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A comparative study of patent counts by the inventor country and the assignee country

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Abstract This paper compared and contrasted patent counts by examining the inventor country and the assignee country. An empirical analysis of the patent data revealed how assignment principles (i.e. by the inventor country and by the assignee county) and counting methods (i.e. whole counts, first country and fractional counts) generate different results. Quadrant diagrams were utilised to present the patent data of the 33 selected countries. When countries had similar patent counts by inventor country with patent counts by assignee country, all the countries allocated along the diagonal line in the quadrant diagram were developed countries. When countries had more patent counts by inventor than by assignee, developed countries were more likely to sit in the right upper section of the quadrant diagram, while more developing countries were situated in the left lower section. Countries with higher patent counts by assignee than by inventor were more likely to be tax havens. A significant contribution of this paper resides in the recommendation that patent counts be analysed using both the inventor country and the assignee country at the same time if meaningful implications from patent statistics are to be obtained.

Keywords Patentometrics · Patent counts · Assignee country · Inventor country

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Introduction

Patent statistics have been widely employed to measure technology output and innovative activities (Schubert 2011). However, patent counting per se is complex, often covering rich sources of information, utilising different counting methods, and comprising various counting processes (e.g. choice of patent office, choice of reference data, and choice of country of attribution). Analogous to co-authorship in scientific publications, rapidly increasing trends toward international research and development (R&D) collaboration, the growth of multinational firms, and globalisation of technology have been reflected through co-patented inventions (Guellec and van Pottelsberghe de la Potterie 2001; OECD 2009; Huang et al. 2012; Zheng et al. 2012, 2013; Gao et al. 2013; Lei et al. 2013). When using patent statistics for international comparisons of technology, nuanced patent regulations across different countries need to be considered.

An examination of the patent statistics from various patent offices/research institutions (e.g. USPTO, EPO, JPO, OECD, IMD, and WEF) reveals that different principles of assigning patents are employed by different countries. Among the various assignment principles, the most common ones include: inventor countries, assignee countries and priority countries (Grupp and Schmoch 1999; OECD 2001, 2009). Table 1 illustrates various assignment principles and counting methods employed in different reports using different patent offices/research institutions.

Recognising that various indicators (e.g. the inventor county, the assignee country, and the priority country) are used to compile patent statistics, the 2009 edition of the OECD Patent Statistics Manual suggested that "[t]hese are all useful approaches and a comparative examination of their meaning is informative" (p. 63). However, it was found that little systematic research has been conducted to empirically examine the differences between these established assignment principles (Bergek and Bruzelius 2005). In order to fill the research gap, this study aims to compare and contrast patent counts by the inventor country and the assignee country, and identifies implications from these comparisons.

This paper begins with a review of the literature on patent counts as indicators of technology output, the assignment of patents to countries, and foreigner invention. It then

Table 1 Assignment principles and counting methods used in different reports by different patent offices/research institutions

Patent office	Assignment principle	Counting method	Report
U.S. Patent and Trademark Office (USPTO)	Inventor country	First country	FY 2012 Performance and Accountability Report
European Patent Office (EPO)	Inventor country	First country	Annual report 2012
Japan Patent Office (JPO)	Inventor country	Whole counts	Annual report 2012
Organisation for Economic Co-operation and Development (OECD)	Assignee/Inventor country	Whole counts	OECD Science, Technology and Industry Outlook 2012
Institute for Management Development (IMD)	Inventor country	Whole counts	World Competitiveness Yearbook 2013
World Economic Forum (WEF)	Inventor country	Fractional counts	Global Competitiveness Report 2012–2013

goes on to explain the methodology employed in the empirical study. The patent data analysed are presented by quadrant diagrams, with textual explanation. Finally, implications derived from the results are summarised in the conclusion section.

Literature review

Patent counts as indicators of technology output

According to Narin (1994, p. 147), patent bibliometrics, also termed "patentometrics," is "for the use of patents, and patent citations in the evaluation of technological activities." In relation to patentometrics, the meaning of this notion is twofold. On one hand, patent counts and patent citations are used as indicators. On the other hand, patent-based indicators are used to show technology output and innovative activities. Over the last couple of decades, much effort has been devoted to the development of more complex patent-based indicators. Examples of this kind include: current impact index, technology strength, technology cycle time, science linkage and science strength (Narin 2000), patent family size (Neuhäusler and Frietsch 2013), patent renewal (Schubert 2011), and triadic citations (Messinis 2011). Among various indicators, patent counts (i.e. the number of patents) are commonly used to form the basis of many other indicators (Han 2007; Jaffe et al. 1993; OECD 2001; Stuart 2000; Trajtenberg 1990).

