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Evaluating Innovation Performance of Countries in the Construction Industry by Using Patent Data

Esin Ergen, Cemil Baspinar
Civil Engineering Department, Istanbul Technical University, Istanbul, Turkey
esin.ergen@itu.edu.tr, cemilb@itu.edu.tr

Abstract
It is a difficult task to evaluate innovation performance in the construction industry. Various metrics are used to measure innovation performance, such as research and development (R&D) expenditure of sectors, number of R&D personnel by sector, surveys and patent statistics. Among these metrics, patent statistics is one of the most commonly used data for evaluating the innovation performance in other industries. However, there are not any recent research studies that investigated patent activities in detail for the construction industry. In the study explained in this paper, it is aimed to evaluate and compare the innovation performance of countries and innovative firms in the construction industry over the years by using patent statistics. The international patent data was retrieved from the database of World Intellectual Property Organization. To filter the international patent data that is relevant to construction industry, international patent classification (IPC) symbols of patent applications were used. To investigate the accuracy of using IPC symbols for construction industry, concordance tables of WIPO and Maastricht Economic Research Institute on Innovation and Technology (MERIT) were applied to patent statistics. The results show the patterns of innovative activities among the construction firms, and countries, and in the industry. Also, the limitations of using IPC symbols to evaluate innovation performance of construction industry were discussed.

Keywords
Innovation, Patent, IPC, MERIT, Concordance table

1. Introduction

Various metrics are used to measure innovation performance, such as research and development (R&D) expenditure of sectors, number of R&D personnel by sector, surveys and patent statistics. Among these metrics, patent statistics is one of the most commonly used data for evaluating the innovation performance since patents are considered as traditional output of innovation (Cebon *et al*., 1999). Patent, as a term, signifies a monopoly right for the technical inventions, given by the authorized offices to the owner of invention. As the patent applications are examined by the official authorities, they are considered to have reliable information about innovation performance. According to a research study, patent statistics is the most important resource when analyzing process of a technical change (Griliches, 1990).

It is a difficult task to analyze patent data to evaluate innovation performances of different industries, including construction industry. Some of the reasons for that are inequalities of patent values (i.e., different effects on the market), differences in patent regulations across the countries and not being able to patent of some inventions etc. (Dernis and Guellec, 2001). One significant problem is related to

classification of patents. The International Patent Classification system (IPC), which is used internationally to classify patents, is not an industry based classification system (IPC, 2008). IPC was developed for the purpose of facilitating the search of published patent documents. Thus, it is difficult to retrieve patent statistics of different industries by using the patent data classified through IPC system. To overcome this problem, some research studies were performed and concordance tables that associate patent classes with different sectors were developed.

The goal of this paper is to evaluate innovation performance of construction industry based on patent statistics. Patent statistics were derived from construction related international patent applications and they were classified by using IPC system. Patent data was retrieved from the electronic database of World Intellectual Property Organization (WIPO). Any technology concordance was not used to convert the technical patent data to the sectors. Instead IPC was analyzed in detail and construction related classes are determined. To depict the limitations of the IPC system and highlight the need for using concordance table that relate IPC to sectors, an analysis was performed using Turkish patent data. Turkish national patent statistics related to construction sector were calculated by using the IPC system, and WIPO and Maastricht Economic Research Institute on Innovation and Technology (MERIT) concordance and the results were compared to each other to discuss the limitations.

2. Background on Patents and Patent Classification

Patent rights are only granted to technical inventions that meet the patentability criteria, which are novelty, inventive step and industrial applicability (EPO, 2006). The first criterion is that the invention must be novel. To explain novelty criteria 'the state of the art' term is used. In patent literature, state of the art means all kinds of information which was made available to the public in any way and in any place of the world, before the date of application. Any invention which does not belong to the state of the art is considered as novel. The second criterion is the inventive step, which means that the invention must not be obvious to a person who has an average knowledge of the technical field. To meet the last criterion, industrial applicability, inventions must be applicable to any field of industry. To receive a patent, a patent application must meet all these criteria. Patents are granted for a limited period- commonly for twenty years.

WIPO is an international organization under United Nations, and it is devoted to develop international intellectual property system among the world (WIPO, 2008). One of the main tasks of WIPO is to receive and evaluate international patent applications under the Patent Cooperation Treaty (PCT). PCT does not provide a grant procedure; on the other hand, it provides an application procedure. In other words, when an international patent application is filed to WIPO under PCT, procedures are performed in WIPO up to a certain level. To receive a patent in different countries, applicants or their representatives must apply to the national patent offices of these countries and must follow the legal procedures of each country. In order to file an international application, the applicant must be a citizen or a resident of any of PCT contracting parties. At present, there are 139 PCT contracting states (WIPO, 2009). International patent application is an effective way of protecting patents in multi countries. However, just to protect an invention in a country, a national patent application can be filed, too.

