# FIRMS' GLOBAL PATENT STRATEGIES IN AN EMERGING TECHNOLOGY

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*Abstract* – **Despite international patenting can be a costly and risky investment, an increasing number of firms patent proprietary technologies in foreign countries. This paper explores trends of global patenting in a new domain of technology characterized by rapid globalization. The research setting consists of the population of U.S.-based Large and Small and Mid-Sized firms (SMEs) filing nanotechnology-related patent applications at the World International Patent Office (WIPO) during 1996-2006.**

**JEL CODES**: O31, O38, H32, C25, C35.
**KEYWORDS**: Globalization; SMEs; MNCs; Patents; Emerging Technologies; Emerging Markets.

## I. INTRODUCTION

The decision on where, when, and what to patent abroad is complex. International patenting may be necessary to protect sales and technical inventions in foreign markets, but it usually implies high costs and high risks. In addition to the costs of applying, translating and maintaining patents in multiple countries, substantial hidden costs can emerge with the infringement and enforcement of patent rights. Entrepreneurs and small companies are particularly vulnerable to these hazards, as they typically face time constraints, limited financial resources, and less knowledge of foreign patent systems. Not surprisingly, the U.S. General Accounting Office advises small businesses to "cradle-to-grave" every aspect of holding and enforcing foreign patents during their average 20-year life span (GAO, 2003).

Despite these obstacles, evidence suggests that the international exploitation of technology has become popular during last decades. For example, Archibugi and Iammarino (2002) show that the share of non-resident patenting and the share of patent applications for national inventors abroad increased in all OECD countries during the early 1990s. Data from WIPO (2008) reveals a significant increase of international patent applications in the late 1990s and early 21st century. For U.S. assignees WIPO applications more than doubled, rising from 23,845 in 1997 to 50,134 in 2006. Work by Schmoch (1999) and Mogee (1996) point to similar conclusions.

A number of factors could explain the increased globalization of patenting. The first is that patent reforms (and associated institutional changes like stronger patent systems and harmonization of patent laws) have changed the incentives to obtain patents abroad (Kortum and Lerner 1998; Lerner 2002; Eaton et al. 2003). An alternative view is related to the greater importance of patents as tools to gain competitive advantage (Grindley and Teece 1997; Rivette and Kline 2000; Cohen et al. 2000; Hall and Ziedonis 2001). A third argument is in line with new international business theories. Multinational Corporations (MNCs) decentralized competence models (Cantwell 1995; Florida 1997; Birkinshaw et al. 1998; Kuemmerle 1999; Frost 2001), and the international new venture approach (Oviatt and McDougall, 1994; Knight and Cavusgil, 1996, Bell et al. 2004) point that businesses do not necessarily pass through a series of predetermined internationalization stages, involving gradual entry in foreign markets through exports, foreign direct investment and licensing. Instead, patterns of internationalization are path dependent, diverse and determined to a large extent by firms' vision about international opportunities. Patenting abroad is therefore a globalization strategy that fits well with current business practices of both small and large firms. Despite conceptual advances, we still know very little about how and why companies patent abroad.

The aim of this paper is to contribute to this area of research by better understanding global patent strategies in a new domain of technology characterized by rapid globalization and cumulative innovation. In particular, the paper explores how U.S.-based small and large firms differ in their approach toward the international exploitation of technology, and whether systematic differences exist between companies that face unequal barriers to invent and patent abroad.

## II. RESEARCH SETTING

The emerging field of nanotechnology is the focus of this analysis. Nanotechnology refers to a set of technologies involving the creation and manipulation of structures, materials and components at a nanometer scale (one nanometer being a billionth of a meter). Nanotechnology is not an industry *per-se*, rather it involves multiple industrial fields such as engineering, biotechnology, medicine, physical

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sciences and information technology (Rocco and Bainbridge 2003; Nordmann 2004).[1]

