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Why Small Technology Firms are Producing More High Impact Patents - And How Resources Such as IEEE Help Small Firms Compete

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A fascinating trend has emerged in the area of patent production. A recent study by 1790 Analytics shows that small firms are producing a larger percentage of emerging technology patents given their participation in the patent system. For example: while small firms in the U.S. represent less than 2% of all Computer Hardware patents, they account for almost 12% of all of the Computer Hardware patents considered likely to contain leading edge technology. What's driving the small firm's patent success? That is the topic of the attached research paper, "IEEE Referencing By Small Technology Firms". Below is a summary of the paper's findings.

The key to small firm patent success: scientific articles

A common denominator among many high impact patents is the referencing of scientific articles. (This use of leading edge science suggests that small firms tend to get more patents for new inventions rather than incremental improvements, which often reference prior patents.) Within several major technology areas, including telecommunications, semiconductor manufacturing, computer software and hardware, small firm patents reference more scientific articles on average than large firms, with IEEE journal papers and conference papers comprising the bulk of these articles. In fact, *small firm patents reference about twice as many IEEE articles on average as large firms*.

> Here's another statistic worth noting: fully 61% of the science references from patents in Computer Hardware appeared in IEEE journals or IEEE-sponsored conferences. Similar results were found in other high tech categories such as Telecommunications, Robotics, Software, and Optics and Information Storage.

Scientific referencing also enhances patent performance

Not only do small firm patents tend to have greater technological impact on average than larger firm patents, they generally score higher in a variety of metrics, from citation impact to patent originality. These metrics have been used for a number of years to gauge interesting technology and often correlate to inventor awards, increases in contravention revenues, stock price appreciation and other major accomplishments.

IEEE plays a role in leading edge innovation

It is well known that IEEE is an important science base for patents most likely to become leading edge innovations. The breaking news is the extent to which small firms are using IEEE publications and meeting with tremendous success. This doesn't mean all patents linked to science will be groundbreaking, but there is compelling evidence that patents that build on IEEE scientific papers deliver positive results.

Analysis of Patent References in Small Firms

Executive Summary

Recently, 1790 Analytics completed a project for the Small Business Administration (SBA) that resulted in a database of all small and large firms with significant patent portfolios. We also recently completed a project to identify emerging technology patents. In addition, we completed a project for the IEEE that examined the extent to which technology firms reference scientific papers. In this paper we leverage data collected in these projects to discuss the role of IEEE science in technological developments of small firms. Some of the key findings include:

- In each of 11 technology categories examined, we found that small firm patents on average reference twice as many scientific articles as patents from large firms. IEEE journal papers and conference papers make up a large percentage of the scientific articles (as much as 58% in Telecommunications) and again small firm patents reference about twice as many IEEE articles on average as large firms. This use of leading edge science as prior art suggests that small firms tend to be more selective about which patents get filed, and small firms tend to get patents for new inventions rather than incremental improvements at a higher rate than large firms.

- In each of the 11 categories small firm patents tend to perform better in a variety of metrics including citation impact, current citation impact, as well as patent generality and originality. These metrics have been used for a number of years to identify interesting technology and they have been shown to correlate with a number of positive outcomes including inventor awards, increases in licensing revenues, stock price appreciation and others. Again this suggests that small firm patents tend to be of higher technological impact on average than larger firm patents.

- The latter results suggest an association between patents that reference scientific papers (and IEEE papers in particular) and patents with high scores in performance metrics. That doesn't mean that all patents that are linked to science will be valuable, but it does suggest that there is some relationship between patents that build on scientific papers and positive outcome metrics in the future.

- Small firms produce a larger fraction of emerging technology patents than is expected given their overall participation in the patent system. For example, US small firms account for less than 2% of all Computer Hardware patents, but they produce almost 12% of all of the Computer Hardware patents identified as those likely to contain emerging, high-risk, leading edge technology. Moreover 61% of the science references from the patents in these emerging technology clusters appeared in IEEE journals or IEEE sponsored conferences. Similar results were found in other high tech categories such as Telecommunications, Robotics, Software, and Optics and Information Storage.

In short, small firms create a surprising amount of high impact technology, and that technology often builds upon science. Much of that science is published in IEEE journals or IEEE sponsored conferences.

Introduction

This paper leverages a database built to study small business technology. Recently, 1790 Analytics completed a project for the Small Business Administration (SBA) where we analyzed all US firms with 15+ granted patents in the years 2002-2006. There were 1293 such firms, and 40% of them were small businesses. Various attributes of the patents from these 1293 firms were examined in order to determine differences between small firm patenting and large firm patenting. In this paper we will mine the database from the SBA project in order to analyze the extent to which small firms reference scientific papers compared with large firms in 11 technology areas. We will further analyze the database to examine prior art that appears in IEEE journals or IEEE sponsored conferences.

Background

Technology builds on earlier scientific and technological developments. A 2009 Lexus could not have been created in the time of Henry Ford's Model T because it contains technology developed and improved upon over many years. Many of the innovations in modern cars are discussed in thousands of patents and each of these patents in turn is built upon thousands of earlier patents and scientific articles. When a new patent is filed, the inventor convinces the patent office that the invention is novel by referencing earlier patents or scientific articles and showing that the new invention contains a new advance over this earlier prior art. In some cases the new invention represents an incremental improvement over existing technology while in other cases the invention may be completely new use of a scientific discovery.

