J Int Entrep (2018) 16:486–503
https://doi.org/10.1007/s10843-018-0225-8

A cross-country comparison of the effects of institutions on internationally oriented innovation

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Published online: 1 March 2018

Abstract In this paper, we probe the relationship between institutions and internationally oriented innovation. For the first time, we use Patent Cooperation Treaty statistics as a new source of national-level data on the inventive activities of internationally oriented innovators, which we refer to as "global innovators." One third of global innovators are small- and medium-sized enterprises (SMEs). We apply these new data and investigate the effects of corruption and business climate on patenting activity. It is ascertained herein that the inventive activity of global innovators has a linear relationship with institutional factors, while there is no observed relationship between the quality of the institutional environment and PCT patenting by multinational enterprises (MNEs).

Abstract (German) In diesem Artikel erforschen wir den Zusammenhang zwischen Institutionen und international ausgerichteten erfinderischer Tätigkeit. Zum ersten Mal untersuchen wir, ob PCT-Patentanmeldungen auf nationaler Ebene als eine neue Datenquelle für die erfinderischen Aktivitäten der neuen Art von international ausgerichteten Unternehmen, die als „global innovators" bezeichnet werden können. Das Drittel von global innovators besteht aus Klein- und Mittelunternehmen. Wir anwenden diese neue Datenquelle und untersuchen die Auswirkungen von Korruption und Geschäftsklima auf international ausgerichtete Erfinder. Es wurde festgestellt, dass es einen linearen Zusammenhang zwischen den Institutionen und erfinderischer Tätigkeit der global innovators gibt. Und es gibt keine Verbindung zwischen den Patentanmeldungen von großen multinationalen Firmen und institutionellen Gegebenheiten.

Keywords Innovation · Invention · Institutions · Inventive activity · Patent statistics · Corruption · Institutional quality

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JEL classification O30 O38 O57 L25

Summary highlights

Contributions: For the first time, we use so-called international applications filed through a Patent Cooperation Treaty (PCT) as a novel data source for capturing the internationally oriented innovation of small, technology-driven companies, or "global innovators." We apply a new procedure, namely the regular expression technique in Perl, to a dataset of over 200,000 PCT applications published in 2013, to isolate two groups of filings—"global innovators" and multinational enterprises (MNEs)—from a pool of other applicants, including government agencies and research institutes, as well as patents filed by individuals. The reason for this categorization is to test the impact of two institutional factors, namely corruption and the quality of the business environment, on two types of PCT applicants: global innovators and MNEs.

Research question: What is the relationship between institutional factors in home markets and the innovative activity of "global innovators" vis-à-vis the associated actions of MNEs?

Theoretical framework: The entrepreneurship literature emphasizes the effect of institutional factors in home markets that determine both the innovation and internationalization strategies of small businesses. Small firms are expected to be especially susceptible to institutional deficiencies.

Data: We use over 200,000 PCT applications from 43 countries in 2013. The two institutional indices are the Corruption Perception Index (CPI) and the Distance to Frontier (DTF) of the World Bank Ease of Doing Business Index.

Findings: A linear relationship has been established between global innovators and the DTF, as well as between global innovators and the CPI. No statistically significant relationship has been identified between the two indices and patenting activity undertaken by MNEs.

Theoretical implications: The project opens up the discussion on the use of patent statistics as a measure of inventive activity by technology-driven, internationally competitive firms. Not only MNEs are involved in the internationalization of innovation, however, as we identify herein a new breed of international player—the global innovator—that must be studied closely. Moreover, global innovators are affected by the quality of the business environment more than MNEs.

Introduction

According to *The Oslo Manual*, innovation is the implementation of a new or significantly improved product or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations (OECD

2005, p. 46). Invention, which is the process of conceptualizing an idea and transforming it into a practical form, is the first stage in the innovation process (King et al. 1994, p. 140) and is usually followed by innovation (application or realization) and diffusion (spread and usage). The process of invention (particularly of product and process, as per *The Oslo Manual*) can be captured by patent statistics, with patents being seen as the physical realization of a creative impulse. *The Oslo Manual* treats patents as a "method for maintaining and increasing competitiveness of innovations" (OECD 1996, p. 58), and they are granted to inventions that are novel, contain an inventive step ("non-obvious to persons skilled in the art"), and are amenable to industrial applications (Paunov 2016, p. 216). Furthermore, they can be filed domestically or internationally. The act of international filing suggests an effort toward safeguarding intellectual property rights abroad and provides direct evidence of overseas-oriented commercial intentions. This is, in essence, an act involving the internationalization of innovation.

We believe that innovation-driven companies that intend to internationalize their inventions can be classified as "global innovators"—a term that is actually a spin-off from the frequently used "born-global," a usually small and agile technology-driven firm that internationalizes from its very inception (Rennie 1993). When internationalization happens, in our view, is of less importance than the fact that the process of moving abroad is accompanied and sometimes driven by innovation. Today, due to technological globalization, even a small firm can internationalize at any point in its development, either from early beginnings or after decades of successful domestic operations. Here, we distinguish "global innovators" (the term "global" refers to the international orientation of innovation activities) from large multinational enterprises, namely the world's largest (in terms of revenue) multinational enterprises (MNEs) from the Fortune Global 500 list. It is believed that the latter are the leaders of global innovation, due to their supreme ability to take advantage of internal and external sources of innovation and manage these networks of knowledge exchange on a global scale (Narula 2016; Zanfei 2000). This ability, as well as other organizational competencies, economies of scale, R&D capabilities, global brands, etc., sets them aside from other companies that might not possess advantages shared by MNEs. For the sake of simplicity, we call the group of large Fortune Global 500 list multinationals "MNEs" and the remaining companies "global innovators."

