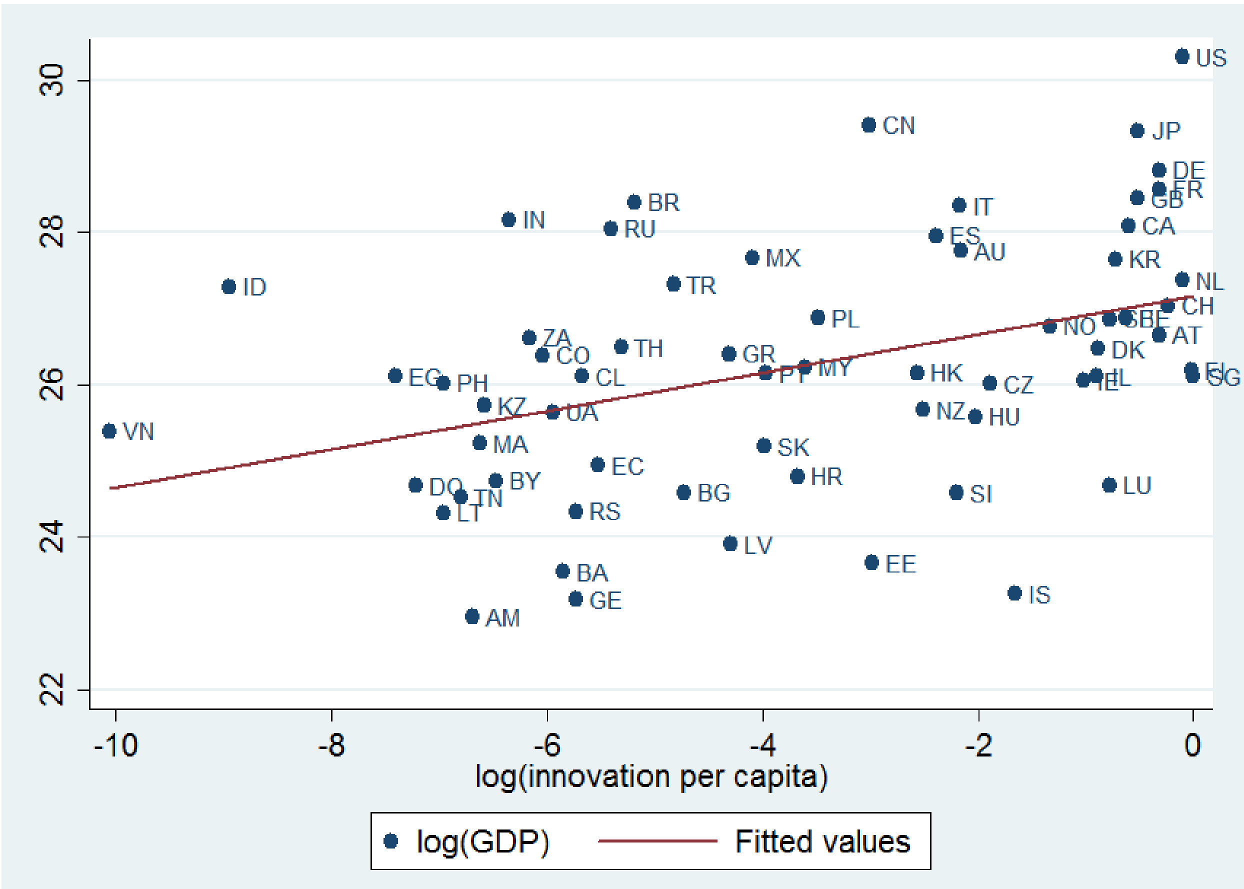
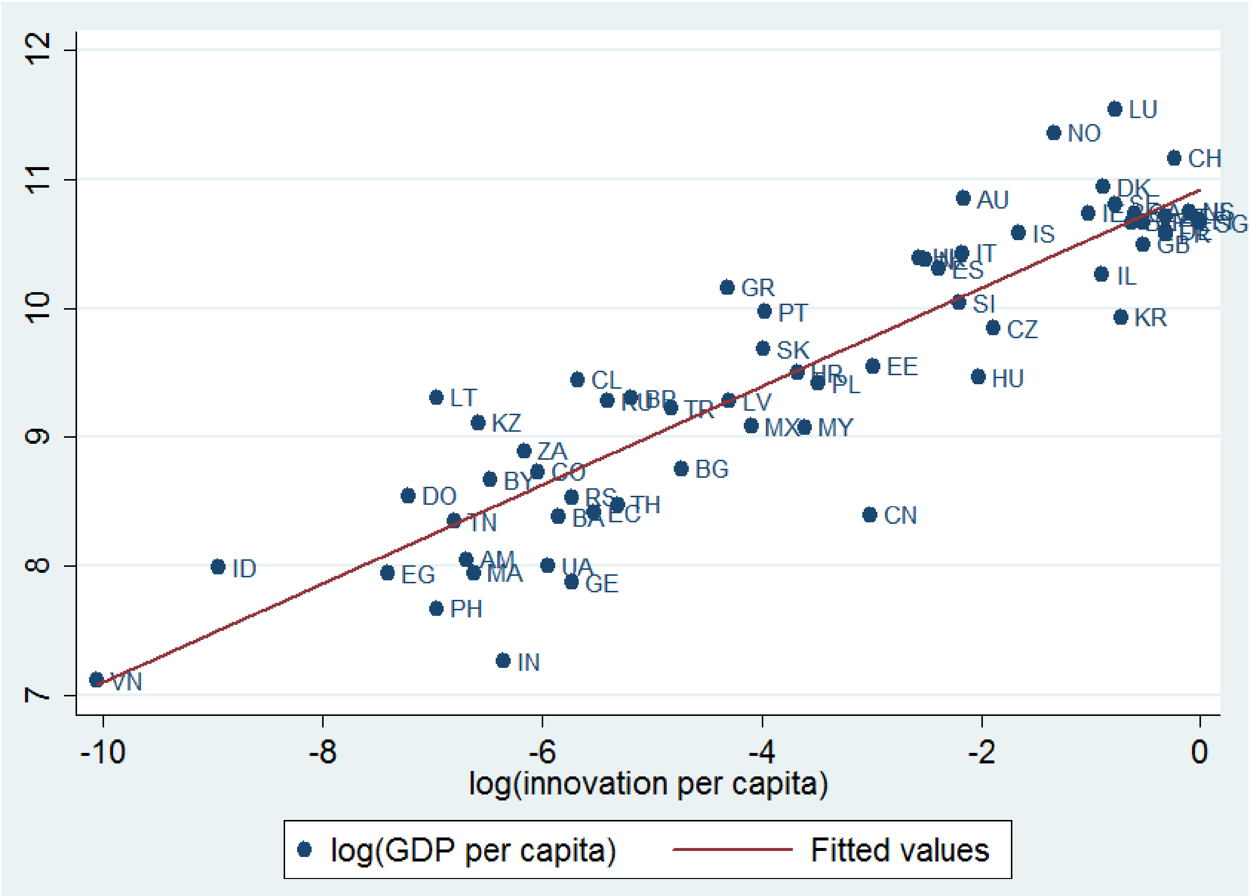
SI
MX
CL
CZ
SK
TR
LT
LV
DO
TN
CO
TH
RU
KZ
MA
PH
ID
CN
AM
UA
IN
VN

Innovation per capita index





12
11
10
9
8
7
-10
-8
-6
-4
-2
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log(innovation per capita)
log(GDP per capita)
Fitted values
LU
NO
CH
DK
AU
IS
IT
ES
IL
GR
SI
KR
PT
CZ
SK
EE
HU
PL
CL
LT
TR
LV
KZ
MX
MY
ZA
CO
BG
BY
DO
RS
TH
TN
CN
ID
AM
UA
EG
MA
GE
PH
IN
VN
GB

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 B23K; 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 H01M)
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 F02M; 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, H01K,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, B21K; 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 G06M); 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