Foreign Patenting Behavior of Small and Large Firms: An Update

by

Mary Ellen Mogee, Ph.D.
Reston, Virginia

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EXECUTIVE SUMMARY

This report summarizes the results of a study investigating U.S. small-business foreign patenting behavior and how it differs from that of large business. Patents in foreign countries are necessary to protect sales of innovative products in those countries. Lack of patent protection abroad may cause small businesses to lose potential sales, both through reduced marketing channels and through the copying of their inventions by foreign competitors — thus adversely affecting the U.S. economy.

This study covers domestic patents issued to U.S. small businesses in 1988, 1992, 1996, and 1998. The method employed was statistical analysis of pairs of small-business patents and large-business patents. Each pair was matched with respect to technology field and issue date.

The study found that small businesses patent abroad less often than do large businesses. Even when they do patent abroad, they patent in fewer countries than their larger counterparts. As this pattern persists in all fields of technology, it cannot be attributed to differences in the technology fields in which small and large businesses work.

Differences between the number of countries in which small-business and large-business patents are filed are explained to some extent by differences in the value of small- and large-business patents, but patent value is a much less important factor than company size. Both the public value of the patents, as measured by the number of citations from patents that belong to companies other than the owner (other-citations), and the private value of the patents as measured by the number of citations received from the owner's own patents (self-citations) and by patent renewal rates, have an effect. Private value as measured by self-citations has the greater effect, with an impact second only to that of company size. The private value of patents should be expected to have a substantial effect on a firm's decision on the number of countries in which to file patents, since the firm presumably makes the decision based on its estimate of the profit it can potentially earn with that patent.

Small-business patents have higher public value (i.e., value to parties other than the patent owner) than large-business patents, but large-business patents have higher private value (i.e., value to the company that owns the patent) than small-business patents. This suggests that the limited resources of small businesses not only inhibit them from filing for foreign patents, which are very costly, but also limit their ability to commercialize their patented inventions and thereby profit from them. As the patents of small businesses have high public value, this issue should be of concern for U.S. public policy.

INTRODUCTION

The growing importance of international commerce makes it vital for U.S. firms to have patent protection in foreign markets. A 1995 study[1] funded by the Office of Advocacy, U.S. Small Business Administration (SBA), and conducted by Mogee Research & Analysis (MRA), found that U.S. small businesses with U.S. patents issued in 1988 were less likely than were large businesses to file for protection for those inventions in other countries. The study showed that the reason small businesses patented a smaller proportion of their inventions abroad was not because their inventions were less valuable or because they invented in fields of technology where patent protection or foreign business is not important. Although it did not conclusively identify the causes for this pattern, the study suggested that U.S. small businesses might not be pursuing foreign commercial opportunities as fully as possible because of the challenges and costs associated with obtaining foreign patent protection. To further explore this issue, the Office of Advocacy has funded a follow-up study covering the years since 1988; this paper reports the results of that study.

BACKGROUND

Trends in Patenting

Worldwide use of the patent system is growing. From 1983 through 2001, patent applications at the U.S. Patent and Trademark Office (USPTO) tripled from about 100,000 to more than 326,000.[2] During this time, the percentage of domestic patent applications filed by U.S. patentees fell slightly, from 58 percent to 56 percent, while foreign origin applications grew correspondingly, from 42 percent to 44 percent.[3]

To fully understand worldwide patenting trends, one must distinguish between "priority applications"—the application filed in the first country where a company seeks patent protection— and "equivalent applications"—applications filed in additional countries, which indicate the geographic breadth of protection sought for that invention. Together, the priority and equivalent applications form a patent "family."

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[1] Mogee Research & Analysis Associates, "Foreign Patenting Behavior of Small and Large Firms," final report to the Small Business Administration under Contract No. SBA-8140-) A-94. March 5, 1996. Published as M.E. Mogee, "Foreign Patenting Behavior of Small and Large Firms," International Journal of Technology Management, *v.*19, (Nos. 1./2), 2000: 149-164 (special issue on Intellectual Property Protection and Economic Development edited by Edwin Mansfield and Edward D. Mansfield.)

[2] Data Source: U.S. Patent and Trademark Office, "U.S. Patent Activity: Calendar Years 1790 – 2001," *www.uspto.gov*, June 4, 2001. Data include patents of invention, design patents, and plant patents.

[3] Ibid.

At the global level, patent rights are becoming increasingly internationalized. Growth in the number of priority applications has been slow, worldwide, from 629,733 in 1994 to 665,233 in 1998. The number of equivalent patent applications, however, has grown rapidly, from 2.3 million in 1994 to 5.8 million in 1998. The fact that the growth rate for equivalent patent applications is outpacing priority filings means that patentees are seeking protection for their inventions in more countries. In 1994, each priority filing led to an average of 3.3 equivalent applications in other countries; by 1997, each priority filing led to an average of 8.8 equivalent applications.[4] The rapid expansion of patenting around the world raises the question of whether U.S. small business is following the same trend.

Small Business and the Economy

Small businesses are important to the U.S. economy, through sheer numbers as well as their contribution to production, jobs, and exports. Small businesses represent 99.7 percent of all employer firms, employ 51 percent of the work force and account for 51 percent of private sector output.[5] The SBA reported that from 1990 to 1995, small businesses accounted for 76.5 percent of the 6.85 million net new jobs.[6]

Small firms are also important as exporters. In 1997 they represented 96.5 percent of U.S. exporters of goods and contributed 30.6 percent of the value of exported goods, showing an upward trend from 1992.[7] Nonetheless, only about 1.8 percent of small firms export goods or services.[8] An exception is small high-technology companies; a 1999 study of this sector found that three-quarters of the respondents had foreign sales.[9]

The Role of Small Business in Innovation

Research provides evidence that at least some sectors of small business play an important role in technological innovation. For example, Lerner found that companies that won Small Business Innovation Research (SBIR) awards grew significantly faster than a matched set of firms over a 10-year period.[10] Another study of 228 small manufacturing firms found that the innovator firms

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[4] Data Source: Trilateral Statistical Report 1999, Trilateral Web Site (U.S. Patent and Trademark Office, European Patent Office, and Japanese Patent Office). http://www.european-patent-office.org/tws/tsr99/tsr.htm, August 8, 2002.

[5] U.S. Small Business Administration, Office of Advocacy, Small Business FAQ, May 2002.

[6] U.S. Small Business Administration, Office of Advocacy, Small Business Growth by Major Industry, 1988-1995, 1998.

[7] U.S. Department of Commerce, International Trade Administration, Trade Development, Office of Trade and Economic Analysis, Small & Medium Sized Exporting Small & Medium Sized Exporting Companies: A Statistical Profile; Results from the 1997 Exporter Data Base, December 1999.

[8] U.S. Small Business Administration, Office of Advocacy, *Exporting by Firm Size*, March 1998.

[9] Joseph J. Cordes, et al., "A Survey Of High Technology Firms," Submitted to Office of Chief Counsel for Advocacy, United States Small Business Administration, Contract No. SBA-8141-OA94, February 1999.

[10] Josh Lerner, The Government as Venture Capitalist: The Long-Run Effects of the SBIR Program, National Bureau of Economic Research Working Paper No. 5753, Cambridge, MA,1996.

were more likely than non-innovators to be among the relatively small number of companies with extremely high rates of growth.[11] The small high-technology firms studied by Cordes et al. were also very innovative.[12]

Consensus is growing among researchers that the roles of small firms and large firms in innovation are different, reflecting their relative strengths and weaknesses, and that these roles may be complementary.[13] Small firms seem to have organizational advantages. They are able to respond quickly to changing market demand, are organizationally flexible, and have efficient internal communications.[14] Larger firms have a relative material advantage. This reflects their ability to: "maintain sophisticated management teams; attract highly skilled technical specialists; support large R&D facilities; amass financing to support parallel R&D programs; easily connect to external sources of finance and technical expertise; benefit from scale and scope economies due to size and diversification."[15]

Small Businesses and Patenting

The two most important empirical studies of U.S. small business foreign patenting are the 1995 Mogee Research & Analysis (MRA) study and a study by the U.S. General Accounting Office published in 2002.