"Global innovators" can be small- and medium-sized enterprises (SMEs)[1] or larger firms with over 1000 employees. They stem from developed as well as developing economies, and being highly innovative firms, they must contribute to increased productivity and the national economic growth of their respective countries of origin. This breed of international innovator can be compared to Simons' "hidden champions," which are innovative companies prominent in niche markets but "hidden" from the public eye (Simon 1992). Furthermore, global innovators are "invisible" at the macro

[1] The definition of an SME is geographically bounded and therefore differs. According to the European Commission Recommendation from May 6, 2003 (2003/361/EC), however, "the category of micro-, small-, and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million and/or an annual balance sheet total not exceeding EUR 43 million." Retrieved on March 8, 2015, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF.

level, except when they are caught in the act of internationalizing their inventions—an act Patent Cooperation Treaty (PCT) statistics capture very well.

For North (1991), institutions are "the humanly devised constraints that structure political, economic, and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct) and formal rules (constitutions, laws, property rights)" (p. 97). Institutions, including those that make up business infrastructure, are important factors determining the intensity of entrepreneurial activity and economic development (Barro 1996; Rodrik et al. 2004; Easterly and Levine 2003). Even though the link between institutional arrangements and the behavior of SMEs has received considerable attention from scholars of entrepreneurship (Ahlstrom and Bruton 2010; Descotes et al. 2007; Cieslik and Kaciak 2009; Hoskisson et al. 2013; Lu et al. 2008; Yamakawa et al. 2008), there is still a lack of research on the internationalization and innovation strategies of SMEs (Volchek et al. 2013). In addition, the innovative aspect of SMEs' internationalization strategies has received even less attention, while the internationalization of innovation has been addressed mostly by scholars of multinational enterprises (MNEs), for instance in Birkinshaw and Hood (2001), Cantwell (1995), and Zanfei (2000). The effects of institutions on the strategic decisions of SMEs, including outward-looking innovation, require urgent scholarly attention, especially at the macro level, as the rise of emerging economies like China, India, or even Russia implies changes in the global economic balance of power. Global competition frequently takes place in the area of innovation and is driven not only by MNEs, which hail mostly from developed economies, but also by companies such as global innovators. This paper addresses this theoretical and empirical gap by focusing on internationally oriented patenting activity undertaken by global innovators vis-à-vis MNEs.

SMEs lack the sort of resources available to large MNEs, and so their internationalization strategies are sensitive to the deficiencies of institutions in developing or emerging economies (Descotes et al. 2007; Shirokova and Tsukanova 2012). Entrepreneurship scholarship also emphasizes the characteristic vulnerability of SMEs to conditions in the business environment as far as innovation strategies are concerned (Zhu et al. 2012). Since many global innovators are SMEs, then they should display similar levels of sensitivity to the quality of the institutional environment in their attempts to internationalize innovation, contrary to their larger MNE counterparts.

Global innovators must be differentiated from large MNEs, the latter of which are powerful entities, originate mostly in developed economies, and possess a broad range of ownership advantages, such as management expertise and globally recognized brands (Dunning 2001; Ramamurti 2012). Furthermore, MNEs engage in substantial direct investment in foreign countries, and they manage these offshore assets actively and strategically as part of their overall global operations (Bartlett and Beamish 2011). Their ability to leverage and manage internal and external networks of innovation in different locations has been identified as a separate competence or "recombinant advantage" (Narula 2014). In addition, they are in the public eye, and their innovative output has been studied extensively, including in Cantwell and Janne (1999), who examined the patents of Global Fortune 500 list companies for the period 1969–1995. The innovative output of companies like global innovators has been explored mostly at the firm level via

company surveys rather than at the macro level. Consequently, global innovators—being private entities—must be separated from government-funded research institutes, government agencies, universities, and individuals as applicants. In the private sector, large and small firms epitomize, from the perspective of Schumpeterian theory, an entrepreneurial spirit and are the drivers of innovation. In contrast to governments or individual applicants, global innovators are privately owned, profit-driven entities with an ultimate motive of commercially accomplishing their inventions. After all, the goal of commercially diffusing innovation drives economic growth. Individuals filing for patent protection constitute a separate category of inventor because, essentially, they are "lonely" or "unaffiliated" inventors, and among all innovative entities, they have the smallest amount of resources to realize their inventions on a commercial scale.

The act of internationalizing innovation by global innovators, which can be measured by so-called international or Patent Cooperation Treaty (PCT) patent applications, requires empirical investigation. Most empirical enquiries into the innovation or internationalization strategies of companies are conducted at the firm level as surveys or case studies. At the macro level, patent applications made to the US Patent and Trademark Office (USPTO) have been used frequently to capture the internationally oriented inventive output of various companies worldwide. The PCT offers an excellent opportunity for internationalizing innovation, by allowing the filing of a single application in up to 151 PCT members simultaneously, which makes this mechanism especially attractive to globally oriented, innovation-driven firms. Thus, PCT patent statistics constitute a unique opportunity to measure the truly global innovative efforts of companies—and not only those directed at the US market. The macro level is especially appropriate for analyzing the effect of domestic institutions on the innovation internationalization process. In other words, national-level comparisons can capture the effects of contextual factors such as business environment and level of corruption, and show differences across countries. With this in mind, we probe the relationship between the inventive activity of global innovators and MNEs, expressed as PCT applications, and two institutional factors, namely corruption and quality of the business environment.