With the trend towards international R&D collaboration, growth of multinational firms and globalisation of technology, methodological issues related to patent counts as indicators for measuring technology output are acknowledged in tandem. For example, Grupp and Schmoch (1999) raised the issue of duplication of patents in several countries. Additionally, international patent distribution is influenced by country preference, which could be encouraged by trade flows (OECD 2001), geographical proximity, similar technological specialisations, or shared common languages (Guellec and van Pottelsberghe de la Potterie 2001). Furthermore, Bergek and Bruzelius (2005) focused on the assignment of cross-country patents to countries of origin. It was observed that there is an increasing share of patents with the assignee and inventor located in different countries, which may reflect the location of R&D activities of multinational firms (Cantwell 1989) or co-operation between industrial R&D laboratories located in different countries (Guellec and van Pottelsberghe de la Potterie 2001). Two major issues regarding cross-country patents are discussed below: one relates to the assignment of patents to countries, and the other pertains to foreign ownership.

The assignment of patents to countries

Patentometrics, the study of quantitative and qualitative aspects of patents in the realm of technology, shows similarities with bibliometrics, which analyses those of literature in science. Narin (1994) provided a range of examples, including: literature and patent distributions of national productivity, inventor productivity, referencing cycles, citation impact and distribution, and within country citation preferences. Undeniably, differences between the two realms also exist.

As discussed earlier, substantial research has utilised patent data to indicate technology output, and there exist a variety of methods of calculating indicators from patent data. Even before examining the differences between various calculating methods, there is a fundamental difference between patent counts and literature counts. To put it specifically, in

Table 2 Comparison between the assignment of patents to countries

Reference country	Assignment by the inventor country	Assignment by the assignee country
Criterion for calculating	An employee (an individual)	An institutions (a company, a university, a public laboratory)
Focus of the calculation	Assessing the relative share of various countries in innovation on a given national technology market	Designating the ownership or control of the invention
A country's performance	Indicating the inventiveness of the local laboratories and labour force of a given country	Reflecting the innovative performance of a given country's firms, regardless of where their research facilities are located
Implication of patent counts	Reflecting inventive activity	Analysing the market allocation strategy of companies, notably multinational ones

Adapted from OECD (2001, 2009)

bibliometrics literature is assigned to the author's country of residence only (i.e. the location of the author's professional affiliation), whereas in patentometrics patents, based on different regulations, can be assigned to the inventor country, the assignee country or the priority country.

OECD (2001, 2009) has clearly stated the distinctions between patent counts by the inventor country, the assignee country, and the priority country. In this paper, the primary focus is placed on the comparison between the former two assignment principles, as illustrated in Table 2. Simply put, whilst assignment by inventor country reflects the inventive activity of a given country, the assignment by assignee country shows the market allocation strategy of companies.

Different principles of assignment of patents to countries are shown to generate different results. For instance, Grupp and Schmoch (1999) compared patent statistics taken from the USPTO, for the U. S. by priorities, inventors, and assignees during the period of 1982 to 1991, showing that ~20 % of all U. S. priorities had no U. S. inventor, and inferring from assignment by assignees that most inventors of U. S. patents were employed by U. S. firms in the 1980s. More recently, OECD (2009) analysed country shares in EPO applications with various criteria of attribution, reporting that small countries (e.g. Belgium, Hungary, and Mexico) had more shares as inventor countries than as assignee countries, whereas other countries (e.g. the Netherlands, Switzerland, and Finland) had more patents as assignee countries than as inventor countries, reflecting higher levels of international collaboration in their research activities.

Foreign ownership

Another issue, which remains relevant to the assignment of patents to countries, is foreign ownership. Foreign ownership describes an invention made in country A as being owned by a firm based in country B (Guellec and van Pottelsberghe de la Potterie 2001), which is firmly linked to the use of cross-country patents as an indicator of international R&D collaboration (Bergek and Bruzelius 2005). Indeed, a lot of attention concerning foreign ownership focuses on discussions regarding the R&D activities of multinational firms/corporations/enterprises (e.g. Dachs and Ebersberger 2009; Dachs et al. 2008; Singh 2008; Yamin and Otto 2004). It was also observed from a review of the literature that there is no common agreement in relation to the impact of geographic distribution of a firm's R&D activities on the quality of its innovative output. Two concerns are raised below:

The first concern relates to whether patent statistics are calculated with the address of the first inventor or every inventor, in particular when the inventors of a patent are from different countries. As Archambault's (2002) research showed, calculating statistics for multiple addresses helps to reveal the patterns of international collaboration in technological development. Huang et al. (2012) also used cross-border patent activities to examine the globalisation of collaborative creativity. However, drawing upon patent data, Singh (2008, p. 77) found that "having geographically distributed R&D per se does not improve the quality of a firm's innovations". He also analysed valuable innovations with evidence of "knowledge sourcing from other locations within the firm, having at least one inventor with cross-regional ties, and at least one inventor that has recently moved from another region". A radical question was then raised by Bergek and Bruzelius (2005): how crude are cross-country patents as indicators for measuring R&D collaboration? In their study, Bergek and Bruzelius (2005) concluded that cross-country patents are not very suitable indicators for international R&D collaboration, and called for research to investigate how and to what extent knowledge is actually shared between different countries in an innovation project.