The MRA Study

The objective of the 1995 MRA study[16] was to learn whether small firms working in the same technological fields as large ones, and with inventions of equal or greater value, patent their inventions as broadly as their more sizeable counterparts. The study method was statistical analysis of matched pairs of small- and large-business patents issued in 1988. It found that small businesses patented abroad less often than large businesses and this was true in all technology fields and regardless of the value of the patents. Also, small businesses filed patents in fewer countries than large businesses. This was true in all technology fields and regardless of patent value. When only pairs where both the small-business patent and large-business patent were filed abroad were compared, however, these differences broke down to some degree.

[11] Mark S. Freel, "Do Small Innovating Firms Outperform Non-Innovators?" Small Business Economics 9 (4): 361-381, August 1997.
[12] Cordes et al., 1999.
[13] Cordes et al., 1999.
[14] Cordes et al., 1999.
[15] Cordes et al., 1999.
[16] MRA op cit.

The MRA study concluded:

> The evidence examined in this study suggests that the reason small U.S. companies patent a smaller proportion of their inventions abroad is not because their inventions are less valuable or because they invent in fields of technology where patent protection or foreign business is not important. By elimination, it thus seems likely that small U.S. businesses with valuable inventions face special barriers to obtaining and maintaining foreign patent protection because of limited resources. This is of concern because difficulty in deriving economic benefit from their inventions in foreign countries not only reduces the income of small businesses but also that of the broader U.S. economy, of which small businesses are an important part.

The GAO Study

In 2002 the U.S. General Accounting Office (GAO) published a study that examined factors that are important to the foreign patenting decisions of U.S. small businesses, whether there are particular factors limiting their international patenting, and whether any federal actions could help small businesses overcome impediments to foreign patenting. The study was based on interviews with about 40 small businesses with an interest in foreign patenting and a web-based panel discussion with about 40 patent attorneys who work with large and small businesses.

The study[17] found the most important impediment was foreign patent costs. Other important impediments were: companies' limited resources, limited foreign patent knowledge, differences in foreign patent systems, and the challenging business climate and weak patent enforcement in some countries.

Small Business's Use of Patents

More research has been done on small-business domestic patenting than on small-business foreign patenting. However, even here research to date has not yielded a clear picture of small businesses' use of the patent system. Some studies have found that small businesses make significant use of patents. A study done in 1981 of U.S. small innovative companies found that two-thirds of the firms surveyed held patents.[18] A 1991 study found that both large and small

[17] United States General Accounting Office, International Trade: Federal Action Needed to Help Small Businesses Address Foreign Patent Challenges, Report to Congressional Requesters. Washington, D.C.: July 2002 (GAO-02-789).

[18] Judith H. Obermayer, The Role of Patents in the Commercialization of New Technology for Small Innovative Companies, 1981. Contract awarded in FY 1980 to the Research & Planning Institute, Inc., 137 Main Street, Cambridge, MA 02142. NTIS order number PB84-212067

businesses regarded patents as important ways to protect intellectual property.[19] A 2002 study of Norwegian small businesses found them to be major users of that country's patent system.[20]

Most studies, however, have found that small businesses do not use the patent system much, use it ineffectively[21] or do not regard patents as important as informal mechanisms for protecting IP such as proprietary know-how and trade secrets.[22] These findings are consistent with a major survey of large firms conducted in 1987 by Levin et al. That study found that trade secrets and being the first to the market were viewed the most important forms of intellectual property (IP) protection while patents were low on the list of effective mechanisms of IP protection.[23]

Possibly these differences in research findings can be explained by differences among small firms. It is likely that only a small proportion of small businesses use the patent system, but certain sectors of small business, such as small, high-technology companies may make major use of patents to protect their innovations. Research has pointed to the high costs, time, complexity, risk, and the limited value of patent protection as some of the problems small businesses experience in using patents.[24]

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[19] Mary Seyer Koen, Business Intellectual Property Protection, Report prepared by MO-SCI Corporation for the U.S. Small Business Administration, Office of Advocacy, 1991. NTIS order number: PB92-151703

[20] Eric Iversen, "Experience Regarding the Norwegian SMEs and the Intellectual Property Rights System: Lessons and Policy Recommendations," prepared for WIPO Interregional Forum on Small and Medium-Sized Enterprises (SMEs) and Intellectual Property organized by the World Intellectual Property Organization (WIPO) in cooperation with the Russian Agency for Patents and Trademarks (ROSPATENT) Moscow, May 22 to 24, 2002.

[21] World Intellectual Property Organization (WIPO), International Bureau, "Managing Intellectual Property Assets for Enhancing the Competitiveness of Small and Medium-Size Enterprises (SMEs); WIPO Program for Assisting SMEs," prepared for WIPO National Seminar On Intellectual Property And Small And Medium-Sized Enterprises (SMEs) organized by WIPO in cooperation with the Industrial Property Office and the Small Business and Crafts Directorate, Commerce Division, Ministry for Economic Services of Malta, Valletta, May 28, 2002; Derwent, Dismantling the Barriers: a Pan-European Survey on the Use of Patents and Patent Information by Small and Medium-Sized Enterprises (London, 2000), cited in WIPO, International Bureau "Intellectual Property And Small And Medium-Sized Enterprises (SMES)" document prepared for WIPO Regional Meeting Of Heads Of Intellectual Property Offices Of Caribbean Countries organized by the World Intellectual Property Organization (WIPO) in cooperation with the Government of the Republic of Suriname Paramaribo, June 3 and 4, 2002 (hereafter referred to as Paramaribo); J. Kitching and R. Blackburn "Intellectual Property Management in the Small and Medium Enterprises" in *Journal of Small Business and Enterprise Development*, Vol. 5, N.4, (London, 1999) cited in Paramaribo, op cit.

[22] Obermayer op cit.; Cordes et al., 1999; Kitching and Blackburn op cit.; Wesley M Cohen, "The second `Yale' study," presented at the workshop Industrial Research and Innovation Indicators for Public Policy, sponsored by the Board on Science, Technology, and Economic Policy, National Research Council, Washington, D.C., Feb. 28, 1997.

[23] Richard C. Levin, Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter "Appropriating the returns from industrial research and development," *Brookings Papers on Economic Activity: Microeconomics*, (1987) 3, pp. 783-820.

[24] Anna Norman. (2001) "The Patenting process; for SMEs, does size really matter?" Derwent Information. [online]. Available from: http://www.derwent.com/immatters/statistics/sizematters.html [accessed 14 November 2001]; Department of Trade and Industry, The Economic and Social Research Council and the Intellectual Property Institute of the United Kingdom, Final Report. 1998. Intellectual Property Initiative Research Programme on Intellectual Property. . [online]. Available from: http://info.sm.umist.ac.uk/esrcip/first.htm [accessed 12 November 2001]; Koen 1991, op. cit.; Cordes, et al., 1999.

Small Business Financial Limitations

One of the reasons cited most often for small business's failure to patent abroad even when these companies have made valuable inventions, is that they do not have the necessary financial resources; moreover, because they are engaged in innovation, a speculative activity, it is difficult to secure financing. The Cordes et al. study of small, high-technology firms found that two of every five respondents indicated that they had experienced obstacles to securing needed financing.[25] They found that small, innovative firms rely heavily on equity to finance their activities and that most equity financing appears to come from managers of the firms themselves.
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Policy for Small Business Foreign Patenting

Small business foreign patenting has not been a major focus of U.S. federal policy. One piece of U.S. legislation pertaining to small business foreign patenting was introduced in 2001. The SBIR and STTR Foreign Patent Protection Act of 2001 (S. 1323) would establish a program of grants at the Small Business Administration to help protect the intellectual property of companies that are trying to export promising technology they have developed through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

The GAO study mentioned earlier made policy recommendations aimed at helping small businesses address the challenges of foreign patenting. Based on its research the GAO argued that the best way to help small businesses would be to promote harmonization of U.S. and foreign patent systems and to reduce the high cost of foreign patents. It recommended that the USPTO obtain input from small businesses and other interested parties to assess the advantages and disadvantages of various patent harmonization options. It also recommended that the SBA make information about key aspects of foreign patent laws, procedures, and costs readily available to small businesses.