Innovation and institutions

Institutions and SMEs

It has been acknowledged that the size, structure, and competitiveness of home markets, as well as industry characteristics, play an important role in choosing an internationalization strategy (Elango 2012; Gabrielsson 2005; McNaughton 2003). Home-country institutions should also affect the innovation strategies of internationally oriented, technology-driven companies like global innovators, but there is little empirical research exploring this link. Entrepreneurship scholars offer a body of empirical research on SMEs. First, as far as SMEs are concerned, they insist on differentiating between institutional environments in developed and developing economies, and second, on studying how formal and informal institutions affect their behavior (Ahlstrom and Bruton 2010; Descotes et al. 2007; Cieslik and Kaciak 2009; Lu et al. 2008; Yamakawa et al. 2008). Institutions affect the rate

of innovation, internationalization, or other strategic decisions made by SMEs, and Shirokova and Tsukanova (2012) reveal that a number of institutional factors (such as tax law, levels of corruption, political instability, and the judicial system) have an effect on the internationalization process of SMEs in Russia. Furthermore, SMEs are especially vulnerable to the failures of institutional environments in developing countries (Zhu et al. 2012, p. 1140), thus making their decision to pursue foreign markets or innovation strategies especially risky.

Corruption

Like any other organization, global innovators are embedded in systems of social relations. Formal and informal institutions such as business regulations and corruption influence a firm's behavior (Granovetter 1985; Fields 1995), with the latter being a particularly important factor: "If you know how corrupt a country is, you can predict fairly accurately how much innovation you will see there" (Mungiu-Pippidi 2015, p. 295). The effects of corruption on innovation strategies have been discussed by a number of scholars, especially those focusing on developing economies. Ermasova and Ermasov (2013), for example, argue that high levels of corruption led to the stagnation of innovation activity in Russia between 1995 and 2007, while Veracierto (2008) claims that corruption can decrease the rate of product innovation in an industry. Ayyagari et al. (2010), based on the analysis of a large-scale company survey (25,000 companies in 57 countries), conclude that government corruption "acts as a tax on firm innovation", as innovating firms in less developed countries pay more bribes than non-innovators (p. 72). If, indeed, corruption has a direct effect on the process of innovation, then we should be able to find a strong association between a national level of corruption, measured as the Corruption Perception Index (CPI), and patent activity.

Smaller firms are especially susceptible to the negative effects of corruption. Svensson (2003), for instance, based on the case of Uganda, demonstrated how larger firms have greater bargaining power because they engage in negotiations with corrupt officials and can even benefit from this relationship. Smaller firms, by definition, have less bargaining power, so, as Paunov (2016) hypothesizes, their innovative activities are more likely to be damaged by corruption than those of larger firms. Her conclusion, based on firm-level data from 48 developing and emerging economies, is that corruption does indeed negatively influence the ownership of quality certificates by small firms to a larger extent than by large companies, albeit the relationship between corruption and patent ownership is not conclusive (p. 227). Allegedly, firms can escape domestic extortion by filing patents abroad (Paunov 2016, p. 217), thus alluding to the relationship between innovation internationalization (expressed as PCT applications) and the national level of corruption (measured as CPI).

Business environment

Apart from corruption, the quality of the business environment is another important factor determining the mode of innovation. DiPietro (2009) confirms the relationship between the World Bank Doing Business Index and the World Business Global

Innovation Index in about 100 countries in this regard. Institutional failures harm innovation especially in SMEs. Minh and Hjortsø (2015) find that a "discriminatory legal framework" in Vietnam pushes SMEs to "limit the breadth of innovation" and engage in "cost-control strategies" rather than product-oriented innovation (p. 223). Based on a survey of 505 SMEs in eight countries, Mazzarol et al. (2014) conclude that the major components of an innovation climate, such as the level of red tape and compliance costs, as well as taxation, training, and education policies,[2] have a direct impact on the innovativeness of SMEs. Omer et al. (2015) investigate the effects of institutional constraints (government rules and regulations, and financing gaps among them) on SME internationalization in South Africa, observing that it serves as a coping or escapist mechanism for SMEs in developing economies looking to mitigate local constraints. As noted above, international patenting combines internationalization and innovation strategies, and thus we should be able to find a direct link between the quality of business institutions (expressed as World Bank Doing Business Index Distance to Frontier (DTF) national scores) and PCT applications.

Patents as a proxy for inventive activity

Being a tangible manifestation of inventive effort, patents represent a good measure of inventiveness or inventive activity. Globalization-driven escalation of the diffusion phase of innovation (Gilpin 2001, p. 135) suggests the greater significance of new ideas that feed the innovation process. Patents[3] have been used frequently in economics as an indicator of inventive activity (as part of the innovation process). After all, a patent application indicates some form of investment in a new idea and therefore represents a "minimal quantum of invention" (Griliches 1990, p. 1669). One of the ways to decrease the damaging effects of outgoing spillovers (knowledge leaked to competitors) is to ensure intellectual property rights (Arvanitis and Bolli 2012, p. 165), thus providing companies with the incentive to protect their inventions through patents.