The second concern is related to differences between foreign owned enterprises and domestically owned enterprises. Advantages that foreign owned enterprises have for patent performance are widely evidenced in the literature. For instance, Penner-Hahn and Shaver (2005) found that firms doing international R&D tend to produce more patents than firms that conduct solely domestic R&D. Similarly, Dachs et al. (2008) found that when patent data were used to compare innovative performance of foreign owned and domestically owned enterprises in five European countries with small open economies, foreign ownership is associated with similar levels of innovation input but higher levels of innovation output and higher labour productivity in comparison with domestic ownership. In contrast, some research (e.g. Guellec and van Pottelsberghe de la Potterie 2001; Leiponen and Helfat 2006) suggested that benefits from dispersed R&D only apply to imitative innovation but not novel innovation.

As discussed above, some literature analyzes distinctions between calculating patent statistics with the address of the first inventor or every inventor, and some examines variances between foreign owned enterprises and domestically owned ones. It is evident in the literature that the way patents are counted by country is not always explicitly addressed in statistical reports, e.g. counting the number of patents granted or applications for patents (Archambault 2002), calculating the patent counts by individual inventors or institutional ones (Archambault 2002; Huang et al. 2013) and attributing the patents to the inventor country or the assignee country (Bergek and Bruzelius 2005). Few studies have explored differences between patents with different inventor countries and assignee countries and identified implications from such differences. This research attempts to addresses this gap in the literature.

Methodology

Patent data

As recommended by OECD (2009), indicators coming from different patent offices cannot be compared, partly due to different legal and administrative procedures across different patent offices, and a home bias in the behaviour of applicants. This study gathered the number of utility patents issued in 2012 solely from the USPTO patent database, which is generally accepted and is accessible to the researchers. Originally, this study planned to gather patent data for the top 30 countries for each assignment principle and counting method. Due to the slight differences in assignment principles and counting methods, the number of countries used for patent analysis was 33 in total in this study.

Patent assignment principles

A review of the patent-related literature observed various assignment principles, as noted above. This study focuses on the comparison between patent counts by the inventor country and assignee country. Definitions of each assignment principle are borrowed from OECD (2009), as explained below:

- Patent counts by inventor country: The number of patents assigned to the professional address of the inventor (i.e. the address of the lab in which the inventor works).
- Patent counts by assignee country: The number of patents owned by the assignee of each country.
- Patent counts by assignee country with foreign inventor(s): For each patent, where there is no such inventor of the patent whose country is the same as one of the assignee countries, the number of patents is calculated by the assignee country.

Patent counts by the inventor country reflect the innovation performance of a given country's residents (OECD 2009). Patent counts by assignee country reflect the right to prevent others from applying the patented invention.

After justifying the methods used in this study, the data gathered were divided into two categories, according to different assignment principles (i.e. by inventor country and by assignee country).

Patent counting methods

This study drew upon various counting methods to enhance the comparison between different assignment principles. Based on the radical difference between the two assignment principles and taking into account of the increasing trend towards international R&D collaboration (i.e. patents with multiple inventors from different countries), common counting methods used in the literature include: whole counts, first country, and fractional counts. Definitions of each counting method are borrowed from OECD (2009), as explained below:

- Whole counts: Patents are fully attributed to each country.
- First country: A patent is awarded to the first person who made the invention, as in the USPTO patent system.
- Fractional counts: Patents are partly attributed to each country, which can avoid multiple counting.

In terms of different patent counting methods, whole counts directly measure a country's technology output, first country calculates the number of patents whose R&D activities are led by the country, and fractional counts refer to the percentage of investment from each country to the same patent. In other words, when a patent is invented as a result of international R&D collaboration, the percentage of the investment from each inventor country or assignee country is regarded as the patent count assigned to that country.

Patent count ratio

This study, adopting fractional counts, developed two ratios as indicators of quantitative patent performance. The first ratio, termed the 'I/A assignment ratio,'was calculated using the number of patents by the inventor country compared with the number of patents by the assignee country, as shown below:

$$\text{The I/A assignment ratio} = \frac{\text{Patent counts by the inventor country}}{\text{Patent counts by the assignee country}}.$$

The second ratio, termed the 'foreigner invention ratio,' was calculated by the number of foreign inventor patents compared with the total number of patents assigned to the assignee country, as shown below:

$$\text{The foreigner invention ratio} = \frac{\text{Patent counts by the assignee country with foreign inventor}}{\text{Patent counts by the assignee country}}.$$

Results and discussion

Data gathered from the USPTO patent database demonstrate the 2012's patent counts by the inventor country and the assignee country, which were further differentiated by three separate counting methods. In order to identify the nuances and distinguish the differences, the patent data were visualised using quadrant diagrams.