DATA AND METHODOLOGY

The objective of the original MRA study was to learn whether small firms working in the same technological fields and with equally or more valuable inventions patent them as broadly as large firms. The underlying premise was that if small firms do not patent their inventions as broadly as large firms under these conditions, it suggests that they are inhibited due to resource constraints or other reasons.[26] This study examines the same question. It also addresses whether

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[25] Cordes, et al., 1999.
[26] MRA op. cit.

small firms are patenting their inventions more frequently in foreign countries since 1988 and whether small firms still tend to patent their inventions fewer countries than large firms do.

Changes in the Current Study

The current study uses the data and methodology of the original study to the extent possible. It covers four years -- 1988, 1992, 1996, and 1998. The 1988 patents are the same patents examined in the original study. The current study also incorporates an additional measure of invention value, i.e., renewal/lapse status. The USPTO requires the payment of maintenance or renewal fees at 3 ½ years, 7 ½ years, and 11 ½ years from the date of issue to keep a patent in force.[27] Thus, at the time of the current study, the 1988 cohort of patents had faced all three renewal decisions, the 1992 cohort had faced two renewal decisions, and the 1996 cohort had faced one renewal decision. Although the 1998 cohort had faced no renewal decisions, it was included because it was the most recent cohort of patents for which patent family member information would be complete.

It was also necessary to change the way patent family size was calculated. This will be discussed in the description of the "Breadth of Foreign Patenting" variable.

Data and Sources

U.S. patent data were used to determine patent ownership, patent issue date, and patent technology classification. Patent family data—i.e., data on patent applications in different countries that cover the same invention—were used to analyze patterns of foreign patenting. Patent citations—i.e., references to the sample patents from subsequent patents—were used to measure the patent value. Data on U.S. patent maintenance fee payments were used as an additional measure of patent value.

U.S. patent data were obtained from MicroPatent's *U.S. Patent Search Plus*™ CD-ROM database. International patent family data were collected from the *Derwent World Patents Index (DWPI)*, an on-line international patent database that permits the examination of U.S. firms' patent records in foreign countries. U.S. patent citation data were obtained from the *Patent Citation Analysis Database*^{TM} (*PCAD*^{TM}). *PCAD*^{TM} is a proprietary database of patent citation data owned by Mogee Research & Analysis (MRA). Information on payment of U.S. patent maintenance fees was obtained from the USPTO's *CASSIS:BIB* CD-ROM.

A data set of matched pairs of small- and large-business patents was constructed. Each U.S. patent issued to a small business in 1988, 1992, 1996, and 1998 was matched to a randomly selected large-business patent issued on or about the same date and in the same field of

[27] Patent owners have up to the end of the 4th, 8th, and 12th years after grant to pay each maintenance fee; however, a late fee is assessed if the maintenance fees are not paid by the 3 1/2, 7 1/2, and 11 1/2 year due dates.

technology.[28] This matching was done to reduce possible effects of age and different technology fields on foreign patenting and patent value.

Small-business patents were drawn from U.S. patents filed by firms that claimed small business status at the time of filing.[29] The USPTO definition of small business corresponds to that of the Small Business Administration—i.e., a company must have 500 or fewer employees and not be part of a larger company. The large-business patents were drawn from U.S. patents filed by firms that did not claim small business, government, individual, or not-for-profit status at the time of filing.[30] All companies had to be U.S. (based on the address of the first inventor listed) to be included in the study. The patent could not be filed in any other country before it was filed in the United States. The patent could not be assigned jointly with any other type of organization (e.g., large business or university).

The final sample size consisted of 23,624 small business-large business patent pairs. Table 1 shows the number of sample patents issued in each year.

Table 1

Sample Size

Year	Number of Small Business Patents	Number of Large Business Patents
1988	2751	2751
1992	5021	5021
1996	6880	6880
1998	8972	8973

The number of small-business patents increased by more than a factor of three over this period. This is consistent with the trends in overall U.S. patenting mentioned earlier. Small U.S. businesses are clearly making more use of the U.S. patent system.

[28] All matched pairs for 1992, 1996, and 1998 were in the same U.S. patent class. Seventy-seven percent (77 percent) of the matched pairs for those years were issued on the same date. Ninety percent (90 percent) were issued within two weeks of each other. This was very similar to the match for the 1988 patents, 80 percent of which pairs were in the same U.S. patent class and issued within two weeks of each other.

[29] To verify small business status, the patent assignee names from the small business files for all companies with three patents or more in the set were screened using current business directories such as Hoover's, D&B, and Standard & Poor's. All companies that were determined to be large, foreign, or not-for-profit were removed. A random sample of 600 of the more than 12,000 companies with one or two patents in the small business set were also checked to estimate the proportion of them that were large. Of the 600 companies, employment size was found for 217, and 12, or 5.5 percent of the 217 companies, were found to be large companies. As a result, we can probably safely say that the set of small-business patents contains less than 5.5 percent large businesses.

[30] To verify large U.S. business status, patent assignees were screened to remove universities, not-for-profits, and foreign companies.

Variables

Foreign Patenting Behavior

Foreign patenting is measured with two variables: propensity to patent abroad and the breadth of foreign patenting.

Propensity to Patent Abroad. The first variable is the proportion of inventions that are patented in the both United States and at least one foreign country. This variable measures the extent to which businesses file patents in foreign countries or, conversely, the extent to which they file solely in the United States. This in turn reflects the proportion of new technology which is generated for exploitation in world markets versus that developed for the U.S. market only.

The extent to which companies file patents abroad is measured by the proportion of their patent families that is international. A "patent family" is the collection of patent publications in different countries that cover a single invention. Usually, a patent offers protection only in the country in which it is issued. Thus, to protect an invention in multiple countries, a company must file separate patent applications in each country where it wants protection. (An exception to this is the European Patent Office (EPO), which allows applicants to "designate" (i.e., seek protection in) multiple European countries with a single application. The cost of an EPO application goes up with each additional country designated.) Patent families are divided into "domestic-only" and "international" patent families. Domestic-only patent families are defined as patent families that cover inventions for which protection has only been sought in the United States. International patent families are defined as families with patent publications in the United States and at least one foreign country.

Breadth of Foreign Patenting. The second foreign patenting variable is how broadly inventions are patented around the world. That is, if a U.S. company patents outside the United States, in how many countries does it patent? This represents the number of countries in which the patent owner expects that it may profitably exploit its invention. The variable is operationalized as the mean number of countries in which small- and large-business inventions are patented, given that they are patented in both the United States and at least one foreign country, and is called mean patent family size.[31]

Mean patent family size is weighted by the gross domestic product (GDP) of the countries for each year. This is done to adjust for the different market potential represented by different countries. The weights are based on an index, with the GDP of the United States equal to one; other countries' GDPs are each a fraction of one, since they are smaller than the U.S. GDP.

Mean family sizes reported here are calculated differently than in the original study. In the original study, patents published by the EPO were broken down into their designated EPO member countries and counted as patent documents published in those countries. For example,

[31] Countries generally have multiple publication stages in their patenting process, which are usually called A, B, and C publications. If a family contained A and B publications from a country, only one country was counted.

an EPO patent designated for France and Germany was counted as both a French patent publication and a German patent publication. When weighted, these families were given the weight of the designated countries. By the time of the current study, the EPO had changed its designation procedures in such a way that designation data became impractical to obtain for the large number of patents in this study. To address this, data were obtained on the countries most often designated on U.S. origin patents granted by the EPO in 2000 and were used as a weight for EPO patents.[32]

Patent Value

It is widely acknowledged by researchers and practitioners that patents vary widely in their quality or value.[33] Researchers have used a variety of techniques to account for these differences. Prominent indicators of value that have been used include the number of times a patent is cited by later patents and whether patent renewal fees have been paid.