Schmookler and Brownlee (1962), Kuznets (1962), Griliches and Schmookler (1963), Scherer (1965), Schmookler (1966), Mueller (1966), and Comanor and Scherer (1969) discussed the use of patent statistics as an indicator of inventive output. The more recent investigations based on patent data include studies on interregional differences in innovative activity (Broekel et al. 2015) or international competitiveness (Pavitt and Soete 1980; Dosi et al. 1990; Scherer 1992; Sood and DuBois 1995), while Jaffe and Trajtenberg (2002), for instance, worked on the methodology of patent analysis.

There are, of course, concerns about the validity of using patent statistics as a measure of inventive activity or, in a broader sense, innovation. For example, companies might not patent their ideas, out of fear that disclosing them would lead to imitation, especially in developing markets where intellectual property rights are not guarded as well as in industrialized countries. There are alternatives to the operationalization of inventive activity as patent statistics for the purposes of cross-country comparisons. Taylor (2009),

[2] These indicators mirror indicators in the World Bank Doing Business index.

[3] According to WIPO, a patent is a "set of exclusive rights granted by law to applicants for inventions that are new, non-obvious, and commercially applicable. It is valid for a limited period of time (generally 20 years), during which patent holders can commercially exploit their inventions on an exclusive basis." See WIPO Glossary at http://www.wipo.int/ipstats/en/statistics/glossary.html.

for example, in addition to using patent data from the US Patent and Trademark Office (USPTO) as numbers of patents per capita, utilizes two other measurements of innovation, namely scientific publications (per capita) and high-technology exports (p. 131). Tebaldi and Elmslie (2013) use patent statistics from the USPTO as a proxy for innovation together with other measurements such as science books and other non-periodical publications, as well as personnel engaged in R&D, measured as a total number of scientists, engineers, technicians, and supporting staff. For a cross-country comparison, Steel et al. (2012) use two multinational innovation indices: the International Innovation Index, by the Boston Consulting Group, and the Global Innovation Index, by INSEAD (p. 5). Griliches (1990, 1994), in the meantime, discusses the use of R&D expenditure as a measurement of inventive activity in addition to patent statistics.

Despite the alternatives, patent statistics, as a measure of inventive output, offer a number of advantages. First, patents are easily traceable to a specific company, and second, data are usually available and convenient to use.[4] The World Intellectual Property Organization (WIPO), a specialized agency of the United Nations, compiles data on patent filings and grants collected from national and regional (for example, the European Patent Office (EPO)) intellectual property (IP) offices and makes these data available to the public. Patent statistics, especially so-called international patents filed through the Patent Cooperation Treaty (PCT), could serve as a tangible indicator of the inventiveness of global innovators, since the international orientation of these patent applications is implied. We can assume that when firms file for patents abroad, they indeed intend to realize these inventions in a foreign country. Moreover, what characterizes the PCT path is the ability to file for multiple national patent protections simultaneously in up to 151 PCT member states. The PCT thereby offers a truly global mechanism, but additionally, it provides fee reductions to small business (PCT Working Group 2012, p. 3), which makes it overall more attractive to small, technology-intensive start-ups pursuing a strategy of accelerated internationalization.

Methodology

The use of PCT applications as a measure of invention

The PCT is an international treaty with 151 contracting states,[5] through which applicants can seek patent protection for an invention simultaneously in a number of countries by filing a single "international" patent application with the WIPO or a national (or regional) patent office. This initial filing through the WIPO PCT mechanism allows companies to save time and resources before the so-called national phase of patent application, which involves applying to national patent offices where an applicant seeks protection (WIPO, Protecting your Inventions 2014). Various fee reductions available to small businesses (WIPO, Protecting your Inventions 2014)

[4] Using the PATENTSCOPE, the WIPO Statistics Database provides an opportunity to search 43 million patent documents, including 2.5 million published international patent applications under the PCT. Furthermore, PATENTSCOPE makes available patent statistics in the form of all PCT applications published by WIPO for a number of recent years, which was especially helpful to this project.

[5] Please see at WIPO, PCT System, http://www.wipo.int/pct/en/pct_contracting_states.html. Accessed on October 28, 2016.

make the PCT process especially attractive to small, internationally oriented, technology-intensive companies (PCT Working Group 2012, p. 3) or, in other words, global innovators. Moreover, the fact that PCT cuts red tape and allows for a simultaneous filing for patent protection in all PCT member nations makes it especially attractive to ambitious start-ups vying to enter international markets.

We attempt herein to address the lack of research on the inventive aspect of the behavior of technology-driven firms, by targeting companies that have applied for a patent through the PCT mechanism. Specifically, we intended from the outset to look into the relationship between two groups of patent applicants (large MNEs and global innovators) and local institutions. These two types of private enterprises should, as we expected originally, have different levels of dependence on the levels of corruption and the quality of the business environment, as expressed by the CPI and DTF. To address this assumption, we first needed to identify MNEs and then global innovators—hidden in patent statistics among other types of organizations, including government agencies, academia, and individuals. Therefore, global innovators were identified based on the principle of exclusion. We used all patent applications published on PATENTSCOPE, WIPO's patent database, in 2013.[6] Since the same application can go through various stages of assessment in a given year, we removed all duplicates, based on the unique identification number assigned by WIPO to each applicant, and ended up with a list of 221,613 applications.