International patent applications are published by WIPO after eighteen months from the application date. Patent information is made available to the public both in paper and electronic formats. The electronic database of WIPO includes over 1.5 million international patent applications. WIPO classifies the patent applications according to the IPC system. IPC system was introduced by Strasbourg Agreement and it is managed and updated frequently by WIPO, with the contribution of national patent offices. IPC categorizes patent applications according to the technical features of inventions, which are included in the patent documents.

IPC system has a hierarchical structure that divides technologies into more than 70.000 fields. Eight main sections exist in IPC: Human Necessities (Section A); Performing Operations, Transporting (Section B); Chemistry, Metallurgy (Section C); Textiles, Paper (Section D); Fixed Constructions (Section E); Mechanical Engineering; Lighting, Heating, Weapons, Blasting (Section F); Physics (Section G); Electricity (Section H). Each section also has sub-divisions, such as classes and sub classes. At least one IPC symbol is assigned to each patent application and these symbols allow for language-independent queries while searching the state of the art. One IPC symbol consists of seven or eight digits and digit groups represent sections, classes, sub-classes, main groups and sub-groups. For instance, E02B5/00 is an IPC symbol that corresponds to 'artificial water canals' main group, which is under Fixed Constructions section (E) and Hydraulic Engineering; Foundations, Soil-Shifting class (E02).

Statistical data from WIPO is retrieved by querying the database by using IPC symbols. However, patents that are categorized under an IPC class might belong to multiple industries. For example, some of the patents under E21 (i.e., Earth or Rock Drilling, Mining) might be filed by mining companies whereas some of them might be submitted by construction firms. To solve this problem, several concordance tables were developed to relate IPC classes to different industries. The examples of those concordance tables are Yale Technology Concordance Table (Kortum and Putnam, 1997), MERIT Concordance Table (Verspagen *et al*., 1994), OECD Technology Concordance Table (Johnson, 2002), WIPO concordance table. However, only MERIT and WIPO concordance tables include patent categories that are related to construction sector.

3. Research Methodology

In the research explained in this paper, to identify patent data related to construction sector, the contents of sections and classes in IPC were examined (IPC, 2008). Section E and class C04 under Section C were identified to be related to construction industry. Section E of International Patent Classification includes seven classes related to construction industry, which are listed as follows:

- E01: Construction of Roads, Railways or Bridges
- E02: Hydraulic Engineering; Foundations, Soil-Shifting
- E03: Water Supply, Sewerage
- E04: Building
- E05: Locks, Keys, Window or Door Fittings, Safes
- E06: Doors, Windows, Shutters or Roller Blinds, Ladders
- E21: Earth or Rock Drilling, Mining

Under the chemistry section (C), C04 class is composed of building materials such as cements, concrete, artificial stones, ceramics, refractories. Therefore, this class is also included in the analysis.

For each of the given classes, patent statistics are calculated. For instance, any application which has an IPC symbol that starts with "E01" is considered as related to Construction of Roads, Railways or Bridges. Online searching tool of WIPO provides statistical results that show number of patents with respect to years, countries and applicants.

To identify the limitations of patent data derived by using IPC, the authors performed a detailed analysis and applied MERIT concordance table and WIPO's concordance table to Turkish national patent data. In this analysis, Turkey's national patent data was used since online access to WIPO's international patent data was limited and the details of the international patent information could not be accessed. Turkish patent data was retrieved from Turkish Patent Institute (TPI). TPI uses International Patent Classification (IPC) system to classify the patent documents, as well as WIPO and other national patent offices.

In MERIT concordance table, subclass level IPC symbols are linked to sectors. According to this table every IPC subclass is related to one sector or multiple sectors at a specific percentage. For instance, 60% of E04G class is assigned to construction industry and 40% of the same class is assigned to metal products sector. Since the percentages were derived from actual number of applications, number of patent applications in any sector could be decimal numbers in the results. Table 1 shows construction industry related IPC subclasses and their percentages in MERIT concordance table. In this table many of IPC subclasses under E section are not included. Therefore, patent statistics found by using MERIT table are expected to be quite lower than the results found by IPC.

