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# Patent Trends among Small and Large Innovative Firms during the 2007-2009 Recession

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by

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*The statements, findings, conclusions, and recommendations found in this study are those of the authors and do not necessarily reflect the views of the Office of Advocacy, the United States Small Business Administration, or the United States government.*

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# I. Introduction and Key Findings

## *A. Overview*

This report describes the key findings from an ambitious project designed to measure the effects of the recent economic downturn on highly innovative US small and large firms. For this project, we leveraged and updated a detailed database of 1,279 small and large technology firms built for the SBA-Green project (Breitzman and Thomas, 2010). The firms in this database are referred to as highly innovative firms because to enter the database they must have been granted at least 15 US patents in the period 2005-09. As such, they are a special subset of US firms that produce significant numbers of patents. In total, these firms own more than one million patents.

For the SBA-Green project, we built the database of innovative firms and then removed any that appeared to be out of business through December 31, 2009[1]. We also identified the number of employees as of that date, and tagged as small businesses any with 500 or fewer employees. In addition to patent information, the database contains information on revenues, and industry classification where available. There are significant advantages to leveraging the database from the prior study. First, it contains all US firms with extensive patent activity over the period 2005-09, and is not restricted to small or large firms. Second, the patent activity for these firms during these years covers both the period leading to the recession, and the period after the recession had begun.

As noted above, we used the selection criteria of 15 patents from 2005-09 in order to leverage the extensive database from the previous project. For this project, we enhanced the database to include US patents granted from January 1, 2005 through June 30, 2011, as well as all published US applications from January 1, 2005 through July 31, 2011.

## *B. Issues*

There is great academic and policy interest in studying the macroeconomic effects of an economic downturn on small and large businesses. To our knowledge, however, nobody has previously studied the effects of recessions on R&D outputs of small and large firms by analyzing patent trends. Since we had already built the extensive database of highly innovative small and large firms for the SBA-Green project, we proposed mining it for macroeconomic use.

Some of the issues we wished to explore include: Do small innovative firms increase their patent activity before large firms at the end of a recession? Do foreign firm patent filings slow down after those of US small and large firms during a recession and how quickly do they recover? Do small and large US firms from the Western region recover faster than their counterparts in the Eastern and Central US regions?

## *C. Key Findings*

[1] It is not always easy to determine if a firm is no longer operating because their websites are often still up and they are frequently too small to be in many online business databases, but we try to remove them for two reasons. First, if a firm went out of business in 2005, it might still have patents issue in 2005 or 2006 making it eligible to be in the analysis. Such a firm would create an artifact in the general patenting trends of small firms because they would not have patents in the latter period of the analysis. A second reason for removing such firms is that we used current employee counts and current sales as indicators in the analyses.

The major findings from the project are summarized below. Additional details of these findings, and a full discussion of each topic, can be found in the main body of the report.

## Basic Statistics

1. In the SBA-Green study, we identified 1,279 US firms that were granted 15 or more US patents in the five-year period 2005-09. In this project, we leveraged the this existing database but added any new patents patents issued to these companies through June 30, 2011. We also added all published US patent applications for these companies from 2005 though July 31, 2011.

2. 42% of the 1,279 firms are small firms with 500 or fewer employees, so we have more than 500 small firms and more than 700 large firms to use in tracking trends in R&D during the recent recession.

3. 57% of all the firms (and 29% of the small firms) in the database are publicly listed on major US exchanges (i.e. not including companies whose stock is traded over the counter). We estimate that less than 0.1% of all firms are publicly traded on major US exchanges. The large share of publicly traded firms in the database for this project is therefore notable. It suggests that firms of all sizes with patented technology are more likely to become successful enough to go public than firms that do not produce patents[2].

4. In our earlier SBA studies, we showed that small innovative firms are much more productive than large innovative firms from a patents-per-employee perspective. Using the updated data in this report, small innovative firms continue to outperform their large counterparts, producing 15 times as many patents per employee.

5. Numerous validation studies have shown a relationship between patent citation impact and positive outcomes such as inventor awards, licensing revenue, increases in sales and profits, etc. See (Breitzman and Mogee 2002) for a detailed review of validation studies. Our analysis shows that patents of small firms are cited 57% more by recent patents than is typical for patents of the same age and patent classification, while patents of large innovative firms are cited just 10% above average. This finding coincides with our earlier SBA studies, where we showed that small firms filed more patents in emerging technologies, and also that small firms had to be more selective with which patent applications to file because of financial constraints.

## Small and Large Firm R&D Patterns During the 2007-2009 Recession

1. Using granted patents in this report to analyze the effects of the recession was not feasible because of the lag in issuing US patents. However, most US patent applications are published within 19 months of filing. Enough time has therefore passed to examine the effects of the recession using patent application data. Published applications have their own drawbacks, such as an 'opt-out' option and a large number of documents that are published without assignees. Having said this, we were able to show that, for our data set, these are relatively minor problems.

2. According to the National Bureau of Economic Research (NBER), the recession started following the fourth quarter of 2007, and bottomed out in the second quarter of 2009. Our results show that there

[2] This calculation comes from an analysis produced in the previously mentioned SBA Green Project. Although the calculation is a few years old, it is unlikely too change much over time.

was an immediate decline in patent applications from small innovative firms coinciding with the start of the recession. Prior to the recession, small firms averaged about 8% of the applications filed by the innovative firms in our database. During the decline, the small firm share fell to 5.6%.

3. Quarterly filings of larger firms compared year-over-year indicate patent application rates did not change significantly until 2009.

4. Over the 2007-2009 recession, small firm patent activity changed earlier than large firm patent activity. It is unclear whether downturns cause small firms to cut R&D expenses immediately, whereas large firms try to maintain R&D throughout a downturn. Alternatively, small firms may make R&D plans on an ongoing basis, while large firms plan well in advance. Either way, it appears that small firm R&D is more sensitive to recession than large firm R&D, but further empirical analysis regarding these questions is needed.

5. During the recession, the decline of small firm patent activity not only occurred sooner than it did for large firms, but the decline seems to have been more severe. Although small firms started to increase their patenting sooner after the recovery than large firms, the long-term affects of the decline still existed. In the two quarters following the start of the recovery in 2009, small innovative firms filed patents at approximately the same rate as they had in 2005. Meanwhile, large firms filed patents at a rate 20 to 30 percent higher than their 2005 rate.

6. It thus appears that small firms saw a much deeper decline in R&D outputs (such as patents) than large firms during the recent recession. Whether small firms are less capable of launching new products following a recession in order to take advantage of the subsequent economic expansion is a question for further study.

## US and Non-US Invented Patent Application Patterns During the 2007-2009 Recession

1. Patent filings from US and non-US inventors declined immediately following the start of the recession. They began to recover following the second quarter of 2009, which coincides the end of the recession according to the National Bureau of Economic Research (NBER).

2. During the recent recession, large US firms who file the most patents did not slow down their patent filing until a year after most other sectors. This could suggest several things: that large innovative US firms either continued to do well during the recession, or were able to rely on their prior wealth advantage, or considered R&D important enough to budget or finance in advance. Further research with an empirical model is needed to determine exactly which of these factors drove this result.

3. Small US innovative firms did slow down their patenting almost immediately after the start of the recession. However, they also increased their patenting following the recession sooner than the other sectors. When we compare quarterly patenting year over year, small innovative firms were the only sector to have upturns in the third and fourth quarters of 2009 compared to the same quarters in 2008.

4. Although foreign invented patent filings fell generally during the recession, filings from China merely leveled off, and did not decline. China currently files only about 1% of all US patents (compared to 19% for Japan, 6% for Germany, and 5% for Taiwan and South Korea). However, China has been the fastest growing country in terms of number of US patents filed over the past six

years. It is also notable that India's US patent filings actually increased during the first four quarters of the recession. It then had three declining quarters but reached a peak in US patent filings in the fourth quarter of 2009.