In a series of reports going back to 2004 we have analyzed the use of IEEE journals and IEEE sponsored conferences on technology developments. The key findings of those reports can be summarized as follows:

1. The top patent producing firms overwhelmingly reference IEEE publications and conferences. For instance about 35% of all scientific references from the top patenting firms go to IEEE publications. About 10% of all scientific references from the top patenting firms go to second place Reed-Elsevier [2].

2. In Information Technology (IT) related patents such as Telecommunications, Semiconductor Manufacturing, Computer Software and Hardware, the IEEE provides an even larger portion of the science base of technology. For example in the last 12 years nearly 200,000 US patents have issued related to Communications and Telecommunications. About 48% of all scientific references from these patents have been to IEEE journals or IEEE conference papers. During the same time period, only about 5% of all science references from these patents have gone to the second place publisher The Institution of Engineering and Technology (IET, formerly known as IEE) [2].

3. It has been shown that high-quality, high-impact, and valuable patents tend to be cited more frequently by later patents [3]. Citation impact is thus often used as a quantitative measure for evaluating patents. Patents that reference IEEE papers are cited more often than patents that do not. Thus not only do IEEE publications frequently provide the

science base for new inventions, but inventions that build upon IEEE publications are more likely to be valuable in the future than inventions that do not build upon IEEE publications [2].

4. The importance of scientific and technical literature to patented technology is increasing in all areas. Our research shows that the average US patent had only 2.76 non-patent references (NPRs) back in 1997. That number jumped to 5.28 by 2008 – a 91% increase. However, patent referencing to IEEE has increased at an even faster rate with a 159% increase in the same time period on an NPR per patent basis. In terms of total references, NPRs to IEEE published papers have increased 261% since 1997. This means that in the overall patent system (and not just in IT categories), patented technologies are increasingly referencing scientific articles and that IEEE provides an increasing portion of that science base [2].

Recently in a project sponsored by the Small Business Administration (SBA), we created a database consisting of all US firms with 15+ patents issued from 2002-2006. The database consists of 1293 firms, which were then researched to determine their size. The SBA considers a firm a small business if it has 500 or fewer employees. By this definition, 40% of the 1293 firms with 15+ patents in the 5-year period can be considered small firms [4]. Having this database allows us to explore differences between small firms and large firms.

Before looking at the scientific referencing patterns of small firms it is worth reviewing some of the key findings about small and large technology firms from the SBA study.

1. Patents are expensive to file and maintain, so small firms tend to file patents for their most important inventions. Although small firms make up 40% of all firms in the database, they make up just 6.5% of all the patents within the database [4].

2. Small firm patents outperform large firm patents on a number of impact metrics including growth, citation impact, patent originality, and patent generality. These metrics have been used for decades to measure the innovativeness of firms, labs, and agencies. The metrics have been validated and have been shown to correlate with increases in sales, profits, stock-prices, inventor awards, and other positive outcomes. This suggests that the patents of small firms in general are likely to be more technologically important than patents of large firms. This is not to suggest that every small firm patent will be more valuable than its large firm counterpart, but that statistically the patents of small firms perform better on average than those of large firms. Again this is probably due to the expense of building and maintaining a large patent portfolio. Because small firms have to patent selectively, they are likely to only patent their most promising inventions [4].

3. Small firms with 15+ patents are much younger than the large firms with 15+ patents. 90% of the large firms are 15 or more years old while only 43.5% of small firms are 15 or more years old. Moreover, 1 in 5 small firms have been in business less than 10 years, while only about 1 in 40 large firms are that young [4].

4. Small firms are more likely to develop emerging technologies than are large firms. Although small firms account for only 8% of patents granted, they account for 24% of the patents in a set of patents from a set of 100 emerging technology clusters. This means that they produce three times as many patents in this special patent set as one would expect. To put this another way, approximately 1 in 31 small firm patents are contained in the top emerging clusters but only 1 in 117 large firm patents are in these top emerging clusters. Again, this suggests that small firms tend to only file a patent if they think they have an important invention to protect.

Database Construction

It is important to understand that the patent office records assignees and not necessarily companies. Therefore it is not trivial to get all of the patents owned by Microsoft or General Motors. Patents owned by General Motors and others are a mixture of names of firms, establishments, subsidiaries, and variants of firm names. Mergers and acquisitions are also constantly changing the status of firms. As an example, large firms like General Motors and Procter & Gamble patent under more than 100 names. Extreme cases of firms that have a history of mergers, such as Glaxo-SmithKline, will have patents filed under more than 300 names.

The core database used by 1790 Analytics on a day-to-day basis, and licensed to information companies such as Thomson Scientific, tracks nearly 4,000 organizations in three patent systems and is made up of more than 75,000 individual subsidiary and variant assignee names. This database is maintained by a data manager with more than 20 years experience with tracking mergers, acquisitions, and divestitures.