Citations. The front page of a patent document contains references to earlier patents and other technical or scientific publications. These references are the result of patent examiner searches of the "prior art," searches that are required to establish the novelty of an invention claimed by a patent. Patent references that appear on the front page of U.S. patents are listed by the examiner as being relevant to the patented invention, but do not bar the patent from being granted. Many of these citations may have been identified by the applicant and included with the filed application.

Over the past twenty years, an increasing number of studies have found that the number of times a patent is cited by subsequent patents correlates with various independent measures of importance or value.[34] Technology analysts have related citations to the technological value of a patent, arguing that the number of times a patent is cited by later patents reflects the extent to which subsequent inventions have built upon the cited patent.[35] Economists have found a relationship, albeit somewhat noisy, between the number of citations a patent has received and its economic value.[36]

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[32] Of U.S.-origin patents granted by the EPO in 2000, 98.30 percent were designated for Germany, 96.63 percent were designated for Great Britain, and 94.80 percent were designated for France. The next most often designated country was Italy at 72.87 percent. Based on this, an EPO patent was counted as a German patent, a British patent, and a French patent.

[33] For example, see F. Narin, E. Noma, and R. Perry, "Patents as Indicators of Corporate Technological Strength," Research Policy, v. 16 (1987): 144.

[34] M. Trajtenberg, "Patents, Citations, and Innovation: Tracing the Links," National Bureau of Economic Research, Working Paper 2457 (1987); M. Carpenter, F. Narin, and P. Woolf., Citation Rates to Technologically Important Patents, World Patent Information, v. 3, 1981, pp. 160-163; F. Narin, M. Rosen, and D. Olivastro, "Patent Citation Analysis: New Validation Studies and Linkage Statistics," Handbook of Quantitative Studies of Science and Technology A.F.J. van Raan (ed.) (Elsevier Science Publishers: North-Holland 1988).

[35] For example, see M. Carpenter, F. Narin, and P. Woolf op. cit. and F. Narin, M. Rosen, and D. Olivastro, op. cit.

[36] For example, see Trajtenberg op. cit. and J. Putnam, How Many Pennies for Your Quote: Estimating the Value of Patent Citations," unpublished paper presented at the 1997 National Bureau of Economic Research Productivity seminar series, Cambridge, MA.

Researchers make a further distinction between "self" and "other" citations. Self-citations are references made to a company's patents by its own later patents, while other citations are references made to a company's patents by later patents assigned to other companies. Self-citation is quite common and suggests that a firm is building on its previous inventions to pursue a line of research and development. Since large companies have more patents than small companies, it is likely that they cite their earlier patents more than small companies. Removing the self-citations avoids this possible source of bias.

This study uses the number of other-citations each patent received from later patents as an indicator of its value.[37]. Other-citations are analyzed in two ways. The first method counts the number of other-citations and calculates the mean number of other-citations per patent. Because it is known that the distribution of citations is highly skewed and therefore measures of central tendency may be misleading, we also count the number of patents that fall among the most highly other-cited patents in the combined sample. The latter is interpreted as measuring the proportion of patents that have extremely high public value.

Patent Renewals. As noted earlier, once a U.S. patent has been granted, the owner must pay periodic maintenance fees to keep the patent in force. The fees increase in size at each of the three decision points. The decision to renew a patent (i.e., pay the maintenance fee) is widely regarded as an indicator of the value of the patent to the company that owns it. The failure to renew a patent suggests that the company believes the patent is not worth the cost of renewal. Because the owner makes the renewal decision, patent renewals are regarded by economists as a measure of the "private" value of the patent – i.e., the value that the owner expects to receive.

Payment of patent renewal fees is operationalized as the percent of patents for which the renewal fee was not paid, that is, the percent of patents that were allowed to lapse.

Field of Technology

The U.S. Patent Classification (U.S.PC) is the primary technology classification applied to U.S. patents. As of the end of December 2001, there were 413 utility patent classes and roughly 135,000 utility patent subclasses corresponding to primary technology classifications for patents. For purposes of this project the U.S.PC classes are aggregated into the following 13 broad technology areas:[38]

[37] The citations were divided into "self" and "other" citations by comparing the patent assignee name on the citing and cited patents. If the name was the same, the relationship was "self;" if it was not the same, the relationship was "other." We used the standardized patent assignee names the USPTO puts on the records in its CD-ROM product "CASSIS:BIB" to reduce the problem of missing matches because of nonstandardized names. These names, while not perfect, are substantially cleaned up and standardized compared with the data on the patents themselves.

[38] This aggregation is based largely on the December 1994 edition of the USPTO's Manual of Classification, the section entitled "Classes within the U.S. Classification System: Arranged by Related Subjects." New classes that had been added to the U.S.PC since the original study were added to the 13 technology fields.

Bioengineering
Communications (Electric)
Computers (also includes calculators, data processing, and information storage)
Heating & Cooling
Material Handling (also includes material storing, and article and fluid handling and storing)
Measurement (measuring, testing, precision instruments)
Medical
Metal Work (cutting, comminution, and machining)
Miscellaneous Chemical
Miscellaneous Electrical
Miscellaneous Mechanical
Traditional Manufacturing
Vehicles, Earth Working, Agricultural Machinery

ANALYSIS

Technology Distribution

A question of interest is the technology fields in which small businesses patent. One might expect small-business patents to be concentrated in so-called "high" technology fields such as computers, communications, and bioengineering, given the kinds of industries in which other studies have found small business plays an important innovative role. Table 2 shows how the small-business patents in this study were distributed across the 13 technology fields.

Table 2		
Small Business Patents by Technology Field		
Technology Field	**Number of Small Business Patents**	**Percent of Small Business Patents**
Bioengineering	791	3.3
Communications	1741	7.4
Computers	1257	5.3
Heating & Cooling	404	1.7
Material Handling	1156	4.9
Measurement	1046	4.4
Medical	2979	12.6
Metal Work	832	3.5
Miscellaneous Chemical	3413	14.4
Miscellaneous Electrical	2598	11.0
Miscellaneous Mechanical	4421	18.7
Traditional Manufacturing	1943	8.2
Vehicles, Earth Working, Agricultural Machinery	1043	4.4

The data on small-business patenting presents a different picture from that expected. Small-business patenting is spread over a broad range of technologies. Relatively small percentages of patents are in Computers (5.3 percent), Communications (7.4 percent), and Bioengineering (3.3 percent). Large percentages of the small-business patents are in Miscellaneous Mechanical (18.7 percent), Chemical (14.4 percent), and Electrical (11.0 percent) technologies. (This is not surprising given the "miscellaneous" nature of those fields.) Small-business patents are also heavily concentrated (12.6 percent) in Medical technology, which includes surgery, drugs, dentistry, and prostheses. In general this is a field that is known for its high level of activity and the involvement of numerous small businesses. About 8 percent of small-business patents are in the Traditional Manufacturing technology field, which includes very traditional technologies like textiles, apparel, shoes, glass, paper and printing.

Foreign Patenting

Propensity to Patent Abroad

Table 3 presents data on the propensity to patent abroad of U.S. small and large businesses for the four years covered by this study.