### Regional Patent Trends of Innovative Firms During the 2007-2009 Recession

1. As reported above, in the period immediately after the recession started, large firms continued to file patent applications at high levels, while small firms quickly reduced their filings. This finding holds for all four US Census Regions (Northeast, Midwest, South, West). The end of the economic expansion came in the fourth quarter of 2007, but large firms in all four regions continued to file patents in large numbers through 2008, with some reaching all time highs during that year. In most regions, large firms only started to reduce their patent filing activity in early 2009. On the other hand, small firms in all regions reduced their patent filing activity immediately after the recession started. Indeed, small firms in the Midwest actually reduced filing activity even earlier than the fourth quarter of 2007.

2. The results are similar at state level, with large firms in most states maintaining their R&D for several quarters into the recession, and then showing a decline in 2009. Meanwhile, small innovative firms repeat their pattern of reducing their patent filings immediately and sharply in the first quarter of 2008. California is an interesting exception to this. Large firms in California not only increased their patent applications in 2008, they did not show major declines in 2009 like in most regions and states. Could it be that many large firms in California are so dependent on R&D that they try to maintain it throughout economic downturns, or are large firms from California active in sectors that were less impacted by the recession? This is another interesting question that would benefit from further research.

3. The small firms in California, on the other hand, reduced their patent filings in the first quarter of 2008, immediately after the recession started. The same happened in most other states, but the drop in California was particularly dramatic. Indeed, much of the overall difference between small firm and large firm patent filings during the downturn can be explained by differences in small and large firm behavior in California.

4. This reflects the importance of California as a share of the US innovation sector. Based on inventor addresses, 22% of all patents from large innovative firms in our database come from California, while 40% of all the patents from the innovative small firms are invented in California. Moreover, 25% of all large innovative firms and 68% of all small innovative firms in the database have their major R&D operations in California.

## *D. Summary*

Our earlier reports found that small firms participate extensively in the patent system, they produce large numbers of patents relative to their size, and these patents tend to have very strong quality metrics. This project extends those earlier reports to reveal the different patent trends of innovative small and large US firms during an economic downturn.

Specifically, we found that during the 2007-2009 recession small firm patent activity changed more quickly and extensively than large firm patent activity. As a result, small firms may be less capable of launching new

products following a recession in order to take advantage of the subsequent economic expansion. Since small firms have been shown to develop high impact technologies, and a higher percentage of green and leading edge technologies[3], this result has significant policy implications.

It is also interesting to note that patent applications, particularly those from small innovative firms, fall when GDP falls and rise when GDP rises. Given that patent applications are a popular proxy for measuring R&D output, this suggests that analyzing application activity may offer a new tool for examining R&D behavior during economic downturns.

The analysis presented in this report does have limitations, and offers opportunities for further research. Perhaps the main limitation is the relatively short period of time between the end of the recession (in the second quarter of 2009 according to NBER) and when this report was produced. Since patent applications are typically published 18-19 months after they are filed, we only have data through the end of 2009 – i.e. two quarters after the recovery began. The results related to the recovery would therefore be more robust if the analysis was updated to include additional data in the future. The analysis presented here also focuses only on a single recession, and it would be interesting to determine whether the findings remain the same for earlier economic downturns.

[3] In addition to the previously mentioned SBA Green Technology report where it was shown that small businesses contribute significantly in "Green" technologies. Earlier projects have shown that small business inventors create more patents per inventor and the average citation impact of small firm patents are higher on average than for large firms. See Breitzman and Hicks, 2008 for example.

# II. Innovative Firm Patent Database Methodology

## *A. Introduction*

One of the key tools used in this project is a carefully constructed database of innovative small and large US firms. This database was created originally for a previous SBA study (Breitzman and Thomas, 2010) that examined green technology developments (hereafter referred to as SBA-Green). Specifically, this database contained all US firms that were granted 15 or more US patents in the five-year period between 2005 and 2009. We refer to these firms as innovative firms to highlight the fact that they have been granted significant numbers of patents.

The database is a unique resource, consisting of 1,279 firms and over a million patent records. In addition to patent information, the database contains information on number of employees, revenues, and industry classification where available. There are significant advantages to leveraging the database from the prior study. First, it contains all US firms with extensive patent activity over the period 2005-09 and is not restricted to small or large firms. Second, the patent activity for these firms during these years covers both the period leading to the recession, and the period after the recession had begun.

As noted above, we used the selection criteria of 15 patents from 2005-09 in order to leverage the extensive work from the previous project. We also enhanced the database for this project to include US patents granted from January 1, 2005 through June 30, 2011 as well as all published US applications from January 1, 2005 through July 31, 2011.

In this section of the report, we describe how the database was constructed. We also highlight interesting results, including the high percentage of small firms in the database that are publicly listed, and the extent to which the patents of small firms outperform those of large firms on a number of performance metrics.

## *B. Summary*

In this chapter we look at basic statistics related to the US innovative firm database constructed for this study. We also point out some limitations of the data and discuss the ways that we overcome the limitations. Some key findings are:

1. In the SBA-Green study, we identified 1,279 US firms that were granted 15 or more US patents in the five-year period 2005-09. In this project, we extended this database to include patents issued to these companies through June 30, 2011. We also added all published US patent applications for these companies from 2005 though July 31, 2011.

2. 42% of the 1,279 firms are small firms with 500 or fewer employees, so we have more than 500 small firms and more than 700 large firms to use in measuring the effects of the recent recession on R&D.

3. 57% of all the firms (and 29% of the small firms) in the database are publicly listed on major US exchanges (i.e. not including companies whose stock is traded over the counter). We estimate that less than 0.1% of all firms are publicly traded on major US exchanges. The large share of publicly traded firms in the database for this project is therefore notable. It suggests that firms of all sizes with patented technology are more likely to become successful enough to go public than firms that do not produce patents.

4. In our earlier SBA studies, (Breitzman and Hicks, 2008 and Breitzman and Thomas, 2010) we showed that small innovative firms are much more productive than large innovative firms from a patents-per-employee perspective. Using the updated data in this report, small innovative firms continue to outperform their large counterparts, producing 15 times as many patents per employee.

5. Numerous validation studies have shown a relationship between patent citation impact and positive outcomes such as inventor awards, licensing revenue, increases in sales and profits, etc. (Breitzman and Mogee, 2002). Our analysis shows that patents of small firms are cited 57% more by recent patents than is typical for patents of the same age and patent classification, while patents of large innovative firms are cited just 10% above average. This finding coincides with our earlier SBA studies, where we showed that small firms filed more patents in emerging technologies, and also that small firms had to be more selective with which patent applications to file because of financial constraints (Breitzman and Hicks, 2008).

## *C. Method*

In compiling patent lists for individual companies, it is important to understand that the patent office records assignees, and not necessarily companies. Patents owned by a company may be under different assignee names, including divisions, subsidiaries and acquisitions. 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 under more than 300 names.

In constructing company patent lists for this project, we leveraged the existing 1790 Analytics corporate thesaurus consisting of all organizations with 40 or more patents issued in the last five years. This thesaurus tracks over 4,000 organizations in three patent systems, including US firms, foreign firms, non-profits, universities, and government agencies. It contains more than 60,000 individual subsidiary and variant assignee names, and is maintained by a data manager with more than 25 years experience with tracking and standardizing assignee names. The thesaurus is licensed to information companies such as Thomson Reuters.