Comparing patent counts by different counting methods

For each assignment principle, different counting methods (i.e. whole counts, first country and fractional counts) were employed to present the patent data. Table 3 shows 2012's patent data for 33 countries using each assignment principle and counting method. It is clear that patent counts by whole counts yielded higher results than those by first country and fractional counts, because patents are multiply counted when using whole counts. Most patent counts by first country were higher than those by fractional counts, except Russia for inventor counts, and Taiwan and Hong Kong for assignee counts, partly because the majority of countries that had patents with international co-inventors or co-assignees were also those who led patent invention. However, the patent count by first country is 1, and that by fractional counts is less than 1.

Analysis from the ratio of patent count by first country to patent count by whole counts shows that the percentage of patent invention is led by the country in comparison to its total patent counts. There were fourteen countries (United Kingdom, Switzerland, Netherlands, India, Belgium, Austria, Singapore, Spain, Ireland, Russia, Malaysia, New Zealand, Brazil, and Liechtenstein) whose ratio of patent count by first inventor country to patent count by whole counts was less than 0.80. This indicates that at least 20 % of patent invention for these countries is led by other inventor countries. Therefore, such a ratio reflects the innovation performance of those countries' residents, which is relatively weak. Because most patents are attributed to only one assignee, the percentage of first assignee countries for most countries is relatively high on average. However, Hong Kong's ratio of patent count by first assignee country to patent count by whole counts was only 0.67, showing that 33 % of patents in Hong Kong have co-assignees, but Hong Kong is not the

Table 3 Utility patents issued in 2012 to 33 countries (database source: USPTO)

	Patent Count by Inventor Country				Patent Count by Assignee Country			
	Whole		First (Ratio)[a]	Fractional (Ratio)[a]	Whole		First (Ratio[a])	Fractional (Ratio[a])
	Rank	Count			Rank	Count		
USA	1	125969	121218 (.96)	113860.4 (.90)	1	112552	111857 (.99)	105558.0 (.94)
Japan	2	51677	50869 (.98)	48077.3 (.93)	2	50856	50658 (1.0)	47664.6 (.94)
Germany	3	15580	13851 (.89)	13113.6 (.84)	4	12381	12176 (.98)	11526.9 (.93)
S. Korea	4	13522	13259 (.98)	12411.3 (.92)	3	13012	12977 (1.0)	12124.6 (.93)
Taiwan	5	11234	10640 (.95)	10098.9 (.90)	5	10662	9357 (.88)	9442.2 (.89)
Canada	6	6834	5774 (.84)	5425.1 (.79)	8	3571	3531 (.99)	3319.3 (.93)
United Kingdom	7	6646	5234 (.79)	5014.8 (.75)	9	3022	2960 (.98)	2793.0 (.92)
France	8	6338	5391 (.85)	5064.6 (.80)	6	5111	5003 (.98)	4736.8 (.93)
China	9	5998	4867 (.81)	4697.3 (.78)	7	3728	3646 (.98)	2724.1 (.73)
Israel	10	2803	2475 (.88)	2313.5 (.83)	14	1359	1337 (.98)	1247.5 (.92)
Switzerland	11	2582	1832 (.71)	1765.3 (.68)	11	2803	2686 (.96)	2531.8 (.90)
Italy	12	2477	2122 (.86)	2055.0 (.83)	13	1491	1469 (.99)	1391.0(.93)
Netherlands	13	2475	1905 (.77)	1841.3 (.74)	10	2818	2792 (.99)	2593.8 (.92)
Sweden	14	2410	2082 (.86)	1983.1 (.82)	12	2365	2344 (.99)	2222.3 (.94)
India	15	2393	1691 (.71)	1649.2 (.69)	26	421	408 (.97)	382.2 (.91)
Australia	16	1795	1529 (.85)	1452.1 (.81)	16	1052	1023 (.97)	986.2 (.94)
Belgium	17	1282	866 (.68)	828.7 (.65)	20	651	635 (.98)	584.6 (.90)
Finland	18	1186	1066 (.90)	998.8 (.84)	15	1163	1163 (1.0)	1100.5 (.95)
Austria	19	1089	858 (.79)	832.5 (.76)	23	582	568 (.98)	541.6 (.93)
Singapore	20	1046	806 (.77)	762.2 (.73)	17	1009	990 (.98)	940.1 (.93)
Denmark	21	1011	855 (.85)	812.8 (.80)	18	762	738 (.97)	703.5(.92)
Spain	22	870	642 (.74)	631.2 (.73)	25	423	408 (.96)	384.9 (.91)
Norway	23	525	444 (.85)	414.4 (.79)	27	304	298 (.98)	275.3 (.91)