Table 1: Construction Industry Related IPC Subclasses in MERIT Concordance Table

IPC	Percentage	IPC	Percentage
E01B	50%	E04B	15%
E01C	50%	E04F	90%
E01D	100%	E04G	60%
E01F	100%	E04H	60%
E02B	100%	E21B	10%
E02C	100%	E21D	50%
E02D	65%	E21F	100%
E02F	98%		

3. Analysis of Patent Data Using IPC

International patent data was retrieved from WIPO and statistics are calculated for each class under Section E and for class 04 under Section C for the last 30 years. Figure 1 shows the number of patent applications in each class. As seen in the figure, international patent applications were mostly filed in E04 class (i.e., 16,466 applications which is about 25%). This class contains inventions related to building construction such as structural elements and finishing works in buildings. E04 class is followed by E21 class (i.e., 17%) and C04 class (i.e., 15%), which correspond respectively to earth or rock drilling and mining, and building materials. On the other hand, the smallest number of applications is observed in water supply, sewerage class, which is E03. The number of applications in E03 class (i.e., 3,619) is approximately 1/5th of the number of applications in E04 class. The results points out that most of the innovative activities are related to building construction, building materials and earth or rock drilling activities in the construction industry.

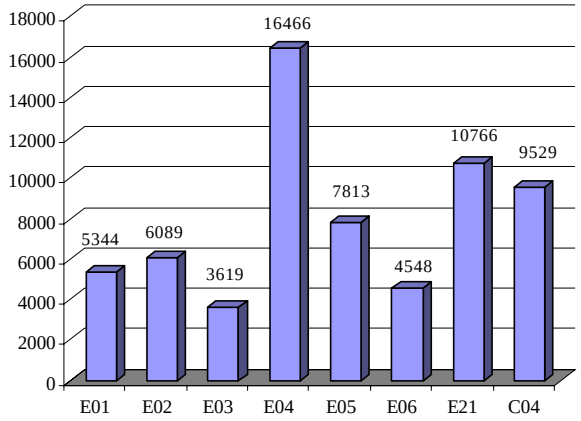

Figure 1: Distribution of International Patent Applications to Construction Related IPC Classes

To identify the most innovative countries, country origins of international patent applications were identified. These results are presented in two tables. Table 2 shows the numbers of international patent applications of countries in E01, E02, E04 and E04 classes. Similarly, in Table 3 distribution of country origins of international patent applications in E05, E06, E21 and C04 classes are given. The percentages of each country's applications among all applications are also reported in brackets.

Table 2: Country Origins of International Patent Applications for Classes E01, E02, E03, E04

E01			E02			E03			E04		
Country of Origin	# of applications	(%)	Country of Origin	# of applications	(%)	Country of Origin	# of applications	(%)	Country of Origin	# of applications	(%)
USA	1177	(22,0)	USA	1432	(23,5)	USA	837	(23,1)	USA	3772	(22,9)
Germany	731	(13,7)	Japan	991	(16,3)	Germany	472	(13,0)	Germany	1698	(10,3)
Gr. Britain	527	(9,9)	Gr. Britain	492	(8,1)	Gr. Britain	281	(7,8)	Australia	1207	(7,3)
France	334	(6,3)	Germany	444	7,3)	Japan	257	(7,1)	Gr. Britain	1203	(7,3)
Sweden	273	(5,1)	Sweden	357	(5,9)	Australia	233	(6,4)	France	967	(5,9)
Australia	256	(4,8)	Australia	318	(5,2)	France	150	(4,1)	Sweden	929	(5,6)
Japan	222	(4,2)	France	299	(4,9)	Korea	139	(3,8)	Japan	832	(5,1)
Austria	162	(3,0)	Netherlands	179	(2,9)	Sweden	136	(3,8)	Canada	804	(4,9)
Switzerland	144	(2,7)	Norway	168	(2,8)	Switzerland	93	(2,6)	Italy	558	(3,4)
Canada	142	(2,7)	Canada	162	(2,7)	Italy	80	(2,2)	Switzerland	436	(2,6)
Others	1374	(25,7)	Others	1189	(19,5)	Others	941	(26,0)	Others	4060	(24,7)
Total	5344	(100)	Total	6089	(100)	Total	3619	(100)	Total	16466	(100)

Country origins of international applications indicate the domination of the US patents in construction sector (i.e., 28 % in all applications). In seven of the eight classes, number of patents of US origin is in the first place. In those classes, the number of applications from the second ranking countries is approximately 2/3rd or half of the number of applications from the US. Moreover, in E21 class, which is about earth or rock drilling and mining, almost half of the international patent applications are US originated. Similarly in C04 class, which is related to building materials, 31.6 % of applications are made by the US resident applicants. In E01, E02, E03, E04, E05 and E06 classes, shares of US patents are very closed to each other. These shares are approximately 1/4th of all applications in those classes (i.e., ranging from 22.0% - 23.5 %). The results of the patent statistics explicitly indicate the high innovation performance of US applicants in construction sector.