In this project, we used a subset of the corporate thesaurus, since the project focuses on US based companies. We also extended the database to include US firms with 15 or more patents granted in the five years between 2005 and 2009 (rather than the 40 patents required for inclusion in the main thesaurus). The database also includes the number of employees for each of the 1,279 firms in the study, as well as 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, Dun & Bradstreet, and companies' Annual Reports[4].

In this project, the cutoff date for the company structure is December 31, 2009. Any firms that merged after that date are kept as they were at the end of 2009. Similarly, while we removed companies that seemed to be out of business as of December 31, 2009 any that have become troubled since December 31, 2009 have not been removed. In the analysis for this report, we compared patent applications filed by small and large firms

[4] Essentially any US firm with 15+ patents granted between 2005-09 is included in this analysis. The reader may wonder why the 15 threshold was chosen and whether it was arbitrary. In short the 15 was a pragmatic choice. It would be ideal to include all technology firms or at least all firms with at least one patent, but there is very little information in terms of line of business, SIC, etc. for most firms with few patents. Even with the 15+ patent cutoff, we were nearing the point where the amount of publicly available firm information was sparse.

between 2005 and the end of 2009. Hence, it would not make sense to adjust for merger activity that occurred in 2010 or 2011, since this is after the patent applications in the analysis were filed.

In general, all subsidiaries are combined with their parent companies within the thesaurus. For example, the patents of Ethicon and Cordis are combined in the database with their ultimate parent company Johnson and Johnson. Meanwhile, 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.

Private equity firms are an exception to this parent-subsidiary rule in the database, because these investment firms may hold a variety of companies for a short period of time. In this project, if an equity firm holds a majority interest in one or more firms that run as independent companies, we treat those companies as independent companies within the database. For example, companies such as Johns Manville and Polaroid are treated as independent companies, even though they are majority owned by holding companies like Berkshire Hathaway, or private equity firms like Hilco Consumer Capital.

It is also worth noting that, although we did not change company structures after December 31, 2009, we did enhance the corporate thesaurus to identify any new variants of assignee names. Specifically, the 1,279 firms in the SBA-Green project patented under more than 25,000 different names. When we added the published applications for this project, this added 2,279 new spelling variants for these companies. These are not structural changes in company ownership, but mostly spelling errors such as “Advnced Micro Devices Inc’ or ‘3M Innovative Poperties Co’.

In summary, the database used for the SBA-Green project consisted of more than one million patents from 1,279 US firms with 15 or more US patents granted between January 1, 2005 and December 31, 2009. For this project, we enhanced the database to include patents issued to these companies through June 30, 2011, and published US patent applications assigned to these companies from January 1, 2005 through July 31, 2011.

## *D. Results*

### Summary Statistics

This section of the report provides summary statistics from the database of small and large innovative firms, in order to give the reader an overview of the contents of the database in general. Table II.1 reveals the overall breakdown of the 1,279 firms covered in the database. 728 of the firms are large firms, 532 are small firms, and no size information could be obtained for 19 firms. These latter firms are very likely to be small firms based on the dearth of information and the small number of patents but since we could not be sure, we removed them from the analysis. However, since they represent only 1% of the total, including or excluding them from any analysis would not change the results in a significant way.

**Table II.1 – Summary Statistics for US Company Patent Database**

| Company Size | # of Companies | % of Identifiable | % of Total | # Publicly Listed | % Publicly listed | Avg # Pats Jan 2005 - June 2011 | Avg # Published Apps Jan 2005 - July 2011 |
|---|---|---|---|---|---|---|---|
| Large | 728 | 58% | 57% | 558 | 77% | 481 | 374 |
| Small | 532 | 42% | 42% | 156 | 29% | 53 | 39 |
| Unknown | 19 | | 1% | | | 32 | 16 |
| Total Known | 1260 | | | 714 | 57% | | |
| Grand Total | 1279 | | | | | | |

Table II.1 reveals that 42% of the US firms with 15 or more patents between 2005 and 2009 are small firms.[5] However, only 10.6% of the patents, and 9.5% of the published patent applications, go to small firms. This is because large firms have a higher average number of both granted patents and patent applications than small companies.

Table II.1 also reveals that 57% of all the firms, and 29% of the small firms, in the database are publicly traded. We include in this definition companies that are traded on the major US exchanges, and not companies that are technically public, but not traded or only traded over the counter. Using this narrow definition of publicly traded, we estimate that less that 0.1% of all firms are publicly traded.[6] The large share of publicly traded firms in this dataset is therefore notable. It suggests that firms of all sizes with patented technology are more likely to become successful enough to go public than firms that do not patent.

**Table II.2 – Additional Summary Statistics from US Company Patent Database**

| Company Size | Avg Sales | Avg # Employees | Avg Sales Per Employee | Median Sales Per Employee | Avg # Pats Jan 2005-June 2011 | Jan 2005-June 2011 Pats Per Hundred Employees |
|---|---|---|---|---|---|---|
| Large | $8,385,038,016 | 19440 | $431,335 | $317,917 | 481 | 2.5 |
| Small | $46,540,617 | 141 | $330,075 | $179,775 | 53 | 37.6 |

Table II.2 shows additional summary statistics from the database. This table reveals that large innovative firms tend to exceed the 500 employee threshold by a wide margin, having an average of 19,440 employees and more than $8 billion in sales. Twenty-nine of these firms have over 100,000 employees, and thirteen of them have sales exceeding $100 billion. Not surprisingly, the large firms produce more patents than the small firms, but the small firms obtain more patents per employee than the large firms.

**Patents per Employee**

The finding from Table II.2 that small innovative firms obtain more patents per employee than larger firms is not a new result, and was discussed extensively in a prior study that we will refer to as SBA-Industry (Breitzman and Hicks, 2008). In that study, we further showed that the patents-per-employee rate decreases

[5] Throughout this project we consider a firm with 500 or fewer employees to be a small firm.

[6] This calculation comes from dividing the 3,162 US publicly traded companies identified via Google Finance http://finance.google.com [accessed August 10, 2010] by the estimated 6,049,655 employer firms in 2007 obtained from US Small Business Profile, SBA Office of Advocacy, 2007, http://www.sba.gov/advo/research/us_07ss.pdf [Accessed August 10, 2010]. Even though the company counts are 3 years old, the estimate of less than 0.1% of firms being publicly traded remains reasonable, since it would remain valid even if the number of employer firms decreased by more than 2 million.

steadily as the firm gets larger. That is, innovative firms with 10 employees have more patents-per-employee than those with 50 employees, which in turn have more patents-per-employee than those with 100 employees and so on. While we do not repeat that analysis here, it is worth highlighting that the overall patents-per-employee relationship continues using the updated patent sets. Specifically, from January 2005 to June 2011, small innovative firms produced more than 15 times as many patents per employee as large innovative firms.

**Patent Citation Index**

In previous studies for SBA, we have shown that patents of small firms tend to outperform their large firm counterparts on a variety of impact metrics (Breitzman et al. 2008, 2010). We do not repeat the entire analyses from these studies here, but since the patent sets were updated for this project to include patents issued through June 30, 2011, it is worth updating a key table containing citation indices.

The basic idea behind patent citation analysis is that highly cited patents (those cited by many subsequent patents) tend to contain technological ideas of particular importance, since many others build upon them and reference them as prior art. Such patents are thus regarded as having a strong impact on subsequent technological developments. Numerous validation studies have shown an association between highly cited patents and various positive outcomes. For example, patents that have won inventor awards tend to be highly cited (Carpenter et al. 1981). In another study (Albert et al. 1991) a correlation was shown between citation impact and selected patents from subject matter experts. A review of many more validation studies is given in Breitzman and Mogee (2002).