Several reasons support the selection of this research setting. First, the development of nanotechnology has become a global phenomenon during the last decade (Youtie et al. 2008). Zucker and Darby (2005) observe that many countries with a limited number of nanotechnology-related articles in the early 1990s increased their production dramatically in the late 1990s and 21st century. Countries like China, India and South Korea are notable examples of this expansion. Similarly, their findings suggest that almost 150 countries had cited publications by 2003. Fernández-Ribas and Shapira (2009), using the Georgia Tech nanotechnology patent database show that during 1996-2006, the most technologically active U.S.-based multinational corporations (MNCs), albeit not decentralizing their invention activities done at home, increasingly develop inventions abroad. As the number of nanotechnology locations increases worldwide, companies may have little choice but to adapt their business strategies to new market conditions, including strategies based on the global exploitation of technology. Moreover, since nanotechnology is a newly emerging focus of invention, it is likely to reflect the latest patenting strategies of companies.

The research setting is also adequate because nanotechnology is characterized for being highly interdisciplinary, complex and cumulative. Avenel et al. (2007) find that the breadth of corporate publications and patents in nanotechnology spreads over a large number of fields, regardless of firm size. Fernández-Ribas and Shapira (2009) also show that the technological diversity of host countries explains to a large extent where firms locate inventive activities abroad. Companies developing such technologies are more likely to use patenting for strategic reasons, such as securing relationships with suppliers and manufactures and improving the bargaining power of companies in future licensing and cross-licensing negotiations (Grindley and Teece, 1997; Cohen, Nelson and Walsh, 2000). Where and why companies seek patent protection and whether small and large firms follow similar or different paths, however, remain empirical questions.

## III. Data Sources

To track the dynamics of global patents I use a panel of international patent applications filed during 1996-2006 through the World Intellectual Property Organization (WIPO Patent Cooperation Treaty (PCT) applications), contained in the nanotechnology patent database developed by the Program in Research and Innovation Systems Assessment (CNS-ASU Center for Nanotechnology in Society) at Georgia Tech (GT). This database gathers more than 50,000 nanotechnology related patents identified using a representative set of nanotechnology key words. To build this database the GT team consulted a group of scientific experts who proposed approximately 16 keyword search terms. Simple measurement terms that typically appear when doing a generic search of nano (e.g. nano*) were excluded from this definition. This included, for example, measure terms such as nanomet* and nanosecond* or chemical symbols, such as NaNO3. Selected keywords were then adapted for a subsequent patent search in patent titles, abstracts and claims within the MicroPatent database. To avoid patent duplications, one patent record was selected per patent family using as main criteria the priority date.[2]

This database is supplemented with information about the geographic breadth of patents, extracted from WIPO PCTs "national phase" reports. The PCT national phase is the second stage of the PCT process. In the first stage patent owners designate countries for patent protection and WIPO provides a preliminary and non-binding opinion about whether the claimed invention is novel, non-obvious, and industrially applicable. In the second stage PCT applicants decide in which countries they want to protect their inventions. Since this information was not included in the GT nano patent database an additional search of patent application numbers was conducted at WIPO's publicly available Patentscope® database.

To capture company's structure and size several sources were consulted, including Lexis-Nexis business directories, 10-K reports of the Securities and Exchange Database, Hoover's Company records, Dun and Bradstreet, and Mergent. The study then applies the definition of 'small' by the Small Business Administration (SBA) and refers to companies with 500 or fewer employees that are not subsidiaries of other corporations.

## IV. Data Characteristics

Table 1 reports the number of international patents applications assigned to small and large businesses. Overall the small firms make up 37 percent of all international patent applications assigned to for-profit U.S. owned organizations. As expected there are less large firms in the sample than small firms, 234 and 335 respectively. The number of patents assigned to the most technologically active (firms with 5 or more patents) is much higher for the largest firms, 78 percent. This finding points to the presence of certain bias in the studies that focus on companies with the largest number of patent applications, and results to a certain underestimation of the contribution of small firms patents in the development of emerging technologies. Time trends indicate that the number of small firm international patent applications has risen both in absolute terms and relative to large firms' patents during 1998-2003. However, from 2003 til mid-year 2006 the share of small firm patents decreases.