Table 3 continued

	Patent Count by Inventor Country				Patent Count by Assignee Country			
	Whole		First (Ratio)[a]	Fractional (Ratio)[a]	Whole		First (Ratio[a])	Fractional (Ratio[a])
	Rank	Count			Rank	Count		
Ireland	24	511	345 (.68)	333.3 (.65)	21	618	594 (.96)	561.5 (.91)
Russia	25	508	332 (.65)	345.3 (.68)	32	71	66 (.93)	65.5 (.92)
Hong Kong	26	395	326 (.83)	300.7 (.76)	22	595	401 (.67)	470.4(.79)
Malaysia	27	287	210 (.73)	199.9 (.70)	33	57	54 (.95)	49.5 (.87)
New Zealand	28	284	221 (.78)	211.4 (.74)	28	145	140 (.97)	131.0 (.90)
Brazil	29	254	196 (.77)	180.1 (.71)	29	101	96 (.95)	86.0 (.85)
New Zealand	30	164	142 (.87)	133.4 (.81)	31	72	67 (.93)	63.3 (.88)
Liechtenstein	31	33	16 (.48)	14.9 (.45)	30	79	79 (1.0)	74.0 (.94)
Cayman Islands	32	11	9 (.82)	8.5 (.77)	24	432	420 (.97)	392.0 (.91)
Bermuda	33	2	2 (1.0)	2.0 (1.0)	19	760	745 (.98)	696.5 (.92)

[a] Ratio: The patent count of first country (fractional counts) divided by whole counts

first assignee. Indeed, Hong Kong's percentage of international R&D collaboration was relatively high, even though it did not lead the R&D.

Analysis from the ratio of patent count by fractional counts to patent count by whole counts shows the percentage of investment made by a country in each patent invention. There were 19 countries with ratios of fractional counts by inventor country to whole counts less than 0.80, including the 14 countries whose ratios of patent count by the first inventor country to patent count by whole counts were less than 0.80, in addition to Canada, China, Norway, Hong Kong, and the Cayman Islands. These 19 countries made less than 80 % of the average investment in each patent, indicating that countries with low leading patent invention also showed lower percentages of investment in patent invention. However, both China and Hong Kong also belonged to the list of countries with a ratio of fractional counts by assignee country to whole counts of less than 0.80, indicating that these two areas' patent activities involved relatively high numbers of international co-assignees, and therefore their ratios of fractional counts by assignee country to whole counts were relatively low.

Pearson's correlation coefficient was computed to assess the relationship between different patent counting methods, as shown in Table 4. There was a strong positive correlation between each variable, r between .985 and 1.000, $n = 33$, $p = .000$. A scatter plot demonstrates the result (see Fig. 1). In Fig. 1, the inventor country is arranged on the y-axis, and the assignee country is arranged on the x-axis. Dots represent the relative positions of countries in the quadrant diagrams, according to their patent counts by inventor country and assignee country. Along the diagonal line sit dots that represent countries with similar numbers of patent counts by inventor country and assignee country.

Table 4 Pearson's correlation coefficient for each patent counting method

		(A)	(B)	(C)	(D)	(E)	(F)
Inventor Country	Pearson Correlation	1	1.000**	1.000**	.998**	.998**	.998**
Whole counts	Sig. (2-tailed)		.000	.000	.000	.000	.000
(A)	N	33	33	33	33	33	33
Inventor Country	Pearson Correlation	1.000**	1	1.000**	.999**	.999**	.999**
First country	Sig. (2-tailed)	.000		.000	.000	.000	.000
(B)	N	33	33	33	33	33	33
Inventor Country	Pearson Correlation	1.000**	1.000**	1	.999**	.999**	.999**
Fractional counts	Sig. (2-tailed)	.000	.000		.000	.000	.000
(C)	N	33	33	33	33	33	33
Assignee Country	Pearson Correlation	.998**	.999**	.999**	1	1.000**	1.000**
Whole counts	Sig. (2-tailed)	.000	.000	.000		.000	.000
(D)	N	33	33	33	33	33	33
Assignee Country	Pearson Correlation	.998**	.999**	.999**	1.000**	1	1.000**
First country	Sig. (2-tailed)	.000	.000	.000	.000		.000
(E)	N	33	33	33	33	33	33
Assignee Country	Pearson Correlation	.998**	.999**	.999**	1.000**	1.000**	1
Fractional counts	Sig. (2-tailed)	.000	.000	.000	.000	.000	
(F)	N	33	33	33	33	33	33