Citations to patents vary with age and technology. For example, a 5-year-old patent has had more time to accumulate citations than a 2-year-old patent, while a patent related to semiconductor technology is more likely to receive citations than a patent related to buggy whips. We therefore generate a Citation Index by dividing the number of citations received by a patent by the mean number of citations received by patents of the same age and technology (expected citations). The Citation Index is thus a normalized citation measure, with an expected value of 1.0 for an individual patent, or portfolio of patents. A Citation Index higher than 1.0 shows that a patent (or portfolio of patents) is cited more frequently than expected (for example, a Citation Index of 1.3 means 30% more citations than expected). Meanwhile, a Citation Index below 1.0 shows that a patent has been cited less frequently than expected (for example, a Citation Index of 0.8 shows 20% fewer citations than expected).

**Table II.3 – Citation Index for Small and Large Firms in Database**

| Company Size | # Patents Jan 2005 - June 2011 | Total Citations | Expected Citations | Citation Index |
|---|---|---|---|---|
| Large | 349995 | 619298 | 562907 | 1.10 |
| Small | 28302 | 72144 | 45943 | 1.57 |

In earlier studies (Breitzman et al, 2008, 2010), we showed that small firm patents tend to be more highly cited than large firm patents. There may be several reasons for this. One is that the high costs of filing patents force small firms to be more selective about which inventions they protect with patents, so they may have fewer patents describing technologies of only marginal interest. In the SBA-Industry study, we also showed that patents from small firms were much more likely to contain emerging technologies, and hence attract more citations from subsequent patents.

Table II.3 reveals that, based on the updated patent data set used in this study, small company patents are still cited more frequently than large company patents. Specifically, the Citation Index for large innovative firms' patents issued 2005-June 2011 is 1.1. This suggests patents of large innovative firms are cited about 10% more than peer patents. Meanwhile, patents of small innovative firms from the same period are cited 57% higher than the average for peer patents (i.e. their Citation Index is 1.57).

**Average Patent Pendency**

Table II.4 shows the average pendency (the time elapsed from patent application to grant) for patents granted between 2005 and June 2011 to companies included in the study. Average pendency is over three years, and is slightly lower for small companies (38.3 months) than for large companies (40.3 months). This difference may be caused by expediting fees (a fee paid to the patent office to speed up the examination process slightly). Large firms like IBM, who file thousands of patents per year, typically choose not to pay the fee because, in addition to the cost, they must also do a much broader prior art search than normal. For a small firm that only files a few patents per year, it might be worthwhile to get the patents expedited, since funding is often easier to obtain once a firm has a granted patent (Nothhaft, 2011).

**Table II.4 – Average Pendency for US Patents issued January 2005 to June 2011**

| Company Size | # Patents Jan 2005 - June 2011 | Avg # Months to Grant | % Granted within 19 months | % Granted within 25 months | % Granted within 31 months |
|---|---|---|---|---|---|
| Large | 349995 | 40.3 | 12.8% | 23.1% | 35.3% |
| Small | 28302 | 38.3 | 15.5% | 27.2% | 40.2% |

The results in Table II.4 show that using granted US patents to study the effect of the last recession was not feasible at the time this report was produced. In order to examine R&D activity leading up to, during, and following the last recession, we would need to analyze patents that were applied for between January 2007 and December 2009. However, only a small fraction of the patents applied for in December 2009 had issued by the time we carried out this analysis (19 months later). In fact, less than half of the patents filed in December of 2008 had issued at this time. Hence, one would have to wait until some future time to carry out an analysis of R&D activity during the recession based on data covering granted patents.

**US Published Applications**

While studying R&D activity during the last recession is not feasible using granted US patents, it is possible using published US applications. Such applications are supposed to be published within 18 months of filing. However, because applications can be filed any day, but they are always published on a Thursday, sometimes the time exceeds this 18 month target by a few days. There may also be delays for patents initially filed outside the US.

These short delays are reflected in Table II.4, which shows the percent of applications published within various time periods after priority date.[7] This table reveals that, while only 44% of large company

[7] For patents invented in the US, the application date and priority date are the same; however, some of the large firm patents are invented outside of the US and will have a foreign patent application prior to the filing of the US application (this document has priority and is given a priority date). Since we wish to measure the R&D activity during the recession we use the priority date as being a closer approximation to when the R&D occurred. Since the bulk of the patents of both large and small firms are US invented, the priority date coincides with the application date more than 90% of the time.

applications (an 80% of small company applications) are published within 18 months of filing, over 90% of both large and small company applications are published within 19 months. In our analysis, we therefore included applications published through July 2011, which provides over 90% coverage of applications filed through the end of 2009.

**Table II.4 – % Percent of US Applications Published within X Months of Filing Date**

| Company Size | # Published Applications Jan 2005 - July 2011 | % Published within 18 months | % Published within 19 months | % Published within 25 months | % Published within 31 months |
|---|---|---|---|---|---|
| Large | 272426 | 44.0% | 91.4% | 94.0% | 95.1% |
| Small | 20936 | 79.9% | 97.7% | 99.0% | 99.3% |

**Shortcomings of US Published Applications**

Since our analysis relies heavily on US published applications, it is worth reviewing some key features of these applications, and possible problems with using them as a unit of analysis. In terms of history, until 2001, all US patent applications were sealed until the patent was granted and issued. Rejected patent applications were never seen by the public. In 2001 the patent law was changed to be more compatible with other patent offices around the world. Now, a US patent application is published after 18 months unless the inventor opts out by agreeing not to seek patent protection outside of the US. This 'opt out' option is a relatively minor issue for this study, since most of the innovative firms file their patents in multiple countries, so their US applications will be published after 18 months. The net result is that even if the patent is ultimately rejected by the US patent office, the published application remains available indefinitely.

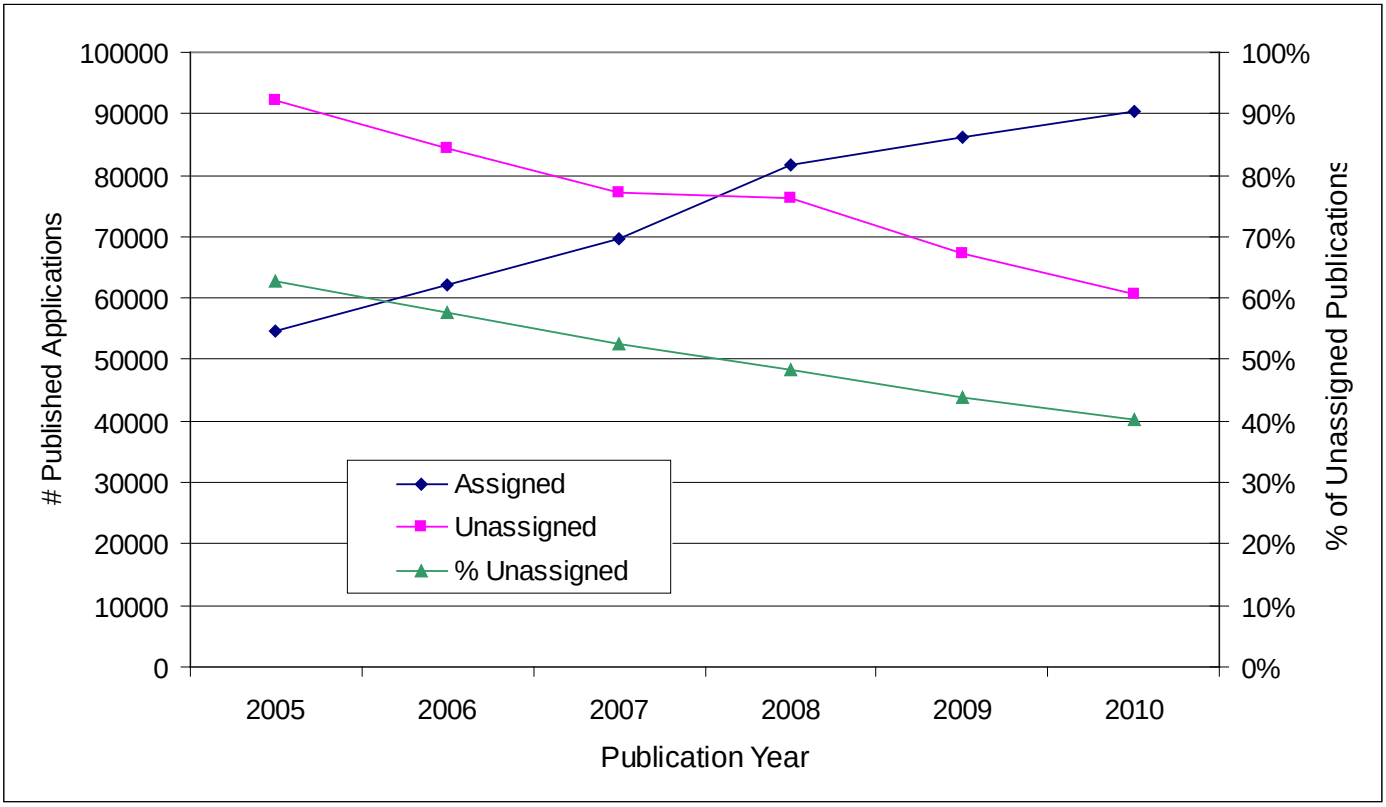
A larger issue with US patents and published applications is that of assignment. By US law, the inventor is considered to be the default patent owner. Hence, a patent filed by an inventor at IBM is owned by that inventor unless or until he or she assigns the rights to IBM. This is why employment contracts typically state that inventors will assign any patents to their company. By the time patents issue, the assignment is usually complete, and the company appears as the assignee on the front page of the granted patent. However, patent applications are published much earlier in the process, and the assignment may not have been completed by that point. As a result, a large number of published US patent applications appear without an assignee.