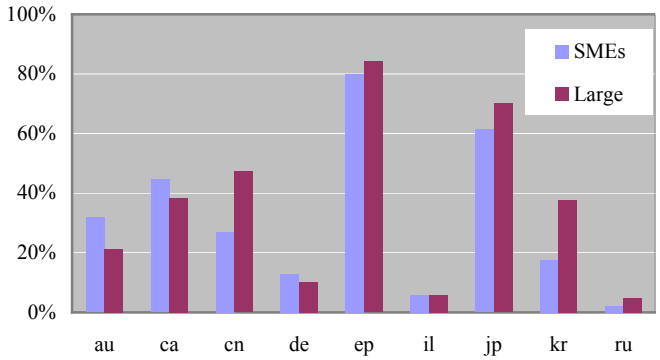
[1] The origin of nanotechnology draws back to the 60s when Nobel laureate Richard Feynman envisioned the potential use of material and devises at the atomic and molecular size. However, the take off of this field is placed in the 80s when a series of enabling inventions, including the scanning tunneling microscope (STM) and the atomic force microscope (AFM) were developed by IBM (Darby and Zucker 2003).

[2] Details of the search method have been published in Porter et al. (2008). Other studies, including Huang et al. (2003) and Zucker and Darby (2005), have already drawn on similar search algorithms and data, albeit using different questions.

TABLE I
PCTs PATENT APPLICATIONS ASSIGNED TO U.S. PRIVATELY OWNED COMPANIES

| | | Large | SMEs | |
|---|---|---|---|---|
| All | Firms | 234 | 335 | 569 |
| | | 41% | 59% | |
| | PCTs | 907 | 528 | 1435 |
| | | 63% | 37% | |
| Five or more patents | Firms | 28 | 14 | 42 |
| | | 67% | 33% | |
| | PCTs | 673 | 193 | 866 |
| | | 78% | 22% | |

FIGURE I
GEOGRAPHIC BREADTH OF PCTs PATENT APPLICATIONS



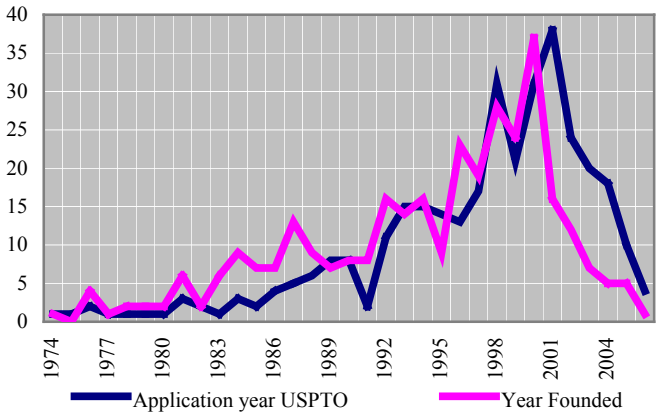

Note: Codes of countries are as follows: au: Australia; ca: Canada; cn: China; de: Germany; ep: EPO; il: Israel; jp: Japan; kr: Korea; ru: Russia.

Figure 1 shows that the geographic scope of patent protection is rather similar for small and large companies. Despite the higher costs of the European Patent Office (EPO), this is the preferred route to protect patents both for small and large firms. These results are in line with Peeters and Pottelsberghe's (2006) findings and seem to indicate a lack of causal relationship between firms' perceptions on patent costs and the decision to apply for patents at the EPO. However, the fact that small firms seek protection in Germany more often than their larger counterparts (instead of using the EPO-German route) is also an indication that for some small firms the higher cost of patenting at the EPO is an issue. The Japanese Patent Office (JPO) is the second most preferred patent system across companies. Some 69 percent of large firm patents and 59 percent of small firms patents file at the JPO. A remarkable difference between firms can be seen in emerging economies. Large businesses appear to file more patent applications in China and Korea than small firms. This difference is about 17 percentage points for China and 19 percentage points for Korea. Concerns about the liability of foreignness and the "psychic distance" can be deterring SMEs from patenting in these countries. By contrast, there is a larger number of SMEs seeking patent protection in countries with stronger patent systems such as Australia and Canada.

Results also show that small firms seek patent protection in fewer countries than larger firms. Several authors suggest that the family size of a patent (and, by extension, the geographic breadth of protection) is positively correlated with the expected profitability of an invention. Inventions with high expected profitability tend to be patented in a larger number of countries. However, one can also argue that larger companies patent more and in more countries both commercially-valuable and less-commercially-valuable inventions.