Selection procedure for MNEs and global innovators

The multistage selection procedure employed to isolate MNEs and global innovators utilized the regular expression technique in Perl (script language). The categorization of applications was based on the first-mentioned applicant. First, using an algorithm written in Perl, we isolated the applications of the 500 largest companies based on The Fortune Global 500 list (2015),[7] because the vast majority of these 500 companies are MNEs. After isolating these organizations, we checked the remaining list of PCT applications in 2013 against the list of MNEs on Wikipedia. Despite its lack of references, the Wikipedia list, containing about 400 MNEs, is a compilation of public inputs, as the listing of these companies represents an act of public selection.[8] All of the listed companies operate in more than two foreign locations with high levels of control or ownership of operations abroad. The PCT applications filed by the selected companies, based on The Fortune Global 500 (2015) and the Wikipedia MNEs list (2017), were placed into the group called "MNEs."

The second selection phase involved isolating universities, other institutions of higher education, and government agencies or government-sponsored institutes

[6] WIPO publishes a patent application on PATENTSCOPE shortly after issuing a written opinion on the invention patentability by an International Searching Authority (ISA) or 18 months following submission (WIPO, Protecting your Inventions 2014). On the WIPO Statistics Database, the nationality of a patent application, expressed as a two-letter country code, is determined by the country where the application was filed. It usually coincides with the country affiliation of the applicant.

[7] The Fortune Global 500 list contains the world's largest corporations, each ranked based on total revenue. Details on the methodology can be found at http://beta.fortune.com/global500/ (accessed May 2017).

[8] The full list of MNEs on this list can be found at https://en.wikipedia.org/wiki/List_of_multinational_corporations. Accessed September 2017.

involved in research. Based on the keywords "government," "agency," "ministry," institute," "university," "univers," "academy," "academic," "college," "école," "fund," and "foundation," we screened the PCT filing list for government agencies, research institutes, and universities. As such, we removed academic and government applicants from the remaining list of 2013 PCT applications. The words "national," "federal," and "state" turned out to be poor indicators of government ownership, since many private firms use these adjectives in their names. We also checked for the keyword "center" and, where appropriate, removed these applications as well.

Finally, we removed all individual applications, e.g., those filed by individuals as applicants without an organizational affiliation. Individual applications on PATENTSCOPE are identifiable based on the last name of the applicant, followed by a comma and then his/her first name. To ensure that no companies were removed as "individuals," we searched the resulting listing for applications that featured the abbreviations LTD, LLC, INC, GMBH, and AG, and then we added them back onto the global innovators' list.

The remaining 110,018 patent applications (after the removal of MNE, individual, government, and academia applications) constituted the filings of global innovators, which is almost half of all PCT applications in 2013. Since we defined global innovators as innovative and internationalizing SMEs (as well as larger companies that do not possess the status and weight category of MNEs), we went through the list manually, to identify any "deviant" cases belonging to the above-mentioned categories of MNEs', individual, government, and academia applications. To verify the accuracy of our selection procedure, we used the RAND function in Excel, which produced random numbers to select a sample of 100 PCT filings from the total group of 110,018 patent applications made by global innovators, belonging in total to 94 companies. We went through each application and then researched and vetted each company based on numbers of employees. As a result, applicants were divided into five categories.[9] In total, 51% of our sample consisted of large companies with over 1000 employees, 36% were SMEs with between 1 and 200 employees, and 11% were firms that employed between 201 and 1000 staff. We were unable to identify the number of employees for two companies. No applications filed by individuals, MNEs, government, or academia were found in our sample, which indicates a zero sampling error. As anticipated, significant numbers of global innovators were small businesses. PCT patent statistics can capture the inventive behavior of innovation-driven internationalizers, small or large, as these companies take advantage of trade liberalization, advances in technology, including the Internet, and accessibility to patent application platforms such as the WIPO PCT mechanism, in order to expand internationally.

As a result of the selection procedure described above, two distinct groups of PCT applications were identified: MNEs and global innovators. The next step was to compare the two groups vis-à-vis the two institutional variables. The 62,778 PCT applications made by MNEs and 110,018 by global innovators were sorted based on the country where the application was filed (WIPO assigns a two-letter country code to each application). MNE applications for 20 countries and global

[9] We studied each company individually and looked for information on the number of employees on LinkedIn, corporate websites, and Bloomberg.com. The five categories of companies were inspired by fixed categories for the number of employees on LinkedIn.

innovator filings for 43 (additionally, we accounted for EP applications,[10] which were calculated as the average for all 38 EPO members) were adjusted for population (per million).[11]

Institutional variables and patent data

A linear regression analysis was employed to test the assumption that global innovators are especially sensitive to the quality of institutions, as opposed to more established MNEs.[12] Specifically, we looked at the relationship between patent statistics and two institutional indices: the Corruption Perception Index (CPI), by Transparency International, and the Distance to Frontier (DTF) score of the Doing Business Index, by the World Bank. The two indices are used frequently to discuss the conduciveness of the business environment to economic development. For instance, the Doing Business Index has been used in DiPietro (2009) and Corcoran and Gillanders (2015), while the CPI has been employed by Halkos and Tzeremes (2010), Mellahi et al. (2012), and Stachowicz-Stanusch (2013).