The 1790 database tracks US firms, foreign firms, non-profits, universities, and government agencies. The database used for this project is a subset of the main database consisting of US based companies. In addition, for the SBA database we extend the set to include US firms with 15 or more patents granted between 2002 and 2006. An additional extension made to the database includes a lookup of the number of employees for each of the 1,293 firms as well as an identification of revenues, line of business and SIC (Standard Industrial Classification) and NAICS (North American Industry Classification System) codes where available. These data were identified using multiple sources including Mergent/Moody's International, Lexis/Nexis, Annual Reports, and Dun & Bradstreet.

The cutoff date for the company structure is December 31, 2007. Any firms that merged after that date are as they were at the end of 2007. Similarly, while we removed companies that were bankrupt in general, any that have become troubled since December 31, 2007 have not been removed.

For this project, all subsidiaries are combined with their parent companies. For example the patents of Ethicon and Cordis Corp. are combined with the ultimate parent company Johnson and Johnson in the database. Similarly the US biotechnology company Genentech is removed completely because it is majority owned by the foreign firm Roche Holdings, and foreign firms are not part of this study. The firms run the gamut from the small business Rain Bird with 15

patents in the 2002-06 period related to sprinklers to computer giant IBM with 16,700 US patents in the period and more than 30,000 patents overall.

Prior art References

When an inventor files a patent for a new invention, he/she will typically reference earlier documents to show that the new invention either builds upon, or improves upon, what came earlier. The inventor's patent attorney and/or the examiner may also add prior art references to either clarify or limit the claims of the new invention.

Prior art comes in the form of patent references and non-patent references. Patent references are earlier patents that are referenced (or cited) in a new patent. Non-patent references (NPRs) are referenced to any document other than earlier patents. NPRs can be to any published document, from comic strips and brochures, to scientific articles and standards documents. In this paper we discuss the science base subset of NPRs which include journal articles, conference papers, and standards documents.

Results and Discussion

As discussed above, 1790 has analyzed all of the science references from 11 technology areas including Communications & Telecommunications, Semiconductors & Solid State Electronics, Computer Hardware, Robotics & Intelligent Manufacturing and others. A list of the technology areas can be found in Table 1 below. We see that in most cases US large firms make up approximately 30% to 40% of all issued patents in each category, while US small firms make up about 2% of the patents in each category. The remaining 50% to 60% of patents in each category are produced by foreign firms such as Canon and Siemens as well as by foreign and domestic universities, non-profits and government agencies. There are also a very small percentage of patents produced by US firms that are not in the SBA database. (Recall that the SBA database consists of US firms with 15+ patents from 2002-06. So there are some US based large and small firms that are not represented because they file too few patents.)

We see that although small firms account for about 40% of the firms in the database, the large firms have 10 to 20 times as many patents in most categories. It is believed that small firms are much more selective in what they patent, and we will see below that small firm performance in various metrics bears this out.

Table 1 - Number of US Patents 1997-2008 in 11 Categories

Category	# US Patents	# US Patents from US Large Firms	% Patents from US Large Firms	# US Patents from US Small Firms	% Patents from US Small Firms
Computer Hardware	135436	54662	40.4%	2256	1.7%
Computer Software	64363	30952	48.1%	980	1.5%
Medical Instruments	82172	25565	31.1%	2862	3.5%
Information Storage	66909	21988	32.9%	1421	2.1%
Measuring, Testing & Control Devices	92884	26759	28.8%	1914	2.1%
Nuclear/X-Ray/Radiant Energy	19329	4703	24.3%	320	1.7%
Optics/Photography/ Electrophotography	81775	18592	22.7%	1341	1.6%
Power Systems	39717	9581	24.1%	1098	2.8%
Robotics and Intelligent Mfg	13968	3759	26.9%	296	2.1%
Semiconductors/ Solid-State Devices	117329	37497	32.0%	1906	1.6%
Telecom and Other Communications	198638	60646	30.5%	4879	2.5%

We have found that all of these categories reference scientific papers and conference papers to a large extent. Until now, we have not looked at scientific referencing by small and large firms. Figure 1 below shows the number of science references per patent for 11 technology categories. Note of course that some technologies are more dependent on science than others. For example patents related to power systems reference fewer than one scientific article on average, while patents related to semiconductors reference about three scientific articles per patent.

We see from Figure 1 that patents from small firms are more science linked than patents from large firms. For example the average telecom patent from small firms references 5 scientific articles, while the average telecom patent from large firms references a single scientific article. Similar differences appear in each of the technology categories. It has been suggested that patents with many science references are likely to contain new leading-edge ideas, whereas patents that only reference earlier patents are likely to be incremental improvements on earlier patented technologies. For a comprehensive study on various hypotheses surrounding the motivations of inventors in citing other references, see [1].

The fact that small firm patents have a higher number of science references on average than large firm patents supports the idea, presented above, that small firms, because of their limited resources, concentrate their patenting on their most important innovations while large firms are likely to patent incremental improvements as well as their most important innovations.