In construction related IPC classes, number of applications from Germany are also high. In E05 class, which is related to locks, keys, window or door fittings and safes, German resident applicants are ranked first (i.e., 23.2% of all applications). Germany ranks second in four out of the seven other classes, which are related to construction of roads, railways or bridges (E01), water supply and sewerage (E03), building construction (E04) and doors, windows, shutters or roller blinds and ladders (E06). According to these results, German applicants from construction industry could also be considered successful for their innovation performance.

Great Britain is ranked in top five in all of the construction related classes. Great Britain is in the second ranking in the class related to earth or rock drilling and mining and in third ranking in classes E01, E02, E03, E05, and E06. These classes are related to construction of roads, railways or bridges, hydraulic engineering, foundations, soil-shifting, water supply, sewerage, building and locks, keys, window or door fittings and safes. Japanese applications received the second highest ranking in the classes related to building materials and hydraulic engineering, foundations and soil-shifting.

Table 3: Country Origins of International Patent Applications for Classes E05, E06, E21, C04

E05			E06			E21			C04		
Country of Origin	# of applications	(%)	Country of Origin	# of applications	(%)	Country of Origin	# of applications	(%)	Country of Origin	# of applications	(%)
Germany	1812	(23,2)	USA	1018	(22,4)	USA	4952	(46,0)	USA	3008	(31,6)
USA	1785	(22,8)	Germany	643	(14,1)	Gr. Britain	1022	(9,5)	Japan	1751	(18,4)
Gr. Britain	538	(6,9)	Gr. Britain	336	(7,4)	Norway	732	(6,8)	Germany	1244	(13,1)
Japan	429	(5,5)	France	273	(6,0)	Netherlands	538	(5,0)	France	637	(6,7)
France	395	(5,1)	Sweden	242	(5,3)	Germany	435	(4,0)	Gr. Britain	460	(4,8)
Sweden	386	(4,9)	Australia	243	(5,3)	Canada	435	(4,0)	Switzerland	213	(2,2)
Australia	296	(3,8)	Denmark	217	(4,8)	Sweden	394	(3,7)	Australia	180	(1,9)
Italy	257	(3,3)	Japan	214	(4,7)	France	374	(3,5)	Italy	155	(1,6)
Canada	211	(2,7)	Italy	197	(4,3)	Australia	350	(3,3)	Sweden	137	(1,4)
Switzerland	167	(2,1)	Canada	122	(2,7)	Finland	174	(1,6)	Netherlands	136	(1,4)
Others	1537	(19,7)	Others	1043	(22,9)	Others	1360	(12,6)	Others	1608	(16,9)
Total	7813	(100)	Total	4548	(100)	Total	10766	(100)	Total	9529	(100)

In the last thirty years, most of the innovative activities are performed by the countries which are in the top rankings. Approximately 45%-50% of the patent applications are filed by the top three countries in each class. The remaining 50% of the patent applications are distributed among other countries with percentages ranging from 1%-7%.

To identify the profiles of the firms that filed patent applications, applicants of two classes were analyzed at firm level: E02 Class and E04 Class (i.e., building). E02 class is related to hydraulic engineering, foundations and soil works. The results indicate that almost all of the most active firms in patenting in this class are construction equipment producers. The ratio of applications made by the first ten firms to all the applications filed in this class is 11,57 %. Top three companies are from the US and Japan, similar to the results related to Class E02 in Table 2. These three companies filed about 60% of all the applications filed by top ten companies in the E02 class.

The second class that was examined at firm level is the E04 class, which has the highest number of applications among construction related classes. The first and second ranking companies specialize in finishing works whereas the third ranking company designs and builds conservatory roofing. These are followed by a company that produces insulation material and another company that produces scaffolding and formwork. The first ranking company filed about 20% of all the patent applications that was filed by top ten companies and the rest of them were distributed to other companies that have shares of 5%-10%. Another interesting point about this class is that only 2.41% of all applications were made by the top ten firms. This is relatively low compared to other classes (i.e., 11.57 %. for E02 class). This fact indicates that in building class (E04), a monopoly in patenting does not exist.