Table 3							
Percent of Families That Are International by Technology Field, All Years							
	Large Business		**Small Business**				
Technology Field	**Number**	**Percent**	**Number**	**Percent**	**Total**	**Chi-Square**	**P-Value**
All Technologies	12425	52.59	8895	37.65	23624	1065.06	<.0001
Bioengineering	553	69.91	483	61.06	791	13.70	0.0002
Communications	920	52.84	720	41.36	1741	46.10	<.0001
Computers	598	47.57	464	36.91	1257	29.27	<.0001
Heating & Cooling	193	47.77	109	26.98	404	37.30	<.0001
Material Handling	571	49.39	357	30.88	1156	82.43	<.0001
Measurement	459	43.88	343	32.79	1046	27.20	<.0001
Medical	1843	61.87	1579	53.00	2979	47.84	<.0001
Metal Work	428	51.44	251	30.17	832	77.94	<.0001
Misc. Chemical	2088	61.18	1486	43.54	3413	212.84	<.0001
Misc. Electrical	1256	48.34	886	34.10	2598	108.73	<.0001
Misc. Mechanical	2120	47.95	1343	30.38	4421	286.57	<.0001
Trad. Manufacturing	904	46.53	562	28.92	1943	128.11	<.0001
Vehicles, Ag and Earth Machinery	492	47.17	312	29.91	1043	65.57	<.0001
Percent of Families That Are International by Year							
1988	1308	47.55	860	31.26	2751	152.775	<.0001
1992	2558	50.95	1719	34.24	5021	286.685	<.0001
1996	3665	53.27	2596	37.73	6880	334.909	<.0001
1998	4894	54.54	3720	41.46	8973	307.698	<.0001

The first row of Table 3 shows the data for all technologies. About 53 percent of large-business patents were international, a figure that is quite close to the 57 percent estimated earlier as the percent of all U.S. origin patents that are filed abroad. A greater proportion of large-business families (52.59 percent) is international than small-business families (37.65 percent). The difference is statistically significant at Pr <.0001, using the Chi square test. This suggests that small U.S. businesses are not as likely to seek patent protection abroad as are large U.S. businesses. This finding confirms that of the earlier MRA study.

The last section of Table 3, which breaks out the data by year, shows that a significantly larger percentage of large-business patents were filed abroad than of small-business patents in each year. The large firm "advantage" over small firms with respect to patenting abroad was not peculiar to 1988, the year originally studied by MRA, but has continued over the years since then.

The percent of patents that were filed outside the United States increased each year for both large and small businesses. Thus it appears that U.S. business is participating in the global move toward increased internationalization of patenting. Although the increase was greater for small firms (10.2 percentage points) than for large firms (6.99 percentage points), small businesses still patent abroad significantly less than do large businesses.

The middle section of Table 3 breaks out the data by technology field. A lesser proportion of small-business patent families is international than of large-business patents in each technology. The difference is highly statistically significant in all technologies. This confirms the 1995 finding that large-business patents are more likely than small-business patents to be international even when they are in the same field of technology. Therefore the difference cannot be attributed to differences in the technology fields where large business and small business tend to patent.

The differences in percent international are not the same across technologies, suggesting that large businesses have more advantage over small businesses with respect to foreign patenting in some technologies than in others. The largest differences are in Metal Work, Material Handling, and Heating and Cooling. Presumably something about these fields, or the industries where they are used, gives large businesses a relatively great advantage over small business in foreign patenting. The smallest differences in percent international are in Bioengineering and Medical technologies. Apparently large businesses and small businesses are on a more equal footing with respect to foreign patenting in these fields.

It is interesting to note that in technologies in which a big proportion of large-business patents are international, a big proportion of small-business patents also tend to be international, and vice versa. Bioengineering, Medical, and Miscellaneous Chemical are the technologies that are most highly international for both small and large firms. A relatively small percentage of both large-business patents and small-business patents is international in Traditional Manufacturing and Vehicles. Perhaps these differences reflect markets that are more international in scope and markets that are less international in scope.

Breadth of Foreign Patenting

Table 4 shows data on the breadth of foreign patenting for small and large U.S. companies in this study. It shows mean weighted patent family size for total families and for international-only families (i.e., only those families with foreign patent applications). International families are examined separately because the 1995 MRA study found that much of the difference between small and large business foreign patenting was due to the fact that fewer small-business patents are filed abroad. By examining only international families we are comparing only patents that were filed abroad.

The first row shows data for all 13 technologies and all 4 years. Looking at total families, small-business families are smaller (1.27) than large-business families (1.45). The difference is significant at $Pr < .0001$ using the two-tailed t-test. This confirms the finding of the 1995 MRA study that small businesses patent in fewer countries than large businesses. When only

international families[39] are considered, large-business patents again have larger mean weighted family sizes (1.90) than small-business patents (1.73). The difference is statistically significant at Pr <.0001, using the two-tailed t-test test. This finding differs from that of the 1995 MRA study, which did not find a statistically significant difference in family sizes for international families. This suggests that even when small businesses patent abroad, they patent in fewer countries than do large businesses.

The middle section of Table 4 shows the data broken out by technology field. Looking at total families, large-business families are greater in size than small-business families in each technology field, and the difference is significant in each technology field, at the level Pr < .0001, using the signed ranks test. This shows that large businesses patent in more countries than do small businesses in all technologies. Therefore the difference in the number of countries is not due to working in different technology fields. This is consistent with the 1995 MRA study finding.

Looking at international-only families, large-business families are again greater in size than small-business families in all technology fields. The difference is statistically significant at Pr equal to or less than .05 in all fields except Heating and Cooling. This suggests that even when small businesses and large businesses invent in the same technology and both patent abroad, large businesses patent in more countries than small businesses. This finding is stronger than that of the 1995 MRA study, which found statistically significant differences in only 5 of the 13 technologies and that large-business families were not always bigger than small-business families in those technologies with statistically significant differences. Thus the effect of company size on foreign patenting seems even more pervasive that thought before. Small businesses's disadvantage in foreign patenting, compared with large businesses, is not due to their working in different fields of technology or the fact that many small businesses do not file abroad at all.

Differences in the family size of small- and large-business patents vary across the technologies. They are largest in Material Handling, Metal Work, and Miscellaneous Mechanical. This suggests that there is something about these technologies, or related industries, that gives large business more advantage over small business in foreign patenting. Differences in family size are smallest in Heating & Cooling, Computers, and Medical Technology. In these technologies, or related industries, large businesses and small businesses are apparently on a more equal footing with respect to foreign patenting.

Both small-business patents and large-business patents tend to have their biggest families in the same technologies and their smallest families in the same technologies. Looking at international families only, families of both small-business patents and large-business patents are biggest in Bioengineering, Medical, and Miscellaneous Chemical technologies. This suggests that the

[39] For the international family analysis, only those pairs where both small and large-business patents are international were included to preserve the patent pairs. This sample size was 4, 924 pairs. The pattern of difference is similar to that observed when all small international patents and all large international patents, regardless of pairs, are included.

industries that use these technologies may have markets that are more international than the industries that use technologies where families are smaller. In contrast, families of both small- and large-businesses tend to be smallest in Vehicles, Miscellaneous Mechanical, and Material Handling. It is interesting to note that these technologies also tend to have relatively small differences between small-business family size and large-business family size.

The bottom section of Table 4 breaks the data out by year. Large-business patent families are greater in size than small-business patent families in all four years, for both total and international-only families. The difference is significant in all cases at $Pr < .0001$. Thus the tendency for large businesses to patent in more countries than small businesses was consistent in the years studied. Family sizes generally grew each year from 1988 to 1996, for both small-business patents and large-business patents, whether looking at total families or international families only.[40] This indicates that U.S. businesses, both large and small, are seeking patent protection in more countries, consistent with the global trend discussed earlier. The difference between small and large businesses in family size does not show a clear pattern of change over time.

A repeated measures analysis of variance (ANOVA) was performed for the mean weighted family size of large- versus small-firm patents, with factors for year and technology. The procedure showed, for both total families and international-only families (i.e., only those families with foreign patent applications), that large-business mean weighted family size is larger than small- business mean weighted family size and that this difference varies by technology field. Both of these findings are highly statistically significant. There was no evidence of year by size effects; that is, the difference in large and small family sizes does not show a trend over time. These findings confirm the patterns seen in Table 4.

[40] They did not continue to grow in 1998. This may be in part because family size for a given invention often grows over the first few years as additional countries publish applications which become part of the family. Thus, families of patents issued in 1998 may be incomplete.