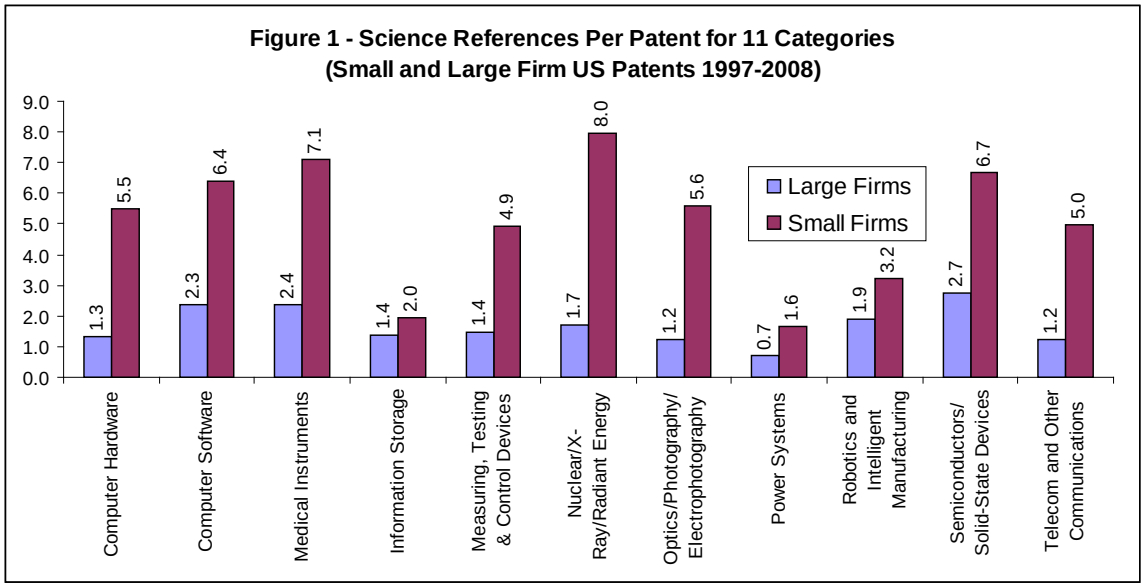
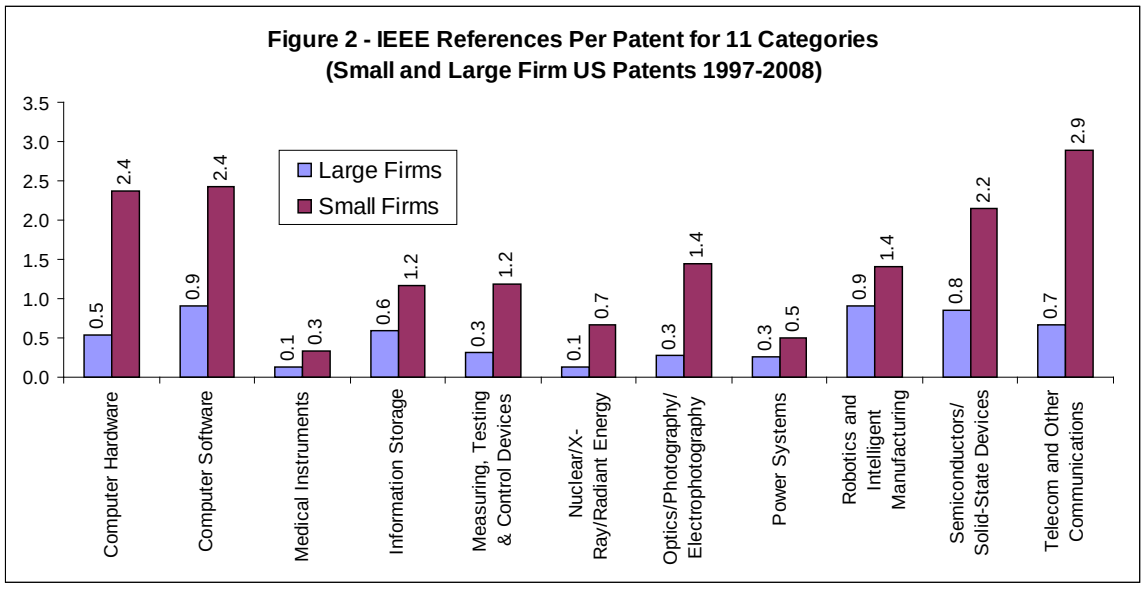
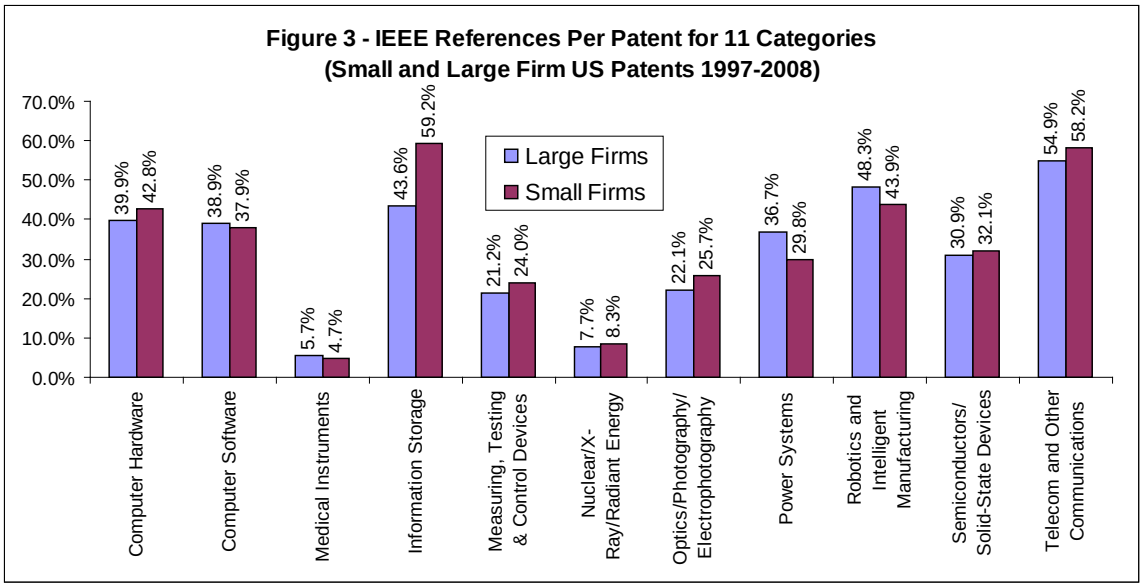