**Correlation is significant at the 0.01 level (2-tailed)

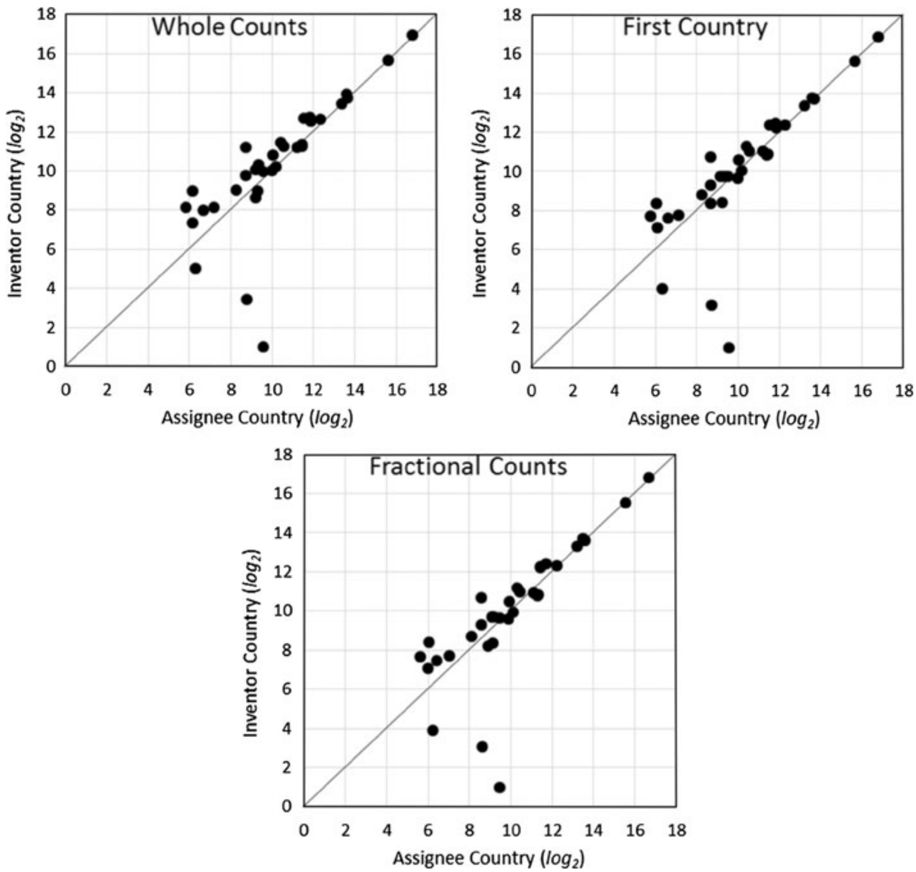

Fig. 1 Scatter charts of different counting methods

The quadrant diagram on the left-hand side in Fig. 1 shows the results by whole counts, those in the middle by first country, and those on the right-hand side by fractional counts.

Generally, there was a strong positive correlation between patent counts by inventor country and by assignee country. An increase in patent counts by inventor country was correlated with an increase in patent counts by assignee country. However, there is evidence of small differences in patent counts between different counting methods, which correspond to similar country rankings between the three counting methods as shown in Table 3. In other words, no matter which counting method is used, the result remains similar.

Developing patent count ratios as indicators and identifying their relationships

Table 5 provides two ratios, i.e. the I/A assignment ratio and the foreigner invention ratio, for the 33 countries observed. In bibliometrics, fractional counts are seen as being mathematically more logical than whole counts (Gauffriau et al. 2008; Lin et al. 2013). Based on a significant number of similarities between bibliometrics and patentometrics, this study used patent counts by fractional counts to calculate the I/A assignment ratio, which measures the ratio of patent count by inventor country to patent count by assignee country.

Table 5 Patent count ratio of I/A assignment and foreigner invention

Country	Ratio of		Country	Ratio of	
	I/A assignment	Foreigner invention		I/A assignment	Foreigner invention
Russia (RU)	5.27	0.07	Germany (DE)	1.14	0.11
India (IN)	4.32	0.04	America (US)	1.08	0.08
Malaysia (MY)	4.04	0.14	Taiwan (TW)	1.07	0.05
South Africa (ZA)	2.11	0.01	France (FR)	1.07	0.23
Brazil (BR)	2.09	0.01	South Korea (KR)	1.02	0.03
Israel (IL)	1.85	0.03	Japan (JP)	1.01	0.03
United Kingdom (GB)	1.80	0.12	Finland (FI)	0.91	0.23
China (CN)	1.72	0.05	Sweden (SE)	0.89	0.29
Spain (ES)	1.64	0.05	Singapore (SG)	0.81	0.51
Canada (CA)	1.63	0.12	Netherlands (NL)	0.71	0.44
New Zealand (NZ)	1.61	0.07	Switzerland (CH)	0.70	0.48
Austria (AT)	1.54	0.17	Hong Kong (HK)	0.64	0.37
Norway (NO)	1.51	0.10	Ireland (IE)	0.59	0.66
Italy (IT)	1.48	0.02	Liechtenstein (LI)	0.20	0.72
Australia (AU)	1.47	0.10	Cayman Islands (KY)	0.02	0.95
Belgium (BE)	1.42	0.24	Bermuda (BM)	0.00	0.97
Denmark (DK)	1.16	0.18			

When the ratio is higher, the inventor's investment is relatively higher than the assignee's in terms of the percentage of the investment that a country makes in patent invention. When the ratio is lower, the assignee's investment is relatively higher than that of the inventor. The foreigner invention ratio measures the number of foreign inventor patents against the total number of patents assigned to the assignee country. When the ratio is higher, a large number of that country's patents by assignee country are invented by foreign inventors.