The DTF is a comprehensive index that covers a broad range of environmental indicators. It ranks economies on the ease of doing business, the quality of the regulatory environment, and basic business infrastructure, including protection of property rights, tax systems, and contract enforcement. Thus, the score is an aggregate value based on ten topics covering the major areas of business practices and regulations. The DTF assesses the distance of each economy away from the "frontier," i.e., the best performance identified across all economies, which is measured on a scale ranging from zero to 100, where zero represents the lowest performance.[13] This project used DTF scores for 43 countries and a cumulative score for EPO members for 2013. We incorporated the CPI into our analysis, because corruption is not measured directly by the DFT.[14] The CPI ranks countries based on surveys and expert assessments of corruption within the public sector. A country's score indicates an aggregate assessment of the corruption level on a scale from zero to 100, where zero indicates the maximum level of corruption.[15] This project used CPI scores for 43 countries and a cumulative score for EPO members for 2013.

[10] EP is a two-letter code assigned to patents filed with the European Patent Organization (EPO). The organization has 38 countries as members. The average of CPI and DTF scores for all EPO members, as well as populations, was calculated. All EU members are also members of the EPO and frequently apply for so-called European patents via this body rather than through their domestic patent offices.

[11] Countries that had fewer than ten applications were removed.

[12] Guided by the distribution of data, we checked if the quadratic model would have been more appropriate. The linear regression model was found to provide a better fit.

[13] The World Bank Distance to Frontier (DTF) score cross-country data, as well as a detailed description of the methodology, can be found on the World Bank's website at http://www.doingbusiness.org/data/distance-to-frontier

[14] The national scores of The Doing Business Index and CPI are strongly correlated (Mongay and Filipescu 2012).

[15] CPI cross-country data, as well as a detailed description of the methodology, can be found on Transparency International's website at http://www.transparency.org/cpi2013/in_detail

Based on our data, the CPI and DTF are highly intercorrelated. The Pearson correlation coefficient for the relationship between the CPI and DTF was 0.81 for global innovators and 0.75 for MNEs. Both correlations are significant at the 0.01 level (two-tailed), which confirms the findings of Mongay and Filipescu (2012). Due to the collinearity of the CPI and DTF, we had to run separate bivariate regressions for the two institutional indices and patenting in both PCT application cohorts. Thus, we utilized a simple linear model based on one predictor, namely $Y = \beta_0 + \beta_1 X + \varepsilon$.

Findings

Figure 1 outlines the relationship between the average CPI and DTF scores for each country and the PCT applications of global innovators per million of population. EPO members (EP applications), Japan, Finland, USA, Denmark, Sweden, South Korea, and Israel are innovation leaders. The figure reveals an easily discernable trend, in that there is a steep increase in the number of patents per million of population at the point where the average of the CPI and DTF scores is between 60 and 70%. This is the "threshold of inventive activity" in respect to the level of corruption and quality of the business environment. After countries step over this threshold of institutional quality, the number of patent applications (per million of population) increases visibly. The countries that did not reach the threshold were Ukraine, Russia, India, Brazil, China, and Mexico, which are shown in the dashed line box in the lower left corner. Indeed, developing economies are contextually different from mature economies, as they feature weak

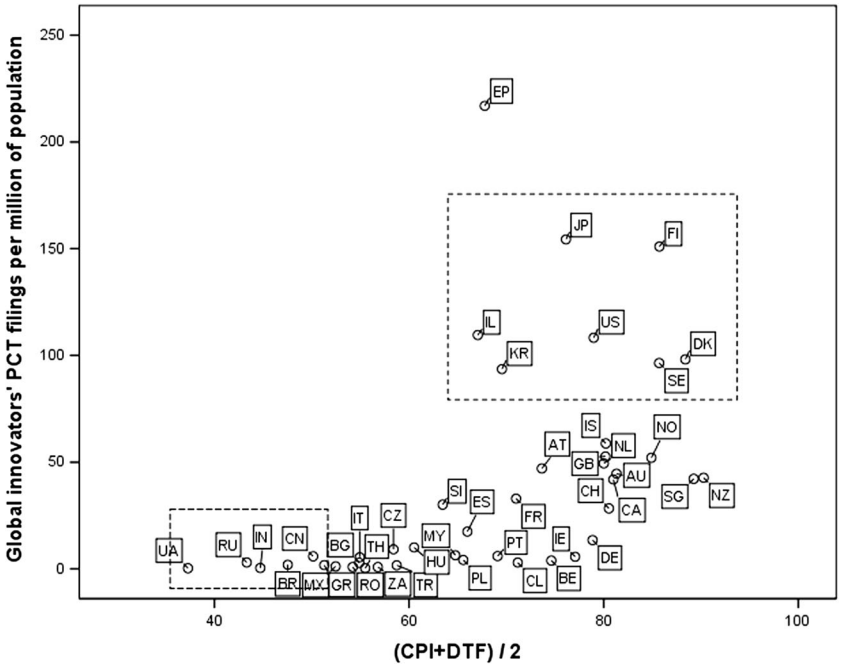

Fig. 1 PCT applications per million of population by global innovators and average CPI and DTF scores for 2013. *Source of data*: WIPO Statistics Database (2015)