Figure 2 below is similar to Figure 1 except it shows the number of science references that are to IEEE journal papers or IEEE conference papers. We see again that small firm patents reference IEEE more on average than large firm patents. We also see that in most of the Information Technology (IT) related areas, the IEEE references make up a significant portion of the science references. For example small firm telecom patents average 5 science references of which 2.9 are IEEE references. In other words 58% of small firm telecom science references are to IEEE publications.



The percentage of IEEE references for each of the categories can be found in Figure 3 below. It is somewhat surprising that although there are large differences between the number of science and IEEE references from small and large firms, the percentages of references to IEEE publications are rather similar. For example there are more than twice as many IEEE references

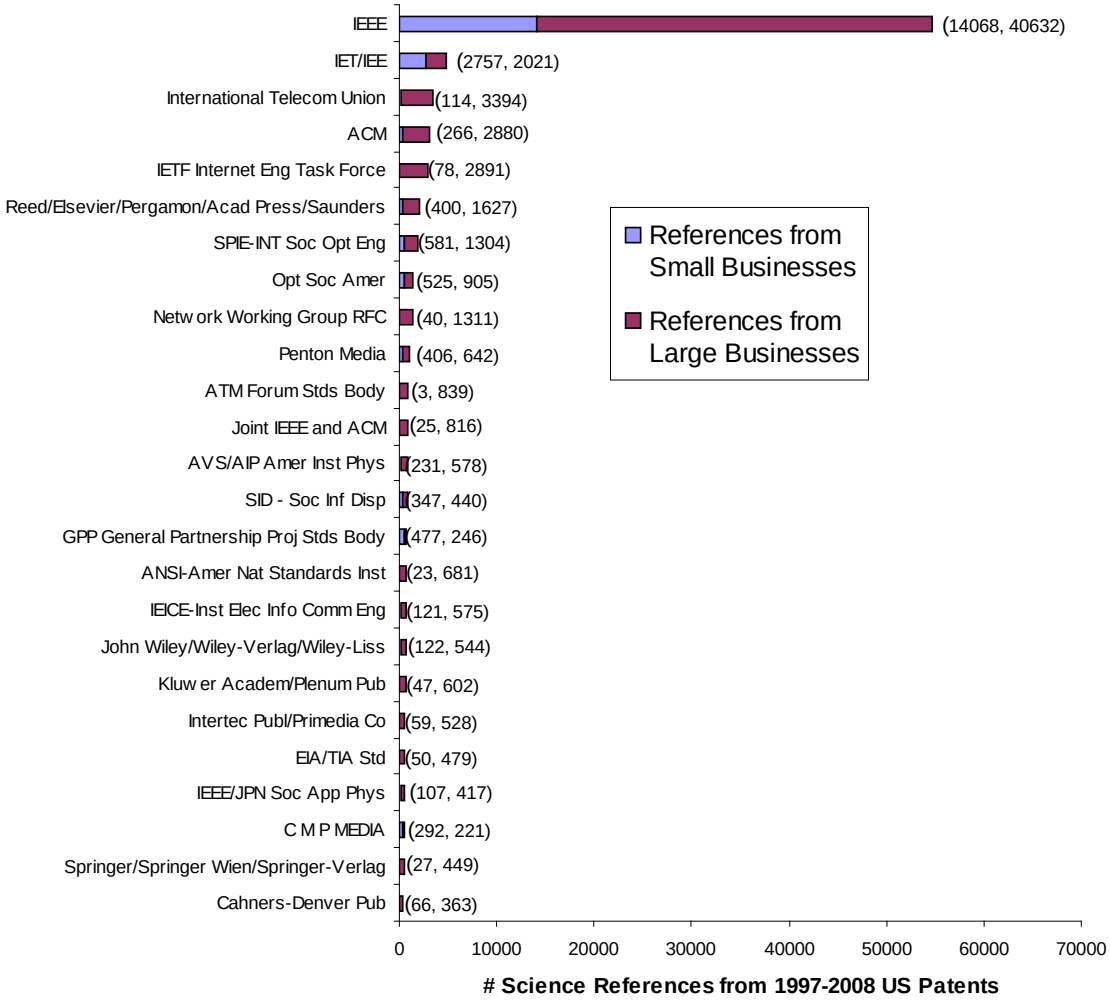
from small firm semiconductor patents as there are from large firm semiconductor patents, but the percentage of semiconductor IEEE references from small and large firms are 31% and 32% respectively. In other words, approximately 1 in 3 science references from all semiconductor patents are to IEEE journal and conference articles.