Regarding the age of SMEs a number of interesting findings emerge. Eighty percent of the SMEs included in the sample were founded from the early 1990s onwards. However, it can be observed that the number of new established companies grows slowly since the early 21st century (see figure 2). This phenomenon is likely to be related to the 2000 vintage of venture capital and the consequent reduction of the number of small companies founded after 2000. About 30 percent of the SMEs apply for a patent at WIPO, three years or earlier that founding (or applying for a USPTO patent for the first time).[3]

FIGURE II
DISTRIBUTION OF SMEs BY FIRST USPTO APPLICATION YEAR AND BY FOUNDATION YEAR

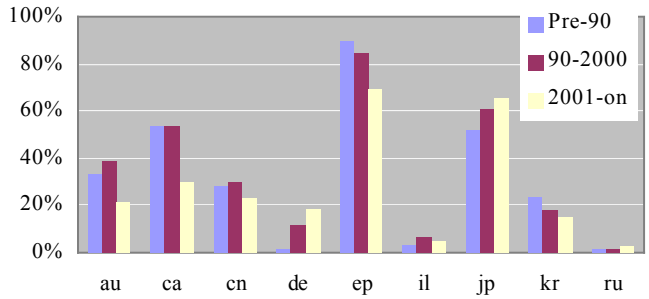



Interestingly, when crossing age and patent offices, it turns out that small companies founded after 2001 have narrowed the geographic scope of patent protection. Start-up firms, funded after the 2000 vintage of venture capital, appear to be more selective in their choices about where to patent (see figure 3). In particular, the data shows that these firms have

[3] To have an accurate picture of the age of an SME, this study uses two measures. The first is based on first application year at the USPTO. The second is based on year founded according to archival data.

reduced the relative number of patenting filings at EPO, and have increased the number of patent applications at the German and Japanese patent offices. These results are in line with the recent findings of van Pottelsberghe and van Zeebroeck (2008). Their longitudinal analysis of EPO patents also suggest that EPO applicants increasingly tend to focus on few patent offices (Germany, France and the UK) rather than on a larger number of European countries.

FIGURE III
GEOGRAPHIC BREADTH OF PCTS PATENT APPLICATIONS BY TYPE OF SMES




Note: Age based on application year at the USPTO. Pre-90 firms with first USPTO application is before 1990, 90-2000 firms with first USPTO is during 1990-2000, 2001-on firms with first USPTO is after 2001.

## V. EMPIRICAL RESULTS SMALL VS. LARGE FIRM PATENTS

To study differences across small and large firms I set up to estimate a simple discrete choice model, where the dependent variable, Y, equals 1 if the company is a SME and 0 if it is a large company. Independent variables refer to a number of patent-related characteristics found to be significant in previous studies. *Patent cost* is proxied by the total number of inventors associated with a patent. The higher the number of inventors involved in the development of a technical invention the larger the cost of producing the patent. *Patent scope* is proxied by the total number of four digit different IPC classes of a patent. Large values of patent scope indicate more technological diversity of a patent. The novelty of a patent (and its relation to prior "state of the art") is proxied by the total number of *Backward patent citations* by the master data. Patents with a high number of patent citations can be considered less novel and more incremental than patents fewer citations. Other observable features of patents include characteristics of the location of invention. *Invented at home* equals 1 if the city of residence of the inventor/s is solely in the U.S. *Invented abroad* equals 1 if the inventor(s) resides outside of the U.S. *Invented intra-state*, equals 1 if a patent has been invented in more than one U.S. state. *Invented inter-state* equals 1 if inventor cities are in more than one state. Year effects are grouped into two five-year periods (1996-2001, 2002-2006) and into single years. Regional effects include dummy variables for each U.S. state that has at least one invention city. Table 2 reports the descriptive statistics for each firm type.