Table 4												
Mean Weighted Patent Family Size for All Data, by Technology Field, and by Year												
	Total Families						**International Families**					
Data Grouping	Sample Size	Small Business	Large Business	Difference	Std Error	P-Value	Sample Size	Small Business	Large Business	Difference	Std. Error	P-Value
All Technologies , All Years	23624	1.27	1.45	0.19	0.00	<.0001	4924	1.73	1.90	0.17	0.01	<.0001
Grouped by Technology Field												
Bioengineering	791	1.54	1.74	0.20	0.02	<.0001	344	1.88	2.07	0.18	0.03	<.0001
Communications	1741	1.30	1.47	0.17	0.02	<.0001	378	1.73	1.89	0.15	0.03	<.0001
Computers	1257	1.26	1.39	0.13	0.02	<.0001	226	1.72	1.81	0.09	0.04	0.0282
Heating & Cooling	404	1.19	1.36	0.17	0.03	<.0001	46	1.72	1.79	0.06	0.09	0.5157
Material Handling	1156	1.16	1.38	0.22	0.02	<.0001	187	1.53	1.79	0.26	0.05	<.0001
Measurement	1046	1.23	1.35	0.12	0.02	<.0001	142	1.72	1.85	0.13	0.05	0.0173
Medical	2979	1.45	1.60	0.14	0.01	<.0001	1010	1.86	1.97	0.10	0.02	<.0001
Metal Work	832	1.18	1.43	0.24	0.02	<.0001	137	1.59	1.84	0.25	0.05	<.0001
Misc. Chemical	3413	1.35	1.61	0.26	0.01	<.0001	916	1.80	2.02	0.22	0.02	<.0001
Misc. Electrical	2598	1.25	1.43	0.18	0.01	<.0001	445	1.76	1.89	0.13	0.03	<.0001
Misc. Mechanical	4421	1.16	1.35	0.20	0.01	<.0001	664	1.52	1.75	0.23	0.02	<.0001
Trad. Manufacturing	1943	1.19	1.36	0.17	0.02	<.0001	268	1.71	1.82	0.11	0.04	0.0033
Vehicles, Ag and Earth Machinery	1043	1.13	1.28	0.15	0.02	<.0001	161	1.43	1.59	0.16	0.05	0.0014
Grouped by Year												
1988	2751	1.20	1.38	0.18	0.01	<.0001	384	1.67	1.82	0.15	0.03	<.0001
1992	5021	1.27	1.47	0.19	0.01	<.0001	933	1.83	1.97	0.14	0.02	<.0001
1996	6880	1.29	1.51	0.22	0.01	<.0001	1453	1.78	1.99	0.21	0.02	<.0001
1998	8972	1.27	1.43	0.16	0.01	<.0001	2154	1.67	1.82	0.15	0.01	<.0001

Foreign Patenting and Patent Value

The preceding sections have shown that small businesses patent abroad less often, and they patent in fewer countries than do large businesses. They have also shown that these differences in foreign patenting were not limited to a single year and are not due to differences in the fields of technology where small and large businesses work. It is possible, however, that the differences in foreign patenting may be caused by differences in the value of the patents owned by small and large businesses. Since foreign patenting is so costly, only the most valuable patents tend to be filed abroad. Thus if patents owned by larger businesses are of higher value than those belonging to small businesses, that could explain why large businesses patent more abroad. This section analyzes the effect on foreign patenting of patent value, first as measured by other-citations and then as measured with renewals.

Value of Small- and Large-Business Patents Measured Using Citations

Table 5 presents the average number of other-citations received per patent for the patents in this study. The first row shows data for all 13 technologies and all 4 years. Small-business patents received more other-citations on average than large-business patents received. This is true for both total families and for international-only families. In both cases the difference is statistically significant at the level Pr <.0001 using the 2-tailed t-test. This indicates that on average small-business patents are more valuable than large-business patents. Thus owning more valuable patents, as measured by other-citations, cannot be the reason that large businesses patent more abroad than small businesses do. The finding that small-business patents are more valuable than large-business patents, as measured by other-citations, differs with that of the 1995 MRA study, which found that large-business patents were marginally more valuable on average than small-business patents, measured in the same way.

It is interesting to note that small-business average other-citations are substantially higher for international-only families (6.71) than for total families (5.72), as one would expect given the high cost of foreign patenting. Large-business international families, however, receive fewer other-citations on average (5.06) than do large-business total families (5.15), which is counter to what one would expect. Perhaps small businesses are constrained by their limited resources to file only their most valuable patents abroad, while large businesses are not so constrained.

Table 5

'Other' Citations Received for All Data, by Technology Field and by Year

	Total Families						*International Families*					
Data Grouping	Sample Size	Small Business	Large Business	Difference	Std. Error	P-Value	Sample Size	Small Business	Large Business	Difference	Std. Error	P-Value
All Technologies, All Years	23624	5.72	5.15	-0.57	0.08	<.0001	4924	6.71	5.06	-1.65	0.20	<.0001
Grouped by Technology Field												
Bioengineering	791	3.50	3.13	-0.37	0.44	0.3941	344	3.86	3.30	-0.56	0.77	0.4627
Communications	1741	10.58	8.45	-2.13	0.29	<.0001	378	15.35	9.10	-6.25	0.73	<.0001
Computers	1257	11.39	8.72	-2.67	0.35	<.0001	226	13.83	9.13	-4.70	0.95	<.0001
Heating & Cooling	404	4.13	4.29	0.16	0.61	0.7990	46	4.76	5.83	1.07	2.10	0.6120
Material Handling	1156	3.52	3.51	-0.01	0.36	0.9714	187	3.88	3.26	-0.63	1.04	0.5480
Measurement	1046	4.48	3.67	-0.81	0.38	0.0332	142	5.30	3.54	-1.77	1.20	0.1392
Medical	2979	8.17	7.61	-0.56	0.23	0.0136	1010	7.56	5.98	-1.59	0.45	0.0004
Metal Work	832	3.41	3.84	0.43	0.43	0.3146	137	3.43	3.98	0.55	1.22	0.6528
Misc. Chemical	3413	4.43	4.00	-0.43	0.21	0.0415	916	5.04	3.96	-1.08	0.47	0.0219
Misc. Electrical	2598	5.70	4.68	-1.02	0.24	<.0001	445	6.67	4.81	-1.85	0.68	0.0061
Misc. Mechanical	4421	4.42	4.42	-0.00	0.19	0.9873	664	5.03	4.15	-0.88	0.55	0.1116
Trad. Manufacturing	1943	4.19	4.38	0.19	0.28	0.4988	268	4.32	4.40	0.08	0.87	0.9282
Vehicles, Ag and Earth Machinery	1043	4.28	4.02	-0.26	0.38	0.4954	161	5.69	3.87	-1.82	1.12	0.1050
Grouped by Year												
1988	2751	10.74	9.76	-0.98	0.23	<.0001	384	13.64	10.45	-3.20	0.73	<.0001
1992	5021	8.99	8.12	-0.87	0.17	<.0001	933	12.50	8.87	-3.63	0.47	<.0001
1996	6880	5.13	4.92	-0.22	0.15	0.1407	1453	6.41	5.27	-1.14	0.37	0.0024
1998	8972	2.80	2.25	-0.55	0.13	<.0001	2154	3.18	2.31	-0.87	0.31	0.0048

When the data on other-citations are broken out by technology field, statistically significant differences are found in only five technologies: Communications, Computers, Medical, Miscellaneous Chemicals, and Miscellaneous Electrical. In each of these technologies small-business patents receive more other-citations than large businesses receive. The fields with the largest differences are Communications (where small businesses receive 6.25 more other-citations on average than large businesses) and Computers (where small businesses receive 4.7 more other-citations on average than large businesses). This means that the relationship between company size and the value of patents varies by technology and that these variations account for some of the difference in the number of other-citations received overall by small- and large-business patents. One may conclude that small-business patents have higher value, as measured by average other-citations received, than do large-business patents in some technologies; in other technologies there is no significant difference in patent value.

The last grouping in Table 5 breaks out the data by year. The average number of other-citations is higher for small-business patents than for large-business patents in each year, for both total families and international-only families. The difference is highly significant statistically in all years for international families and in all years except one for total families. Thus, small business's owning higher value patents, as measured by other-citations, is not a one-time fluke, but continues over time.[41]

A repeated measures ANOVA was performed for the number of other-citations received by large versus small firms, with factors for year and technology. For both total families and international-only families, the size of the company has an effect on the number of other-citations. The effect of company size differs across technology fields and by year. The effect of company size on other-citations within a technology field also varies by year. All of these effects are highly statistically significant. These results confirm the patterns in the data observed in Table 5.