Except for the Medical Instruments and Nuclear and X-Ray categories, the percentage of science references that go to IEEE publications is very high. In the IT fields there are dozens of journal publishers and conference sponsors and in medical fields there are even more; so for a single publisher to get even 10% to 15% of all science references is rather surprising. To see this consider Figure 4 below, which examines the number of scientific references from telecommunication patents from small and large firms to the top 25 publishers. Note that for the 12 year time period 14,068 of the science references from small firm communications patents appear in IEEE publications. We saw in Figure 3 that 58% of all science references from small firms communication patents appear in IEEE publications and approximately 55% of large firm communication references go to IEEE publications. In other words, the IEEE provides more than half of the science base for patents in telecommunications and small firms reference IEEE publications to an even larger extent than large firms. No other publisher is even close to IEEE in terms of references from small or large firms. About 11% of the small firm references are to IET (formerly IEE) publications, which is enough for second place, but still only about 1/5 as high as the IEEE count.

For space considerations we used telecommunications as an example, however if we were to include similar figures for Computer Hardware, Computer Software, Semiconductors, Information Storage, Robotics & Intelligent Manufacturing, Measuring & Testing, Optics, or Power Systems the figures would all look similar with IEEE being the most referenced publisher by both small and large firms and with a huge lead over the second most referenced publisher.

Figure 4 - Science References from 1997-2008 Telecom Patents to Top 25 Publishers, Conference Organizers, and Standards Organizations



To summarize the results so far, what we've shown is that within several major IT related technologies small firm patents reference more scientific articles than large firms on average and that a large fraction of that science base is published in IEEE journals or conference papers. Leading edge patents often reference scientific articles while incremental improvement patents tend to reference earlier patents only. Thus IEEE is an important part of the science base for patents that are most likely to become leading edge innovations. This latter result has been discussed before, but what is new in this paper is the extent to which small firms use scientific articles in general and IEEE publications in particular. In the remainder of this paper we will explore the notion of small firms creating a higher percentage of high impact and leading edge patents, and the correlation with science linked patents. In Table 2 below we show a number of patent metrics for small and large firms. The metrics are somewhat well known, but to make this

paper self-contained we will provide a brief description here. A more complete definition of the various metrics can be found in [4].

1. **Citation Index** is a citation indicator. Research has shown that patents that are cited by many later patents tend to contain important ideas upon which many later patents are building. For example patents that have won awards tend to be highly cited. Also patent citation metrics have been shown to correlate with increases in sales, profits, stock rises and other positive outcomes. For a review of validation studies see [3]. The citation index counts the number of citations received by a set of patents and divides this by the average number of citation for all patents from the same year and technology. Thus a patent set with an average number of citations will receive a Citation Index value of 1.0.
2. **Pipeline Impact** is also a citation indicator. The Pipeline Impact indicator differs from the Citation Index in that it is based on citations from all patents issued in the most recent year to the patents issued to an organization in the previous five years. For example, to calculate a 2008 Pipeline Impact figure for an organization, we examine how many citations the organization's patents issued from 2003-07 have received from patents issued in 2008. Again, a patent set that receives an average number of citations will get a Pipeline Impact value of 1.0.
3. **Originality Index** is calculated by measuring the variety of technologies upon which a patent builds, as reflected in the breadth of patent office technology classes of the patents it cites. The idea is that patents created by combining ideas from several different technologies tend to be more original than patents that make incremental improvements from earlier patents in the same technology. The idea for this metric comes from researchers at the National Bureau of Economic Research (NBER). See [6] for details.
4. **Generality Index** is the analog to originality and is also based on an NBER indicator. The idea is that patents cited by later patents from different fields tend to be more general than those that are only useful to a specific field. For example a patent for a new composite material has more applications and is more general than a patent for a mouse trap mechanism. The former is considered more general because the material will have uses in many different technologies whereas the latter will only be used in mouse traps.
5. **Science Index** computes the number of prior art references to scientific papers divided by the expected number of science references for a patent portfolio.

All of 1790's patent quality metrics are normalized so that an average patent portfolio should receive a value of 1.0. For example, the citation index for the set of all Computer Hardware patents is designed to equal 1.0. This means that Large US firm patents in Computer Hardware are cited 7% more than expected while small firm patents in Computer Hardware are cited 64% more than expected. Similarly in Computer Hardware the 0.98 Science Index for large firm patents means the large firms reference 2% fewer scientific articles than average, while the small firm patents in computer hardware reference 151% more scientific articles than average.

Table 2 below shows that for each metric and each technology category, small firm patents out-perform large firm patents. That is in Computer Hardware, Software and every other category, the small firms have higher values than the large firms for Citation Index, Pipeline Impact Index, Generality Index, Originality Index, and Science Index. These metrics have been used for many

years to attempt to identify high impact technology from among the thousands of patents that issue each month.