As Figure II.1 shows, the number of unassigned patents at the time of publication is substantial. For example, in 2005 about 60% of patent applications were unassigned at the time of publication. This had improved to 40% by 2010. The improvement is due mainly to increased efficiency at the patent office. It used to be the case that if the assignment form was not filled out and sent to the patent office very soon after the patent application, then the application would almost always publish without an assignee. Now, the assignment appears unless it is filed fairly late in the process.

The lack of proper assignments would seem to be a significant shortcoming of using published patent applications for an analysis of company behavior. However, the impact on this study is much smaller than suggested by Figure II.1. First, it should be noted that about 10% of patents are granted without a named assignee and remain the property of their inventors. These are not cases of missing assignments, but instead patents granted to individual inventors. In most cases of missing assignments, the problem is one of filing the appropriate paperwork (although it is conceivable that firms may try to hide the assignee name from competitors, this is not really practical since the eventual assignee can generally be inferred by identifying the inventors or the patent attorney). Since the assignment issue is largely a paperwork issue, one would

imagine that patent savvy firms, like the innovative firms in our analysis, would do a fairly good job of keeping the paperwork in order, and hence getting their names on their published applications.

**Figure II.1 Number and Percent of Unassigned Published Applications by Year of Publiation**




To determine whether innovative firms are indeed successful in having their names appear on published applications, we did a detailed analysis of patent applications published in a single year (2007). Figure II.1 reveals that just over 50% of applications published in that year had no assignment. By looking at subsequent assignment records, we were able to determine how many of these applications were later assigned to companies in the study, after they had already been published. The results can be found in Table II.5.

**Table II.5 – Assignment Data for 2007 Published Applications**

| Company | # Assigned Applications on day of publication | # Subsequently assigned in 3+ Years | % Assigned on day of Publication |
|---|---|---|---|
| Large Firms | 38288 | 6451 | 86% |
| Small Firms | 3372 | 712 | 83% |

Table II.5 reveals that large firms in the study had 38,288 published applications assigned to them in 2007. Subsequently, an additional 6,451 applications published in 2007 were assigned to those firms. Hence, 86% of large firm patent applications were correctly assigned by the time of publication in 2007. IBM, Microsoft, GE, and Honeywell were particularly efficient. Each of these companies had more than 1,000 published applications in 2007, and each had an assignment rate above 93% (Microsoft and Honeywell had 100%).

Using the same approach, we found that 83% of small firm patent applications were correctly assigned upon publication, only slightly lower than the large firm percentage. Among small firms InterDigital,

ZymoGenetics and Tessera had the most published applications in 2007, and each had an assignment rate above 92%, with InterDigital and Tessera at 100%.
These results suggest that small and large innovative firms are indeed successful in having their name appear on published applications. As such, assignment issues should not represent a significant bias in our analysis, and published applications should therefore be a valid unit of analysis when examining companies' innovative activities.

## *E. Conclusion*

In this section, we described the methodology used to build the database of small and large firm patents and published patent applications. This database is the key building block for the remainder of this research project. We also derived some summary statistics from the database and described them in detail, showing that small firms produce fifteen times as many patents per employee as large firms, and that small firm patents perform particularly strongly using citation impact measures.

We also discussed why, at this point, published patent applications represent a better unit of analysis than granted patents for examining companies' innovative activities before, during and after the recent recession. Finally, we discussed potential shortcomings of using published applications, but showed that, for our set of firms, these shortcomings are not a major issue, and should not introduce significant bias to our analysis.

# III. Small and Large Firm R&D Patterns During the Recent Recession

## *A. Introduction*

This project is built upon a carefully constructed database of published US patents applications for highly innovative small and large US firms (see Chapter II for details). In this chapter we use these published applications as a proxy for R&D activity, and compare quarterly patent output of innovative firms to Gross Domestic Product (GDP) data in order to examine how small and large innovative firms adapt to a recession.

## *B. Summary*

In this chapter, we analyze the impact of the 2008 recession on patent activity for small and large innovative firms. Some of the key findings of the chapter are:

1. According to the National Bureau of Economic Research (NBER), the recession started following the fourth quarter of 2007, and bottomed out in the second quarter of 2009. Our results show that there was an immediate decline in patent applications from small innovative firms coinciding with the start of the recession. Prior to the recession, small firms averaged about 8% of the applications filed by the innovative firms in our database. During the decline, the small firm share fell to 5.6%.

2. By looking at quarterly filings compared year-over-year, we found the large firm patent application rates did not significantly change until 2009.

3. During the recent recession, small firms changed patent application activity earlier than larger firms. This observation raises interesting opportunities for further research. For example, it is unclear whether downturns cause small firms to cut R&D expenses immediately, whereas large firms try to maintain R&D throughout a downturn. Alternatively, small firms may make R&D plans on an ongoing basis, while large firms plan well in advance.

4. During the recession, the decline of small firm patent activity not only occurred sooner than it did for large firms, but the decline seems to have been more severe. Although small firms started to increase their patenting sooner after the recovery than large firms, the long-term affects of the decline still existed. In the two quarters following the start of the recovery in 2009, small innovative firms filed patents at approximately the same rate as they had in 2005. Meanwhile, large firms filed patents at a rate 20 to 30 percent higher than their 2005 rate.

5. During the recession, small firms saw a much deeper decline in R&D outputs (as measured by patent application activity) than large firms. As a result, small firms may be less capable of launching new products following a recession in order to take advantage of the subsequent economic expansion.