Table 6 shows the representation of small- and large-business patents among the most highly other-cited patents in the combined sample. Two threshold levels of other-citations are used: the top 1 percent of the most highly other-cited patents and the top 10 percent. The top 1 percent most highly other-cited patents are assumed to be the patents with the highest value. Given the skewed distribution of patent value, these patents represent the small number of patents that have extremely high values. The top 10 percent of most highly other-cited patents represent patents that may be regarded as those in the second tier of value—still relatively small numbers of patents and very high values. This analysis asks whether small- or large-business patents are represented equally among these very high value patents.

[41] The mean number of other-citations received decreases over the four years. This is to be expected because citations accumulate over time and as a result older patents tend to have received more citations.

Table 6		
Proportion of Most Highly Other-Cited Patents		
Firm Size	**Top 1 Percent Most Other-Cited Patents (N)**	**Top 10 Percent Most Other-Cited Patents (N)**
Small	59% (294)	53% (2704)
Large	41% (201)	47% (2403)

Small-business patents form a larger proportion of highly other-cited patents in both the 1 percent and 10 percent groups.[42] The difference between small and large firms is statistically significant at the level of Pr <.0001 using the Chi square test. The difference is more pronounced at the1 percent level, where 59 percent of the patents belong to small businesses and only 41 percent of the patents belong to large businesses. This suggests that small-business patents are more likely than large-business patents to be among those rare patents that hit the jackpot in terms of value. This result differs with that of the 1995 MRA study, which did not find statistically significant differences in the representation of small- and large-business patents among the most highly other-cited patents.

Table 7 shows the percent of small- and large-business patents in the top 1 percent and the top 10 percent of most highly other-cited patents, broken out by technology field. Statistically significant differences (i.e., Pr equal to 0.05 or less) in the proportion of small- and large-business patents in the top 1 percent of most highly other-cited patents are observed in only three technologies: Communications, Computers, and Miscellaneous Electrical. In these technologies, small-business patents were represented more highly among the most other-cited patents.

Table 7B shows that there were statistically significant differences in the proportion of small- and large-business patents in the top 10 percent most highly other-cited patents in four technologies: Computers, Measurement, Miscellaneous Electrical, and Vehicles. Again, in these technologies small-business patents were represented more highly than large-business patents among the most cited patents. Presumably there is something about Communications, Computers, Miscellaneous Electrical, and Vehicles technologies, or the industries where they are used, that stimulates small business to make and patent extremely valuable inventions more often than would be expected.

[42] As can be seen from Table 4, there 495 patents in the top 1 percent most highly cited and 5107 in the top 10 percent. These numbers are higher than 1 percent and 10 percent of the total of 47,248 in the study because of ties in the number of citations received.

Table 7

7.A. Number and Percent of Firms Ranking in the Top 1/100th of Other-Citations Grouped by Technology Field

Technology Field	Large Count	Large Percent	Small Count	Small Percent	Total	P-Value
Bioengineering	5	0.63	4	0.51	791	0.7382
Communications	40	2.30	69	3.96	1741	0.0048
Computers	39	3.10	61	4.85	1257	0.0248
Heating & Cooling	2	0.50	1	0.25	404	0.5630
Material Handling	0	0.00	2	0.17	1156	0.1571
Measurement	1	0.10	5	0.48	1046	0.1020
Medical	75	2.52	82	2.75	2979	0.5713
Metal Work	1	0.12	1	0.12	832	1.0000
Misc. Chemical	11	0.32	16	0.47	3413	0.3350
Misc. Electrical	7	0.27	27	1.04	2598	0.0006
Misc. Mechanical	13	0.29	15	0.34	4421	0.7050
Trad. Manufacturing	5	0.26	5	0.26	1943	1.0000
Vehicles, Ag and Earth Machinery	2	0.19	6	0.58	1043	0.1565

7.B Number and Percent of Firms Ranking in the Top 1/10th of Other Citations Grouped by Technology Field

Bioengineering	49	6.19	59	7.46	791	0.3188
Communications	355	20.39	400	22.98	1741	0.0642
Computers	246	19.57	358	28.48	1257	<.0001
Heating & Cooling	24	5.94	28	6.93	404	0.5663
Material Handling	70	6.06	57	4.93	1156	0.2354
Measurement	63	6.02	86	8.22	1046	0.0506
Medical	534	17.93	548	18.40	2979	0.6380
Metal Work	55	6.61	40	4.81	832	0.1130
Misc. Chemical	257	7.53	284	8.32	3413	0.2264
Misc. Electrical	217	8.35	288	11.09	2598	0.0009
Misc. Mechanical	324	7.33	340	7.69	4421	0.5185
Trad. Manufacturing	156	8.03	142	7.31	1943	0.3987
Vehicles, Ag and Earth Machinery	53	5.08	74	7.09	1043	0.0545

Together Tables 6 and 7 suggest that small-business patents are likely to be more valuable than large-business patents in some technologies, but not in others. Differences in the technology fields in which small and large businesses work may explain some of the observed higher value of small-business patents, as measured by other-citations. As mentioned earlier, other-citations are regarded as a measure of public value, because the decision to reference a patent is not made by the patent holder, but by other parties. It would be interesting to see whether similar findings are obtained when measuring value with an indicator of private value, such as patent renewal rates. Patent renewal rates are regarded as indicators of the private value of patents because the decision to renew a patent is made by the owner of the patent.

Value of Small and Large-business patents Measured Using Renewals

Table 8 presents summary data on the percentage of patents that were not renewed—that is, that were allowed to lapse—at each of the three renewal decision points (i.e., E1, E2, and E3). The table shows, for example, that 441 small-business patents (16.03 percent of the 2,751 patent pairs issued in 1988) were allowed to lapse at the first decision point (E1). This is to be compared with 446 large-business patents (16.21 percent) that were allowed to lapse at that decision point.

Table 8

Patent Renewal Decisions Grouped by Year

		Large Business		Small Business			
Year	**Renewal Decision Point**	**Number**	**Percent**	**Number**	**Percent**	**Total**	**P-Value**
1988	E1	446	16.21	441	16.03	2751	0.8546
	E2	585	21.26	544	19.77	2751	0.1711
	E3	437	15.89	344	12.50	2751	0.0003
	Total	1468	53.36	1329	48.31	2751	0.0002
1992	E1	731	14.56	987	19.66	5021	<.0001
	E2	827	16.47	940	18.72	5021	0.0031
	Total	1558	31.03	1927	38.38	5021	<.0001
1996	E1	693	10.07	1083	15.74	6880	<.0001
1998	E1	0		0		8972	

In the three years for which patent owners have faced at least one renewal decision (i.e., 1988, 1992, and 1996), large businesses allowed 3,719 patents (or 25.38 percent of the total of 14,652 patents issued in 1988, 1992, or 1996) to lapse, while small businesses allowed 4,339 patents (or 29.61 percent) to lapse. The difference is statistically significant at the Pr = .0002 or less level, using the 2-tailed t-test. This indicates that large-business patents had higher value on average, as measured by lapse rates, than did small-business patents.

This discrepancy with the findings on patent value using the number of other-citations received may be due to the fact that renewal decisions are made by the patent owner itself. It is possible that patents represent less private value to small businesses because they often do not have the resources necessary to commercialize them. Interpreted differently, small businesses may be constrained by their limited resources in how many patents they can renew, while large businesses may not be so constrained. It is also possible that small-business renewals are reduced due to the fact that a greater proportion of small firms than large firms go out of business. This difference may serve to comparatively reduce the proportion of small-business patents that are renewed, particularly when addressing the payment of the first fee.[43]

[43] Thanks to Jim Hirabayashi of the U.S. Patent and Trademark Office for this observation.

The patent renewal fee that must be paid to the USPTO increases at each succeeding decision point.[44] One would therefore expect the proportion of patents that are allowed to lapse to increase at each succeeding decision point.[45] This pattern is not observed universally in the data, however. For patents issued in 1988, a larger proportion of both large- and small- business patents were dropped at the second decision point (E2) than were dropped at the first decision point (E1), as expected. However, a smaller proportion of both small- and large-business patents were dropped at the third decision point (E3) than were dropped at the second decision point (E2), which is not expected.