Note that the Citation Index, Pipeline Index, and Generality Index are each 'outcome' metrics. For example citations accumulate over time and a typical patent might take 5 years to accumulate 10 or more citations. The science index on the other hand can be computed the day a patent is issued, because it is based on the prior art listed on a patent. Thus, there is no reason to expect science index to be correlated with the other metrics, yet there appears to be some kind of association.

Table 2 – Patent Metrics for 11 Technology Categories 1997-2008.

	US Large Firms	US Small Firms	US Large Firms	US Small Firms	US Large Firms	US Small Firms	US Large Firms	US Small Firms	US Large Firms	US Small Firms	US Large Firms	US Small Firms	US Large Firms	US Small Firms
Category	# Patents		Citation Index		Pipeline Impact		Originality Index		Generality Index		Science Index		IEEE % of Science Base	
Computer Hardware	54662	2256	1.07	1.64	1.08	1.83	0.99	1.10	1.13	1.73	1.17	4.71	39.9%	42.8%
Computer Software	30952	980	1.10	1.56	1.05	1.51	0.98	1.08	1.08	1.54	1.00	2.56	38.9%	37.9%
Medical Instruments	25565	2862	1.20	1.87	1.30	1.88	1.01	1.17	1.31	1.71	1.00	2.84	5.7%	4.7%
Information Storage	21988	1421	1.19	1.41	1.19	1.43	1.00	1.07	1.17	1.80	1.63	2.38	43.6%	59.2%
Measuring, Testing & Control Devices	26759	1914	1.18	2.00	1.27	2.15	1.02	1.07	1.29	2.08	1.05	3.25	21.2%	24.0%
Nuclear/X-Ray/Radiant Energy	4703	320	1.20	2.11	1.18	1.48	0.98	1.00	1.24	2.51	0.96	4.46	7.7%	8.3%
Optics/Photography/ Electrophotography	18592	1341	1.11	1.88	1.20	1.89	1.01	1.20	1.22	2.42	1.28	4.90	22.1%	25.7%
Power Systems	9581	1098	1.13	1.53	1.15	1.53	1.00	1.03	1.33	1.90	1.32	2.92	36.7%	29.8%
Robotics and Intelligent Mfg	3759	296	1.33	1.78	1.17	2.17	1.08	1.16	1.37	1.94	1.43	2.41	48.3%	43.9%
Semiconductors/ Solid-State Devices	37497	1906	1.26	1.92	1.28	2.25	1.03	1.18	1.31	2.12	1.43	3.25	30.9%	32.1%
Telecom and Other Communications	60646	4879	1.15	1.50	1.13	1.54	1.01	1.09	1.23	1.61	1.07	4.15	54.9%	58.2%

It would be foolish to assume that all highly science linked patents will become highly cited patents or that all highly cited patents should be science linked, but it does appear that at least in these technologies, patents that reference a number of scientific articles tend to perform better in the outcome metrics after several years. This suggests that high science linkage may predict future impact for at least some patent portfolios. Moreover in the last two columns of Table 1 we see that the IEEE is an important source of this science base.

To summarize, we can see that small firms outperform the large firms in each of the metrics and that outcome is associated with large amounts of referencing to scientific articles from those small firms. Moreover a large fraction of those scientific articles are published by IEEE.

Before leaving this discussion we should point out that while the US small firms outperform the US large firms in each of the metrics, in most cases the US large firms performed above average. For example in Computer Hardware we pointed out that large firm patents had a citation index of 1.07 and small firm patents had a citation index of 1.64. The expected value is of course 1.0 which means that large US firm patents are cited 7% more often than expected. This means that the remaining patents – consisting of primarily large and small foreign firm patents as well as US and foreign university and government patents – must have a citation index of less than 1.0.

Table 3 below contains data on a specialized subset of patents from the top 100 emerging clusters of patents from a study done for the US Department of Commerce. In a pair of studies [5, 6], 1790 Analytics developed and validated a method for identifying clusters of patents containing high-risk, leading-edge, emerging technology. As part of that study the top 100 emerging clusters of patents were identified. Each cluster contains 10 to 40 patents, and each cluster falls into a variety of technology categories. The subset of patents that fall into our 11 technology categories are shown below in Table 3.

Table 3 – Number of Patents by Category in Top 100 Emerging Clusters

Category	# Emerging Cluster Patents	US Large Firm # and % Emerging Patents	US Large Firm Expected # Emerging Patents	US Large Firm Expected /Actual Emerging Patents	US Small Firm # and % Emerging Patents	US Small Firm Expected # Emerging Patents	US Small Firm Expected /Actual Emerging Patents
Computer Hardware	229	91 (39.7%)	92.4	1.0	27 (11.8%)	3.8	7.1
Computer Software	202	97 (48.0%)	97.1	1.0	24 (11.9%)	3.1	7.8
Medical Instruments	87	32 (36.8%)	27.1	1.2	18 (20.7%)	3.0	5.9
Information Storage	48	15 (31.3%)	15.8	1.0	9 (18.8%)	1.0	8.8
Measuring, Testing & Control Devices	105	32 (30.5%)	30.2	1.1	17 (16.2%)	2.2	7.9
Nuclear/X-Ray/Radiant Energy	16	4 (25.0%)	3.9	1.0	4 (25.0%)	0.3	15.1
Optics/Photography/ Electrophotography	77	22 (28.6%)	17.5	1.3	7 (9.1%)	1.3	5.5
Power Systems	27	5 (18.5%)	6.5	0.8	8 (29.6%)	0.7	10.7
Robotics and Intelligent Mfg	16	4 (25.0%)	4.3	0.9	6 (37.5%)	0.3	17.7
Semiconductors/ Solid-State Devices	112	31 (27.7%)	35.8	0.9	4 (3.6%)	1.8	2.2
Telecom and Other Communications	358	153 (42.7%)	109.3	1.4	44 (12.3%)	8.8	5.0