## *C. Discussion*

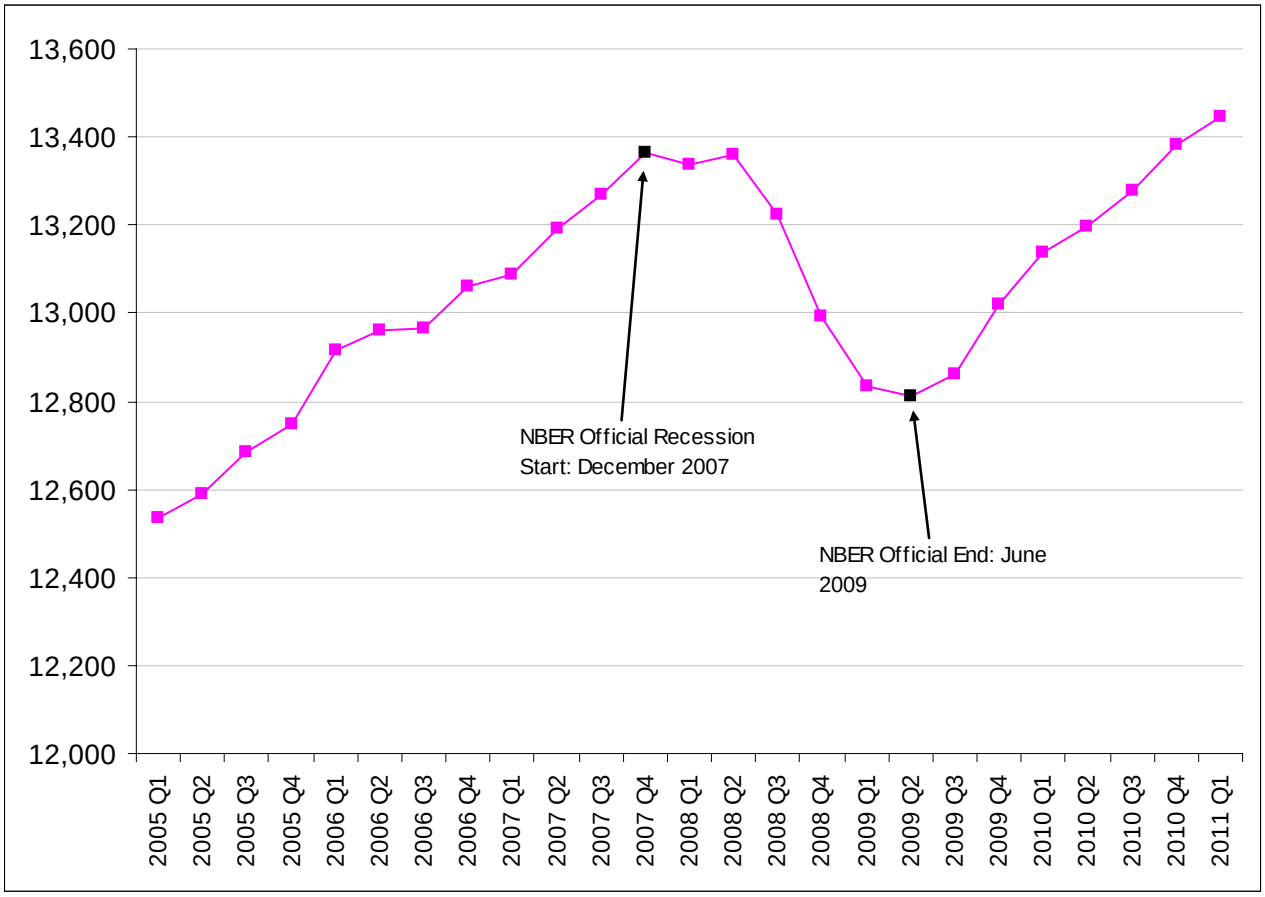
### Period of a Recession

In the US, the National Bureau of Economic Research (NBER) uses a variety of economic indicators to determine when peaks and troughs occur in business activity. NBER declared the last recession started when

business activity peaked in December 2007, with the beginning of a recovery occurring after the trough of June 2009.[8]

Figure III.1 shows quarterly GDP data from the US Department of Commerce Bureau of Economic Analysis (BEA). The graph also highlights the beginning and ending of the recession according to NBER. This figure reveals that NBER's dates closely follow the peaks and valleys in GDP according to BEA.

**Figure III.1 Quarterly GDP in Billions of 2005 Dollars**




Source: Bureau of Economic Analysis – US Department of Commerce

## Priority and Application Dates

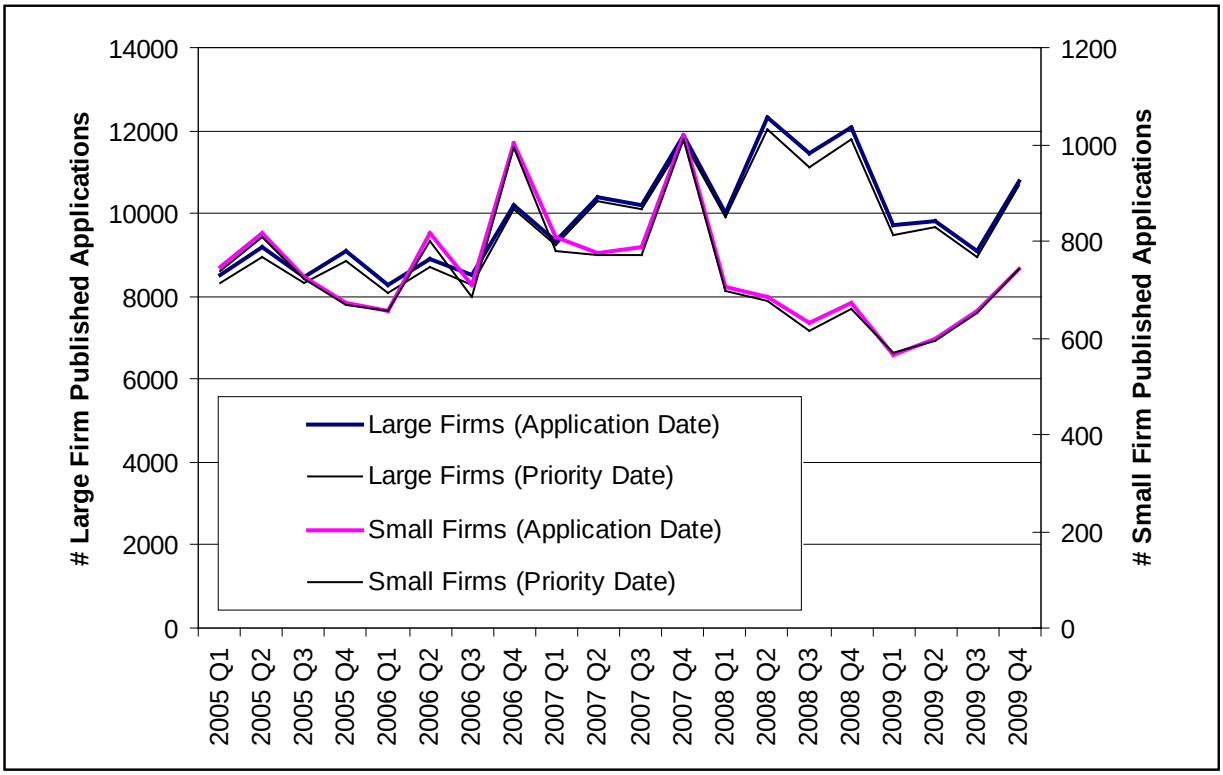
When a US inventor files a patent, he/she first files the patent with the US patent office. He or she may then file subsequent equivalent patents in Europe, Asia or elsewhere. All of these equivalent patents will each have their own application dates in the various patent systems. However, for the purpose of dating the invention, the so-called 'priority date' will be the date of the original US application. Alternatively, if the inventor is based outside the US, the priority date will be the date of the original application in his or her home country. This may be earlier than the subsequent US application date.