As seen in Table 5, when the I/A assignment ratio was higher than 1.0, countries showed more patent counts by inventor country than by assignee country. For instance, ratios for RU, IN, MY, ZA, and BR were greater than 2, indicating that these countries' patent counts by the inventor country were more than double their patent counts by the assignee country. This shows that inventors from the specific country have invested extensively in patent invention while being employed by assignees in other countries. The I/A assignment ratio was less than 1.0, indicating that these countries had fewer patent counts by inventor country than by assignee country. This means that firms in the country invested significantly in patent invention, though the firms tended to employ foreign rather than local inventors to conduct R&D. For instance, the ratios for LI, KY, and BM were equal to or less than 0.2, indicating that those countries' patent counts by inventor country were 20 % lower than their patent counts by assignee country.

A Pearson I/A assignment-Foreigner invention correlation coefficient was computed to assess the relationship between the patent count ratio of I/A assignment and that of foreigner invention. The result showed a negative correlation between the two variables, $r = -.556$, $n = 33$, $p = .001$. Specifically, the I/A assignment ratio was inversely proportional to the foreigner invention ratio.

Comparisons between reference countries through the quadrant diagram, using fractional counts

Patents are counted multiply when using whole counts. Taking into account that patent counts by first country do not consider subsequent countries for patenting, the authors thus decided to further examine the differences between patent counts by inventor country and assignee country using fractional counts. Figure 2 represents a quadrant diagram, showing the relative positions of countries with patent counts by the inventor country and by the assignee country, using fractional counts with the function of $\log_2$ operation. Different shapes were used to represent distinctive groups of countries with different quantitative patent performance.

Based on the criteria set above, it is clear that countries highlighted in circles possessed higher patent counts by inventor than by assignee, indicating that residents of those countries worked at international firms or abroad. Within this group, the countries allocated in the right upper section of the quadrant diagram were more likely to be developed countries (CA, GB, IL, IT, AU, AT, BE, ES, NO, and NZ), except CN and IN, and the four countries allocated in the left lower part were developing countries (RU, BR, MY, and ZA).

Furthermore, countries highlighted in squares possessed higher patent counts by assignee than by inventor, indicating that those countries attracted more international firms. One explanation for this observation is that those countries are usually regarded as tax havens as they tend to charge low tax rates, and the international firms there could sometimes boil down to paper companies (BM, KY and LI). However, it could be argued that IE and HK also belong to this group but are not tax havens. A close examination into