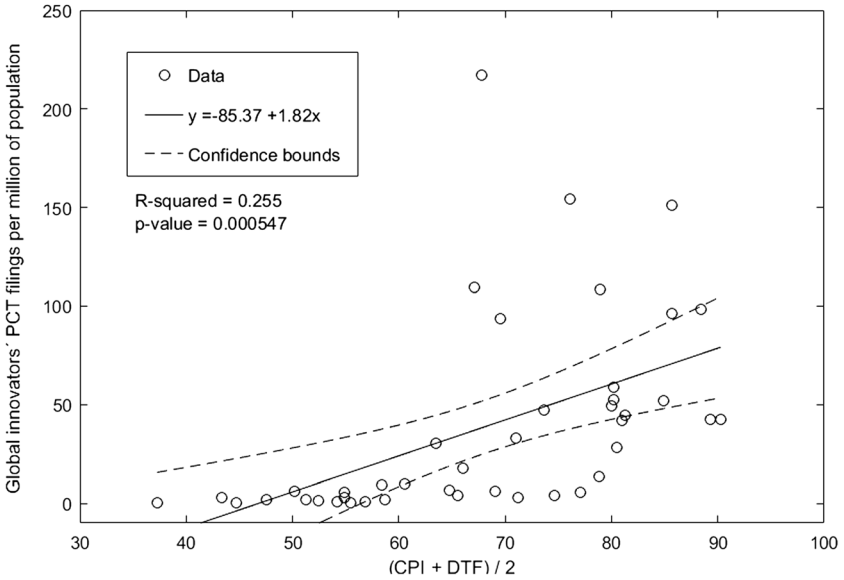

Fig. 2 Fit line: PCT applications per million of population by global innovators and average CPI and DTF scores for 2013. *Source of data:* WIPO Statistics Database (2015)

regulatory institutions as well as social and normative institutions that are not conducive to entrepreneurship (Ahlstrom and Bruton 2010).

It should be noted that many EU firms file for an EP patent. Accordingly, the fact that many EU members in southern and eastern Europe are clustered at the threshold might not be fully reflective of their inventive output. EP patent applications per million

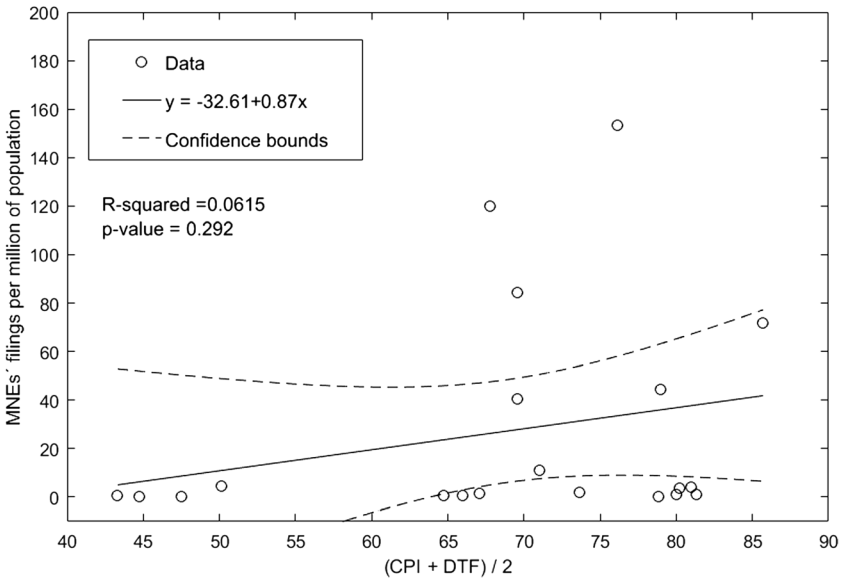

Fig. 3 Fit line: PCT applications per million of population by MNEs and average CPI and DTF scores for 2013. *Source of data:* WIPO Statistics Database (2015)

of population are located above all single countries and denote an average of the CPI and DTF scores of all 38 EPO members, including all EU members. However, the success of global innovative companies (the dashed line box in the upper right corner) in Japan, Finland, USA, Denmark, Sweden, South Korea, and Israel is still undeniable.

Figure 2 shows the fit line for the linear relationship between the average CPT and DTF scores and PCT applications made by global innovators per million of population. Based on the graphics alone, we can deduce that there is a relationship between PCT applications filed by global innovators and institutional indices. Looking into the two indices separately and their relationship with global innovators' applications, the number of PCT applications for global innovators could be predicted from the CPI by the following formula: PCT applications per million of population = − 41.89 + 1.3 × CPI, $R^2 = 0.25$; and from DTF: PCT applications per million = − 133.93 + 2.33 × DTF, $R^2 = 0.21$. Both relationships are significant at the 0.01 and 0.02 levels, respectively. Figure 3 shows the fit line for the linear relationship between average CPT and DTF scores and PCT applications filed by MNEs per million of population. The relationship between MNEs' patent applications and the two indices is not statistically significant. Indeed, data on the MNE chart are scattered and no visible pattern is discernable. Thus, there is no relationship between PCT applications by MNEs and our institutional indices.