Since we are using patents as a proxy for R&D activity, we wish to get an idea of when the original patent was filed, not when it was first filed in the US. We therefore use priority date, rather than US application date, as the basis for our analysis. Having said this, the firms in our study are all US-based, so there are very

[8] NBER Business Cycle Dating Committee - National Bureau of Economic Research. www.nber.org/cycles/sept2010.html, Last accessed: August 4, 2011.

few inventors from outside the US. As a result, the application date is almost always the same as the priority date. This is reflected in Figure III.2, which shows less than a 2% difference in counts of applications per quarter based on application and priority dates. More importantly, there is virtually no difference in the shapes of the graphs of application dates versus priority dates.

**Figure III.2 – # US Applications Published within 19 Months of Priority Date or Application Date**



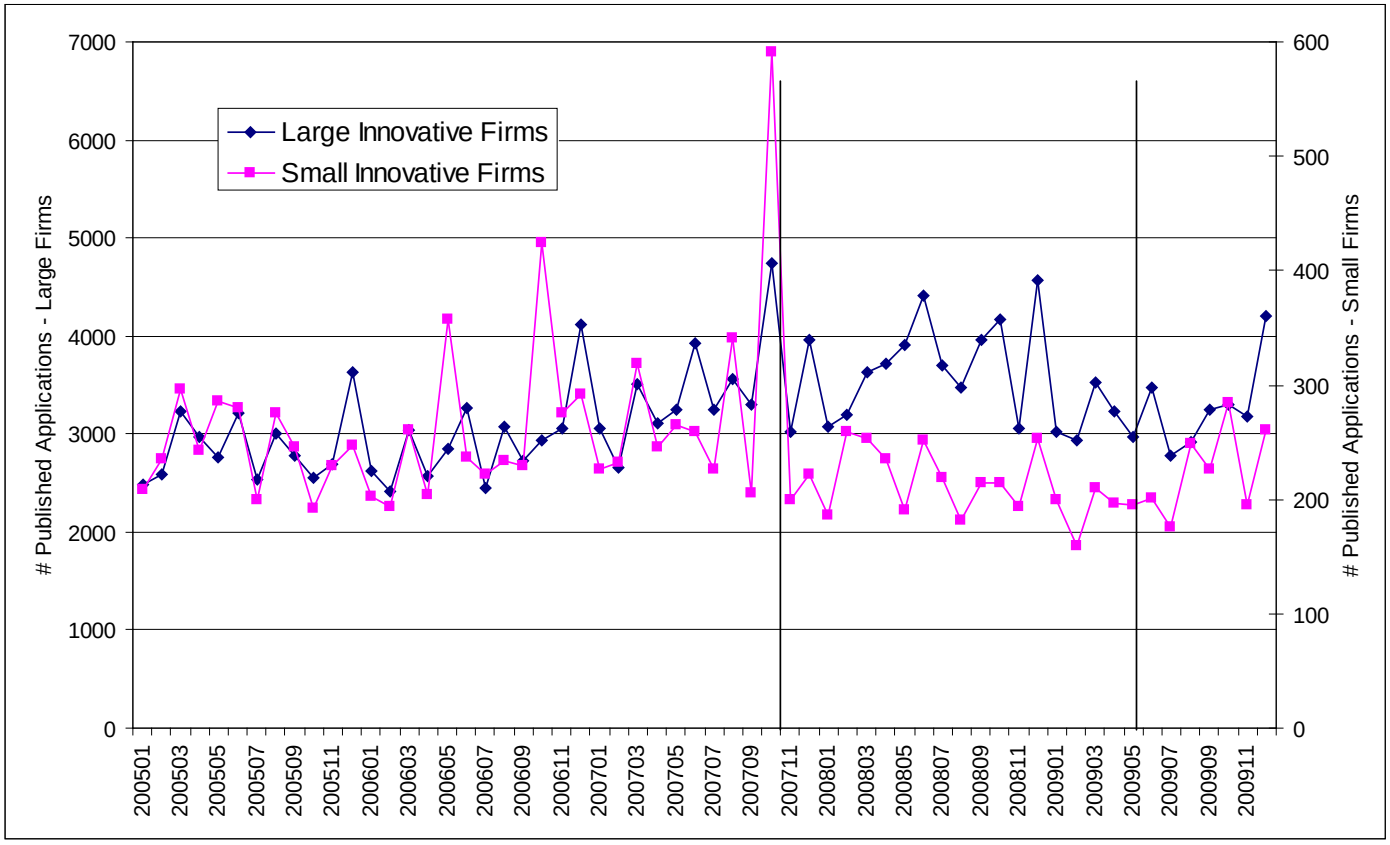

As noted above, the database for this project contains US patent applications published between 2005 and July 31, 2011. In the previous chapter, we showed that more than 90% of US patent applications filed by small and large innovative firms are published within 19 months of priority date (In fact 90% of all patent applications are published after 19 months). By using data through July 2011, we can therefore get a reliable count of patent applications through December 2009. Moreover, to make sure patents from prior periods are not over-represented, we remove any patent applications published more than 19 months after filing. This is necessary because we wish to examine differences over time in monthly applications. For example, if we included applications filed in December 2007, but not published until 36 months later, this would give an inflated view of that month compared to December 2009, because such slow-to-publish applications would not be available for the latter period.

## Analysis of Published Applications Before, During, and Following the Recession of 2008

Figure III.3 shows counts of published applications from large and small innovative firms by month of priority date (first filing date). As noted above, to retain consistency across time periods, we only include applications published within 19 months of the priority date. Figure III.3 includes a secondary axis, enabling trends in small and large company patent applications to be compared on the same graph. There are also

vertical lines added to the chart to show the middle of the fourth quarter of 2007 and the middle of the second quarter of 2009, which were the peak and trough of the business cycle according to NBER.

**Figure III.3 Applications by Priority Month for Large and Small Firms**
(Applications Published within 19 Months of Priority Date)