For large-business patents issued in 1992, the percent allowed to lapse at decision E2 was higher than that allowed to lapse at decision E1, as expected, but the proportion of small-business patents that were allowed to lapse at decision E2 was less than the proportion dropped at decision E1, which is inconsistent with expectation. This discrepancy between the observed trends in lapse rates and the expected trends is interesting and may point to further research on the private value of patents to small business.

Table 9 shows the percent of patents that lapsed by technology field for the years covered by the study. Statistically significant differences (i.e., Pr equal to or less than 0.05) are found in seven of the technologies: Communications, Computers, Medical, Miscellaneous Electrical, Miscellaneous Mechanical, Traditional Manufacturing, and Vehicles. In each of these technologies small businesses allowed a greater proportion of their patents to lapse than did large businesses. There is apparently something about these technologies, or the industries that use them, that causes small businesses to allow a greater proportion of their patents to lapse than large businesses do. It is interesting that these are some of the same technologies where small-business patents have higher value than large-business patents, as measured by the average number of other-citations received.

Looking at both measures of patent value—number of other-citations received and patent lapse rates—it appears that at least in some technologies small-business patents have higher public value, that is value to society as a whole, than do large-business patents, and at least is some technologies large-business patents have higher value to their owners than do small-business patents. This may account for small business's relatively low rate of patenting abroad and the relatively small number of countries in which they patent, compared with large businesses.

[44] The fee at 3.5 years for small businesses is $440; the fee at 7.5 years for small businesses is $1,010; and the fee at 11.5 years for small businesses is $1,550.00.

[45] This would be expected unless the patents become more valuable, either absolutely or in the perception of their owners.

Table 9						
Count and Percent of Lapsed Patents Grouped by Technology Field						
Technology Field	**Large Count**	**Large Percent**	**Small Count**	**Small Percent**	**Total**	**P-Value**
Bioengineering	50	6.32	55	6.95	791	0.6136
Communications	170	9.76	247	14.19	1741	<.0001
Computers	100	7.96	159	12.65	1257	0.0001
Heating & Cooling	100	24.75	124	30.69	404	0.0593
Material Handling	253	21.89	260	22.49	1156	0.7261
Measurement	200	19.12	206	19.69	1046	0.7401
Medical	216	7.25	317	10.64	2979	<.0001
Metal Work	189	22.72	196	23.56	832	0.6841
Misc. Chemical	578	16.94	587	17.20	3413	0.7722
Misc. Electrical	389	14.97	465	17.90	2598	0.0044
Misc. Mechanical	859	19.43	998	22.57	4421	0.0003
Trad. Manufacturing	404	20.79	455	23.42	1943	0.0487
Vehicles, Ag and Earth Machinery	211	20.23	270	25.89	1043	0.0022

Effect of Company Size, Technology, Year, and Patent Value on Foreign Patenting

In order to examine foreign patenting in a model that incorporates all the explanatory variables, a repeated measures ANOVA was performed for the difference in the mean weighted family size of the large and small firm in each pair, with the following source factors: company size, technology field, year, other-citations, and lapse status. The results were similar for all pairs and for international-only pairs. Large-business mean weighted family size is larger than small-business mean weighted family size. From the F-values one can conclude that company size has the largest effect on the difference between large and small companies in mean weighted family size. Other-citations and lapse status have the next-greatest level of effect. Technology field also has a significant effect but on average is not as important as other-citations and lapse status.[46] The coefficients for these covariates are positive, which indicates that the larger the difference in other-citations or lapse status, the larger the difference in weighted family size. These effects are small but highly statistically significant ($p < .0001$). Year does not seem to have any effect on mean weighted family size.

To check effects in the 13 technology fields, we adjusted the weighted mean family sizes for each technology field by the slope of family size difference with respect to other-citations and lapse status. This adjusted mean is an estimate of what the effect of company size would be if there were no differences in other citations or lapse status. The results were similar for all pairs

[46] The technology field effect in this model is an average because there are 13 technology fields. Some fields may have a large effect and others may have a small effect.

and for international-only pairs. For all pairs the adjustment changed the weighted mean family size in 5 of 13 technology fields; for international pairs, the adjustment changed the weighted mean family size in 4 of 13 technology fields. In all cases where the weighted mean family size changed, it changed by only 0.01 unit. From this one may conclude that within each technology field, large-business weighted mean family size is greater than small-business weighted mean family size and this difference is not due to differences in other-citations or lapse status.

The repeated measures analysis was also run including self-citations with the other explanatory variables. This was of interest because of the differences observed in the value of the patents as measured by the number of other-citations and the renewal rate. The number of self-citations is an indicator of private value, because the patent owner itself makes the decision to reference its earlier patent, like patent renewals, so it might be expected to function similarly to patent renewals in this model. Adding the difference in self-citations to the repeated measures analysis shows that it (the difference in self-citations) too is an important predictor of the average weighted family size. In fact, it is a better predictor than either lapse status or other-citations. The redundancy among these variables is apparently small because they all remain statistically significant in the final model.

Finally, if only small firms are included and weighted family size is modeled as a function of technology field, year, lapse status, other-citations and self-citations, a similar picture of relative influence emerges as emerges from the model based on differences. In this model (which removes company size as a factor) the number of self-citations has the largest influence, followed by lapse status and other-citations. Technology sector and year are significant predictors of family size but less important than the covariates. Again, looking at the correlations among the covariates, it appears that the correlations are significant but not high ($r < 0.25$). This would indicate that the covariates are each measuring different attributes of patent value.

SUMMARY AND CONCLUSION

The number of small-business patents increased by more than a factor of three over the period 1988 through 1998. Small U.S. businesses are clearly making more use of the U.S. patent system. Moreover, the percentage of small-business patents that are international grew over this period, and grew faster than it did for large-business patents. Nonetheless small businesses still patent abroad significantly less than do large businesses, regardless of technology field.

Family sizes for both small and large firms generally grew each year from 1988 to 1996. Large businesses patent their inventions more broadly, even when compared with small-business patents that are filed overseas. This has been true over the period studied and in all technology fields but one.

Patent value measures based on the number of other-citations showed small-business patents to be more valuable than large-business patents in all four years. At the technology level, small-business patents are more valuable than large-business patents in some technologies. The

measure based on patent renewals, in contrast, showed that large-business patents are more valuable than small-business patents. Again this was true in some technologies and not others. It should be recalled that other-citations are a measure of "public" value, that is, value to other parties besides the owner, and renewals are a measure of "private" value, that is, value to the patent holder. It is in fact likely that small-business patents have high public value, but lower private value. Small companies are unlikely to be able to appropriate as great a portion of the total value of their inventions as are large businesses because of their resource limitations.

Differences in the value of patents, whether measured as the number of other-citations, self-citations, or lapse status, have a significant effect on differences in the breadth of foreign patenting, but this effect is much smaller than that of company size.

Conclusion

Large businesses seek foreign protection for a greater proportion of their patents and they seek protection in more foreign countries, than do small businesses. This pattern has persisted since the original study. It occurs in all technology fields, where the large business advantage in breadth of foreign patenting is greater in some fields than in others. Although differences in patent value have some explanatory effect, it is a much smaller factor than company size.

If small businesses are not patenting in foreign countries to the extent that they could, it means they are not able to exploit as many commercial opportunities as they might, reducing their potential revenues and hurting the U.S. economy. This should be a concern of U.S. public policy.

This study has not explored all possible sources of influence on the difference in foreign patenting of small and large businesses. The 1995 MRA study, based on differences observed between total families and international-only families, suggested that companies that engage in international business and those that engage only in domestic business may differ in their foreign patenting. The present study, however, did not observe substantial differences for total families and international-only families. That seems to further narrow the range of possible explanatory factors, making resource limitations more likely as an explanatory factor. The role of resources might be addressed more directly in a future study with finer-grained data on company size or financial data for the businesses in this study.

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