TABLE II
DESCRIPTIVE STATISTICS

| Variable | Large | | SME | |
|---|---|---|---|---|
| | Mean | Std. Dev | Mean | Std. Dev |
| Patent Cost | 3.28 | 1.97 | 3.06 | 1.94 |
| Patent Scope (IPC-4) | 1.76 | 0.99 | 1.75 | 1.10 |
| Backward patent citations | 3.81 | 3.10 | 3.30 | 3.21 |
| Time dummy 1996-2001 | 0.49 | 0.50 | 0.40 | 0.49 |
| Time dummy 2002-2006 | 0.51 | 0.50 | 0.60 | 0.49 |
| Invented at home | 0.91 | 0.29 | 0.99 | 0.09 |
| Invented abroad | 0.15 | 0.35 | 0.04 | 0.19 |
| Invented intra-state | 0.46 | 0.50 | 0.52 | 0.50 |
| Invented inter-state | 0.18 | 0.39 | 0.21 | 0.41 |
| Total Obs. | 907 | | 528 | |

Table 3 reports the estimated marginal effects of a series of probit models, controlling for years and regional effects. Results suggest that small firm patents employ less inventors and cite less patents than large firm patents. Overall this may indicate that small patent owners are more productive as when developing cutting-edge technologies. The technological diversity of patents if found to be negatively correlated with the probability that a patent is developed by a small firm. However this is not found to be statistically significant.

TABLE III
ESTIMATED MARGINAL EFFECTS

| Variable | Pr(Y=1) | Pr(Y=1) | Pr(Y=1) |
|---|---|---|---|
| Patent cost | -0.08*** | -0.07*** | -0.09*** |
| | (0.03) | (0.03) | (0.03) |
| Patent scope | -0.02 | -0.02 | -0.02 |
| | (0.03) | (0.03) | (0.03) |
| Backward patent citations | -0.04** | -0.05** | -0.04** |
| | (0.02) | (0.02) | (0.02) |
| Invented intra-state | 0.07** | 0.06** | 0.06** |
| | (0.03) | (0.03) | (0.03) |
| Invented inter-state | 0.07** | 0.06** | 0.09** |
| | (0.03) | (0.04) | (0.04) |
| Invented abroad | -0.24*** | -0.23*** | -0.22*** |
| | (0.04) | (0.04) | (0.04) |
| Year dummy 2002-2006 | 0.07*** | | |
| | (0.03) | | |
| Year dummies | | yes | yes |
| Regional dummies | | | yes |
| Log likelihood | -904.93 | -901.5 | -882.3 |
| Observations | 1435 | 1435 | 1435 |
| Observations (Y=1) | 528 | 528 | 528 |
| LR chi2 | 78.18 | 85.06 | 123.4 |
| Correctly predicted | 63.62% | 64.32% | 64.67% |

Notes: z statistics in parentheses. *** denotes significance at the 1 % level; ** a 5 % level.

Results also point to significant differences in terms of invention location patterns. Large firm international patents are more likely to be developed abroad. This suggests that indeed there is a significant and positive link between inventions developed abroad and global patents of large businesses. By contrast, the marginal effect of inter-state and intra-state inventions is positive and significant, suggesting that physical proximity to other inventors and domestic spillovers are relevant for small firms and entrepreneurs.

## VI. Conclusions

This paper explores systematic differences in international patenting between small and large U.S. firms in the emerging field of nanotechnology. Empirical findings can be summarized as follows: (i) Small firms are contributing significantly to the global exploitation of nanotechnology; (ii) the geographic scope for protection is similar for small and large companies. However, there are some notable differences across companies. Large companies appear to be more prone to file patent applications in emerging countries such as China and Korea. SMEs are more conservative and patent in countries with strong IPR systems like Germany, Canada and Australia; (iii) the global protection of inventions starts early for many small companies; (iv) SMEs' internationalization process is not accompanied by a parallel development of inventive activities in foreign countries. By contrast, large patent holders have increased the number of inventions developed abroad. Overall, findings point to the different nature of inventions developed by small and large firms, their different modes of internationalization, and the "born global" character of many small companies. These results are consistent with the new international venture approach, and the idea that patterns of internationalization by small, young firms depend to a large extent on the firms' capabilities, technology and attitude toward innovation. Findings also seem to suggest that small nanotechnology firms face specific institutional and cultural obstacles when seeking patent protection in emerging economies.

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