Table 3 is complicated but it contains a very interesting result with respect to small firms. The data set for the emerging clusters project [5] identified 1,750 patents from 2005-06 that were most likely to contain high-risk, emerging technology. As Table 3 shows, of the 1,750 emerging cluster patents, 229 are related to Computer Hardware. Of the 229 patents, 91 or 39.7% are owned by large US firms. Back in Table 1 we saw that 40.4% of all Computer Hardware patents were owned by large US firms, so the 91 emerging patents in the category for large firms is close to the expected count. For small firms the result is rather interesting however. US Small firms produced 27 Computer Hardware patents in the emerging clusters or 11.8%. Back in Table 1 however we saw that US small firms produce only 1.7% of all computer hardware patents. From this, we would only expect the small firms to produce about 4 computer hardware patents within the emerging set. The 27 Computer Hardware patents from small firms in Table 3 represents 7.1 times as many emerging patents as expected from small firms.

In fact, in the last column of Table 3 we see that small firms produce many more emerging patents in every category than one would expect from the overall participation of small firms in the patent system. For example small US firms produce only 2.5% of all Robotics patents, but they produce 37.5% of the emerging patents in the category, which is almost 18 times as many as expected. Now one could argue that the numbers are so small in the Robotics category, that the results are inflated by just a few patents. However, the same can't be said for all of the categories. For example the 44 emerging telecom patents from small firms is 5 times higher than expected.

Above we saw that much of the science base for the IT related categories came from journals and conferences published or sponsored by IEEE. Table 4 shows that the patents from the emerging clusters follow this trend as well, and in many cases small firms with emerging patents build on IEEE science to a greater extent than large firms. For example for the emerging cluster patents in Computer Hardware large firms reference IEEE science about 30% of the time, while small firms reference IEEE science 61% of the time. The reader will recall from Table 2 that for the set of all Computer Hardware patents the percentages were 39.9% and 42.8% respectively. In other words, IEEE provides a substantial part of the science base for Computer Hardware patents in general, but small firms working in emerging areas leverage IEEE science even more.

Table 4 – IEEE Percent of Science Base of Emerging Cluster Patents

	US Large Firms				US Small Firms			
Category	# Emerging Cluster Patents	# Science References	# of IEEE Science Refs	% IEEE Science Refs	# Emerging Cluster Patents	# Science Refs	# of IEEE Science Refs	% IEEE Science Refs
Computer Hardware	91	938	284	30.3%	27	508	310	61.0%
Computer Software	97	863	251	29.1%	24	472	138	29.2%
Medical Instruments	32	105	5	4.8%	18	177	1	0.6%
Information Storage	15	301	136	45.2%	9	123	59	48.0%
Measuring, Testing & Control Devices	32	551	101	18.3%	17	340	142	41.8%
Nuclear/X-Ray/Radiant Energy	4	**	**	**	4	**	**	**
Optics/Photography/ Electrophotography	22	131	20	15.3%	7	117	53	45.3%
Power Systems	5	3	3	100.0%	8	173	12	6.9%
Robotics and Intelligent Mfg	4	**	**	**	6	28	9	32.1%
Semiconductors/ Solid-State Devices	31	779	531	68.2%	4	**	**	**
Telecom and Other Communications	153	1096	445	40.6%	44	649	329	50.7%

** Values not computed for cases with fewer than 5 patents.

IEEE is not much of a factor in the medical areas which are not really core to its mission, but in the Information Technology categories such as Computer Hardware, Software, Information Storage, and Telecommunications, the IEEE provides a significant portion of the science base for all of the patents as well as the patents in the emerging clusters.

Conclusions

In this paper we examine small firm and large firm patenting in 11 categories of technology. In each case we examine the extent that firms referenced journal papers and conference papers. We found that in these technologies small firm patents perform better in a variety of performance metrics. We also found that small firms produce a higher number of emerging technology patents than they should given their overall participation in the US patent system. This suggests that small firms are more selective about which patents they file, and are less likely to file mundane, incremental improvements than large firms. In other words, a small firm patent selected at random is much more likely to be a more valuable invention than a large firm patent selected at random.

This is not to say that a small firm patent portfolio would have the value of a large firm such as IBM. Large firms such as IBM produce so many patents that even though a high percentage are incremental inventions, the total IBM portfolio will still have many important, high-value inventions.

The other aspect we examined is the extent to which patents in these categories reference scientific papers in general and IEEE papers in particular. We found that small firm patents reference scientific papers to a greater extent than large firm patents, and that IEEE provides a large portion of that science base.

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