Discussion

The innovative activity of global innovators has an association with the two institutional indices, while that of MNEs does not do so. The number of international patent applications generated by global innovators is linked to institutional quality, a conclusion confirming the importance of institutions conducive to innovation and especially the internationalization of innovation. We explain this outcome by the fact that, based on our estimation, one quarter of global innovators in a sample of over 100,000 PCT applicants are SMEs, and they are more sensitive to the quality of the business environment, as they do not possess resources similar to established MNEs.

Innovation theory suffers from a lack of understanding of the internationalization process in SMEs and more generally in global companies such as global innovators. Most research in this regard focuses on MNEs and their international innovation strategies. There is a reason, however, why smaller companies are able to compete globally. The internationalization of innovation is part of this success story and must be studied carefully, among others, by conducting large-scale surveys at the firm level. For the first time, we used an alternative approach and explored the possibilities of capturing with patent statistics the internationally oriented inventiveness of global innovators at the national level. We studied all (over 221,613) international patent applications published on PATENTSCOPE, the WIPO Statistics Database, in 2013 and isolated filings by global innovators and MNEs by employing a vigorous selection process. Our contribution lies in developing a selection procedure that can isolate global innovators from other types of organizations involved in international patenting, whereby they do not have the same resources as MNEs, and their impact is hard to deduce, especially at the macro level. In this respect, profiting from our selection procedure, the category of global innovators constitutes a promising subject for future research.

The main contribution is the attempt to delve into the link between the internationally oriented innovative behavior of global innovators and the domestic business environment by utilizing two indicators, namely corruption and business climate. We explored whether global innovators and MNEs demonstrate different patterns of interactions with institutions. PCT applications in both groups were counted, adjusted against the population (per million), and regressed with two sets of institutional indices for 2013: the Distance to Frontier (DTF) score and the Corruption Perception Index (CPI). Global innovators were identified as a separate group of companies (many of them SMEs) pursuing the internationalization of innovation and having a "special" relationship with domestic institutions. Even though the role of corruption and the quality of the business environment have been emphasized previously as being important determinants of the national rates of innovation (Svensson 2003; Paunov 2016; Minh and Hjortsø 2015), we demonstrated empirically that the institutional configuration affects not only innovation per se, but also the internationalization of innovation, especially in the group of global innovators. Furthermore, previous research relied mainly on case studies and company surveys to look into the effects of the two institutional factors on the innovative efforts of SMEs. We captured the effect of these factors at the macro level.

Perhaps the most important finding pertains to the nature of the relationship between international innovation efforts and institutional indices. The linear regression equations for both the CPI and the DTF contain negative constants or intercepts, implying that when the CPI and DTF values are at 0 (maximum corruption and lowest quality of business institutions), the numbers of PCT applications made by global innovators go down. Thus, the more corrupt and institutionally challenged the environment, the less likely global innovators will produce international patents. Thus, we do not find evidence that smaller companies internationalize their inventions in the effort to escape corruption and deficient institutions, as suggested in Paunov (2016) and Omer et al. (2015). Based on our data, a poor institutional environment leads to fewer international patent applications, which might imply altogether lower innovative output.

Conclusions

The results of the linear regression analysis point to a relationship between global innovators and the two institutional indices: the Corruption Perception Index (CPI), by Transparency International, and the Distance to Frontier (DTF) score of the Doing Business Index, by the World Bank. Based on our data for 2013, no significant relationship was found between MNEs and institutions. We suggest that the most plausible explanation for this difference is that the internationally oriented innovation of global innovators is more susceptible to the effects of institutions in their home markets. SMEs found among global innovators are more dependent on institutions, due to the lack of ownership advantages and other resources compared to MNEs. Furthermore, our data revealed an interesting pattern in the relationship between institutions and international patenting activity, namely the so-called threshold of inventive activity. There is a steep increase in the number of granted patents per million of population at the point where the CPI and DTF scores are about 60%, and so countries that enjoy an institutional environment advantageous to inventive activity produce more patent applications. What

this means in practical terms is that outward entrepreneurial activity, boosted by innovation, especially in SMEs, thrives in countries ranking higher in terms of institutional development and conduciveness to business. Indeed, we confirm that—as per Zhu et al. (2012)—SMEs require more support in the form of "entrepreneur-friendly institutions" (p. 1140). This conclusion could serve as a guiding principle for those developing or emerging countries aspiring to help SMEs export their innovative efforts.

This outcome has implications for both future research and policymaking. We should take a closer look at specific institutional arrangements that work best for global innovators, in order to promote their innovative efforts. This is the limitation of our approach, though, as we utilize DTF and CPI, which are general, broad-spectrum indicators. Our results show, however, that corruption and defective business environment do not drive small businesses to internationalize their innovations. On the contrary, since the constants of the linear regression equations have negative values, the lower the DTF score, the fewer patent applications global innovators will produce. The same applies to the levels of corruption expressed as CPI. Thus, the poorer the business conditions and the higher the levels of corruption, the less likely global innovators are to generate and export innovation. As a result, the internationalization of innovation does not serve as a route for smaller firms to escape from domestic institutional deficiency. In other words, there is no silver lining, and so firms, especially SMEs, tend to rely on institutional support at home.

Acknowledgements The authors would like to thank anonymous reviewers and the editor for their careful and sympathetic reading of our manuscript and their insightful comments and suggestions. The contribution of M. Zmuda was supported by the National Science Centre, Poland (2015/17/B/HS4/02075).

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