4. Analysis of Patent Data Using Concordance Tables

Since the classes in IPC are too generic and are not industry based, patents that are classified under a construction related IPC class might not only belong to construction industry but also to other industries. To determine the limitations of using IPC system in filtering patent data related to construction industry, the results derived from two concordance tables were used: MERIT concordance table and concordance

table of WIPO. The patent statistics that were obtained using two different concordance tables were compared to the patent statistics that were obtained via IPC system. In this analysis, national Turkish data was used since access to details of international patent applications was limited.

In Table 4, number of patent applications filed in construction industry in Turkey is presented for the period of 1992-2007 according to IPC, MERIT and concordance table of WIPO. Since MERIT concordance table is based on percentages, the results are obtained in decimal numbers. Concordance table of WIPO excludes only a few IPC classes of E section for the construction sector. Thus, the results obtained according to IPC and WIPO concordance are quite similar. For instance, for the resident applications, the numbers of patent applications obtained by IPC and WIPO concordance are equal to each other.

Table 4: Number of Patent Applications of Turkey According to IPC, WIPO and MERIT

Years	Resident			Non-resident		
	MERIT	IPC	WIPO	MERIT	IPC	WIPO
1992	5,9	23	23	10	32	31
1993	1,2	3	3	9,8	31	31
1994	2,8	11	10	13,7	48	47
1995	2,7	26	26	9,5	24	23
1996	4,7	32	32	5,6	13	13
1997	7	24	24	12,1	50	50
1998	18,4	44	43	26	88	88
1999	15,8	58	57	19,6	76	76
2000	11,1	78	77	14,8	95	95
2001	17,6	91	90	24,6	78	77
2002	20,3	121	121	9,9	43	42
2003	24	167	164	6,8	15	15
2004	40,7	233	230	17,2	62	62
2005	46,5	337	336	30,9	114	114
2006	75,5	377	377	43,4	182	182
2007	87,4	446	446	49,9	172	171

MERIT concordance excludes many of the IPC classes under E section that is related to construction industry. Moreover, it includes only a certain percentage of some IPC classes under this section. Therefore, significant differences are observed between results obtained by using IPC system and MERIT. For example, in 2007 among the resident applications, according to MERIT based calculations there exist 87 (87,4) patent applications related to construction, and according to IPC results 446 applications were filed by residents. The data obtained by using MERIT concordance table ranges from half to 1/10th of the data obtained by IPC system. This comparison shows that the patent data that is obtained via IPC system might include some patent applications which are not directly related to construction industry. Thus, existing concordance tables need to be evaluated and if needed, improved to more accurately reflect the construction industry's innovation performance.

The overall results for Turkey demonstrate that despite the increase in the last few years, the numbers of patent applications are not high. This indicates a need to raise awareness in innovation in Turkish construction industry. Turkish Patent Institute could be the leading entity for organizing related activities.

5. Conclusions

This study aims to evaluate innovation performance of countries and firms in construction sector by utilizing patent data, which is associated with innovation in many studies. The international patent application data that was retrieved from WIPO was analyzed to determine the number of international patent applications in construction sector over thirty years in terms of patent types, countries and firms. The results show that international patent applications were mostly filed in the class that contains inventions related to building construction. This class is followed by earth or rock drilling and mining class, and building materials class. Most of the innovative activities were performed by the top ranking countries. In each class, top three countries filed approximately half of the patent applications.

Country distribution of patent applications shows the domination of the US in terms of innovation performance in construction industry. Approximately 1/3rd of all patent applications were filed by US firms in the last thirty years. The number of German patent applications is also significant in many classes. Great Britain is also ranked in top five in all of the construction related classes. Japanese companies were identified to be innovative mostly in the areas of building materials and hydraulic engineering, foundations and soil-shifting.

To identify the types of companies that are innovative, two patent classes were selected and patent statistics are analyzed with respect to firms. In the area of hydraulic engineering, foundations, soil-shifting, almost all of the most active firms in patenting were identified to be construction equipment producers. In the area of building construction, various types of construction related companies were identified, such as companies specialized in finishing works, insulation materials and formwork.

Concordance tables, which relate IPC to different industries, were used to identify the limitations of the IPC system that was used in classifying the patents. MERIT concordance and WIPO's concordance were applied to Turkey's national patent data in order to highlight the differences between these methods. Since WIPO's concordance is quite close to IPC, the results of these two methods were found to be almost identical. However, a significant difference was observed between the results retrieved from IPC and MERIT concordance table. Thus, future studies need to focus on the evaluation of concordance tables, and formation of a new concordance special to construction sector.

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