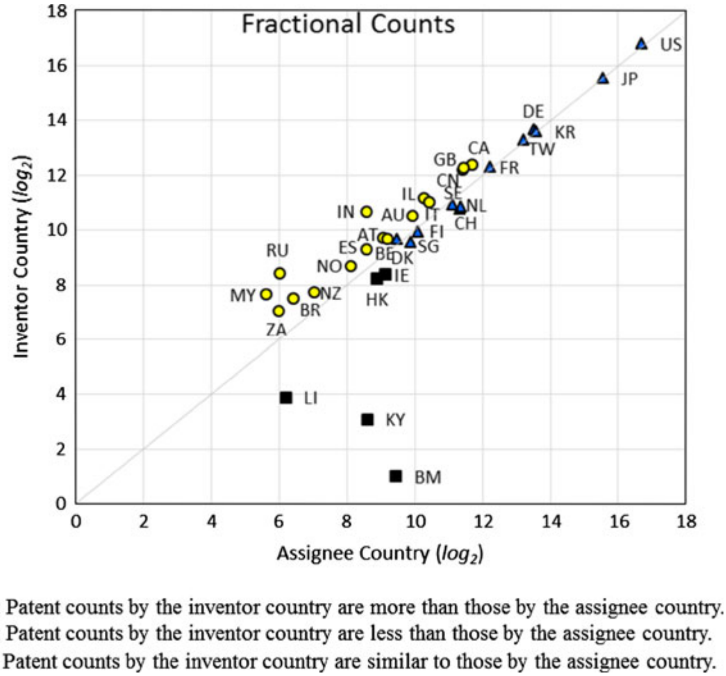

Fig. 2 Quadrant diagram using fractional counts

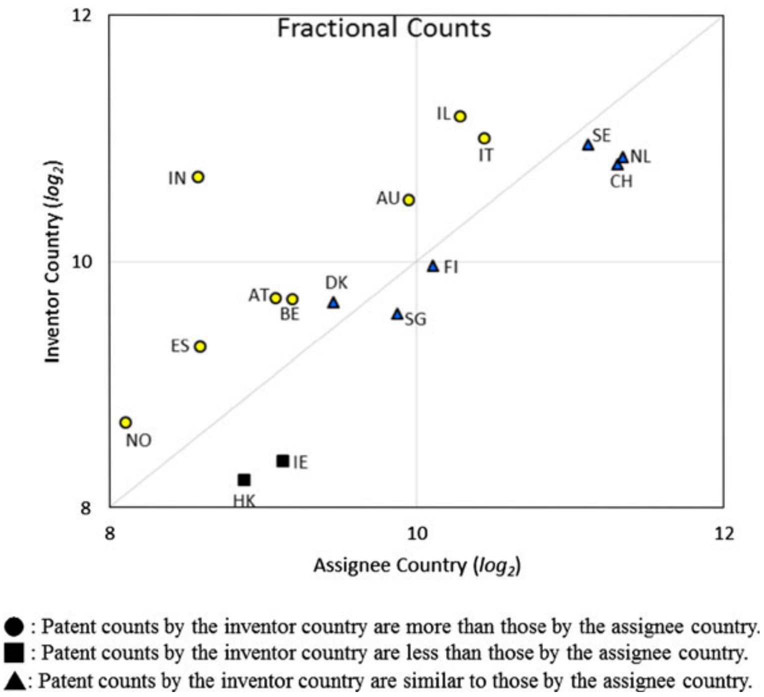

Fig. 3 Quadrant diagram using fractional counts (parts)

the patent counts by assignee country for both IE and HK found that a large number of their patent inventors came from foreign countries; for IE, 32 % of the inventors were from the US and 15 % from AU; for HK, 50 % of the inventors were from CN.

Finally, countries highlighted in triangles showed similar patent counts by inventor and by assignee. It is interesting to note that all the countries in this group (US, JP, DE, KR, TW, FR, NL, CH, FI, SG, BE, and DK) are developed countries.

The difference between various countries' quantitative patent performance can be observed through examining the quadrant diagram. For example, applying the logarithm between 8 and 12 in Fig. 2 resulted in Fig. 3. When examining patent counts by both inventor country and assignee country at the same time in Fig. 3, two interesting phenomena stand out. One is that countries had similar patent counts by assignee country, but their patent counts by inventor country differed significantly (AT vs. IE and AU vs. SG); the other is that countries had similar patents counts by the inventor country, but their patent counts by assignee country differed significantly (IN vs. CH and IT vs. SE). The two phenomena bring into view a critical question—is it appropriate to look at patent counts by either inventor country or assignee country separately?

Drawing upon the discussion above, it is recommended that patent counts are analyzed by both inventor country and assignee country at the same time if meaningful implications from patent statistics are to be obtained. This is particularly useful when countries have similar patent counts by either inventor or assignee, as a comparison can be immediately made. Specifically, when countries have similar patent counts by inventor, it is useful to distinguish those countries using patent counts by assignee, and vice versa.

Conclusions

Few studies have empirically examined the differences between established assignment principles (Bergek and Bruzelius 2005). This study has addressed this gap, and also answered OECD's (2009) call for a comparative examination of the meanings of different assignment principles. Drawing upon the number of utility patents issued in 2012 solely from the USPTO patent database, this study has compared and contrasted different assignment principles (i.e. by inventor country and by assignee country) and counting methods (i.e. whole counts, first country, and fractional counts), as well as the I/A assignment ratio and the foreigner invention ratio. As shown in Table 1, various reports by different patent offices/research institutions generally considered one single assignment principle, either by inventor country or by assignee country. Arguably, this could not reflect a country's patent performance as a whole, as illustrated in Fig. 3. Therefore, a significant contribution of this paper resides in the recommendation that patent counts are analysed using both the inventor country and the assignee country at the same time if meaningful implications from patent statistics are to be obtained.

Clearly, differences exist between patent counts by inventor country and by assignee country; however, specific reasons for these observations are yet to be explored. Some interesting observations are summarised below.

- Whole counts could be regarded as an indicator for directly measuring a country's R&D output, first country could be seen as an indicator for calculating the patent output led by the country, and fractional counts refer to the patent counts of the country depending on its investment. The results used the three counting methods to show statistically significant relevance. However, countries with lower ratios of the patent count by first country to patent count by whole counts also have lower ratios of the patent count by fractional counts to patent count by whole counts. This may be due to the country's international collaboration in patent activities. When a country's number of patents invented as a result of international collaboration increases, its ratio of patent counts either by first counts or by fractional counts to patent counts by whole counts decreases.
- When countries had similar patent counts by inventor country to patent counts by assignee country, all the countries allocated along the diagonal line in the quadrant diagram were developed countries. When countries had more patent counts by inventor than by assignee, developed countries were more likely to sit in the right upper section of the quadrant diagram, while more developing countries were situated in the left lower section. Countries with more patent counts by assignee than by inventor were more likely to be tax havens.
- The foreigner invention ratio represents the degree of internationalisation of a country's firms (see foreign ownership, OECD 2009). If a country is a tax haven, the firms in the country tend to employ foreign inventors for patent invention.

It is worth noting that results reported in this paper are based on patent counts, and patent counts are not without limitations. For instance, one limitation relates to patent statistical bias, i.e. the decision of whether to use raw patent counts or quality of patents (Singh 2008). Other limitations include: duplication of patents in several countries (Grupp and Schmoch 1999), unpatented inventions (OECD 2001), differences in patent regulations across countries (OECD 2001), and country preference (Guellec and van Pottelsberghe de la Potterie 2001; OECD 2001). It is important to consider these limitations when using patents as data.

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