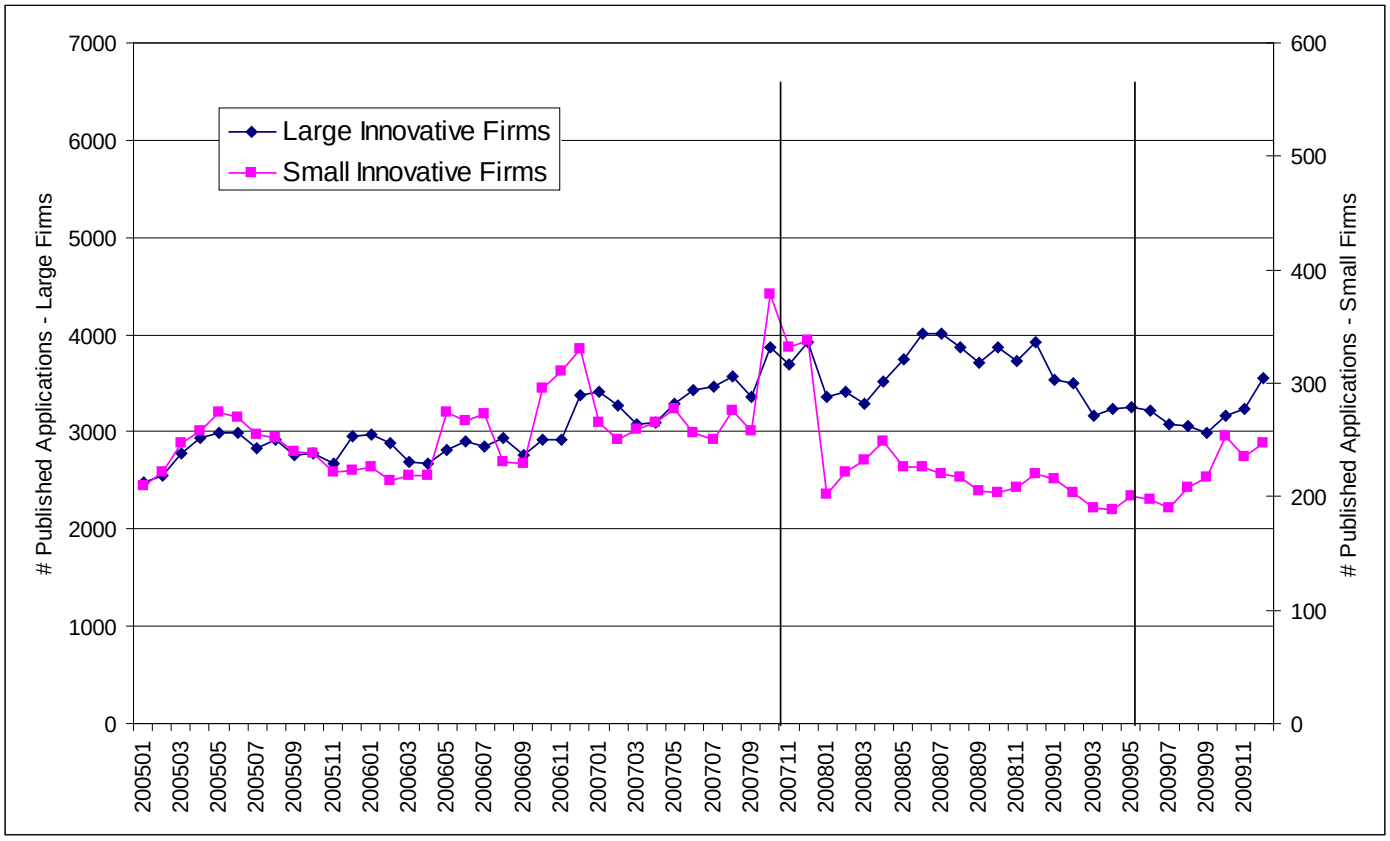



Note vertical lines added to start and end date of recession according to NBER.

Figure III.3 reveals that small firm patent applications tracked large firm applications fairly closely before the recession, albeit with large firms patenting at a rate roughly 11 times higher than small firms. During the period of the recession, a noticeable gap then appears between the two trend lines, with small firms reducing their patent applications much faster than large firms. This may suggest that, following the start of the recession, small firms made an adjustment in their R&D fairly immediately, while large firms maintained their R&D levels for several months.

The trends in Figure III.3 are quite noisy, but they become clearer in Figure III.4, which uses a 3-month moving average based on the same underlying data. Figure III.4 shows clearly that small and large firm patent applications followed a very similar trend before the start of the recession. During the recession, the small firm patent applications then dropped considerably, and a significant gap appears between the trend lines. Once the recovery started, small firm patenting increased again, and the gap between the two trend lines began to narrow.

**Figure III.4 Applications by Priority Month for Large and Small Firms (3 Month Moving Average)**




There could be various reasons for this observed gap in patent application activity between small and large innovative companies, an examination of which requires further research. For example, a US patent filing can cost upwards of $50,000, with additional costs for foreign equivalents. Given these costs, small firms may be forced to cut down on their patent expenses as soon as they see a business downturn, whereas large firms may have more budget flexibility. It could also be that due to wealth constraints, small firms budget for R&D on a monthly or quarterly basis whereas large firms budget on a yearly basis.

Figure III.5 further illustrates the gap between small and large firms during the recession. Prior to the recession, small innovative firms produced 8% of all published applications obtained by the companies included in the study. During the recession, this figure fell to only 5.6%, showing how the patent activity of small companies was affected particularly strongly by the recession.

Figure III.6 shows patent application data from a quarterly perspective, which is useful because GDP data are reported quarterly. This figure also includes trend lines for large and small company patent applications. These trend lines were formed using the least squares method for each individual time period (i.e. pre-recession from 2005 Q1 to 2007 Q4; downturn from 2007 Q4 to 2009 Q2; and recovery from 2009 Q2 to 2009 Q4). These trend lines again show that, while both small and large firms reduced their patent filings during the downturn, small firms reduced their patenting sooner and by a larger extent than large firms.

**Figure III.5 Small Innovative Firm Published Applications as a % of all Innovative Firm Published Applications (3 Month Moving Average)**

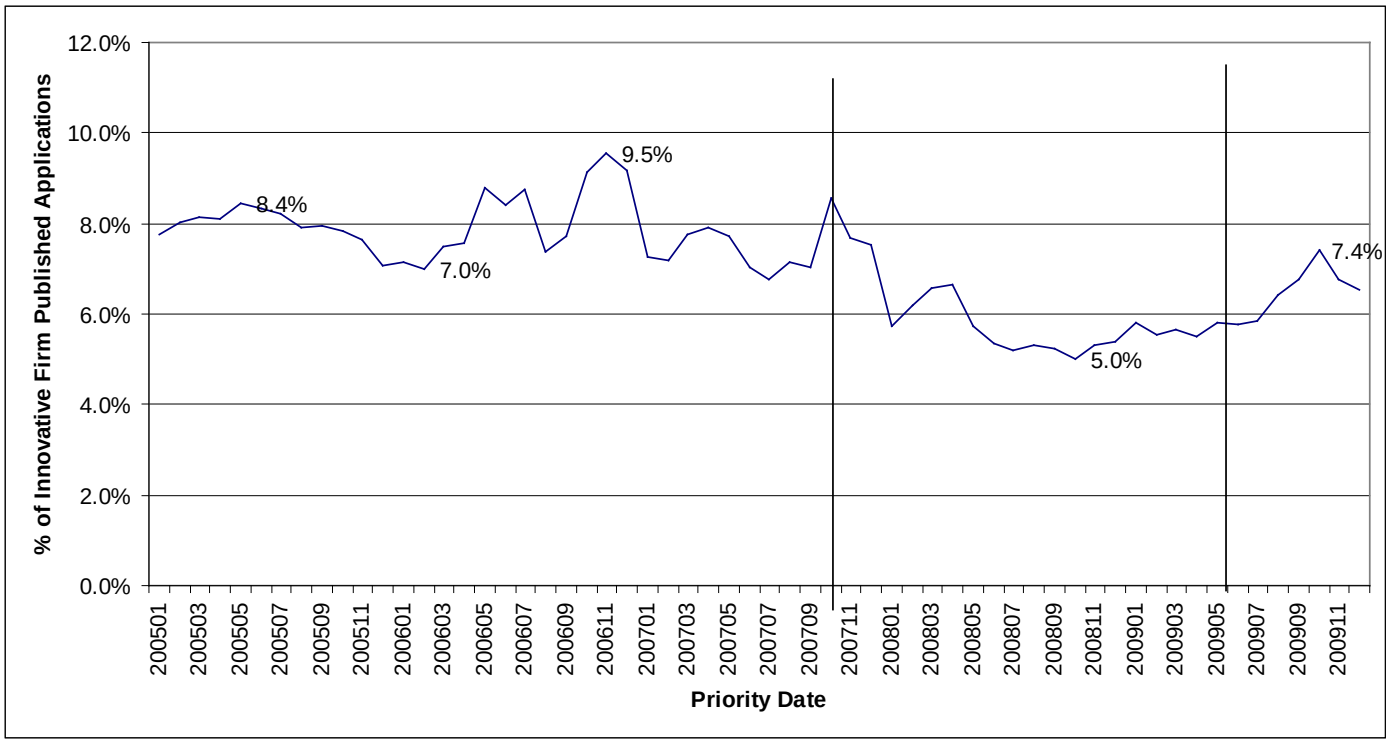



**Figure III.6 Published Applications by Quarter for Small and Large Innovative Firms**
(Applications Published within 19 Months of Priority Date)

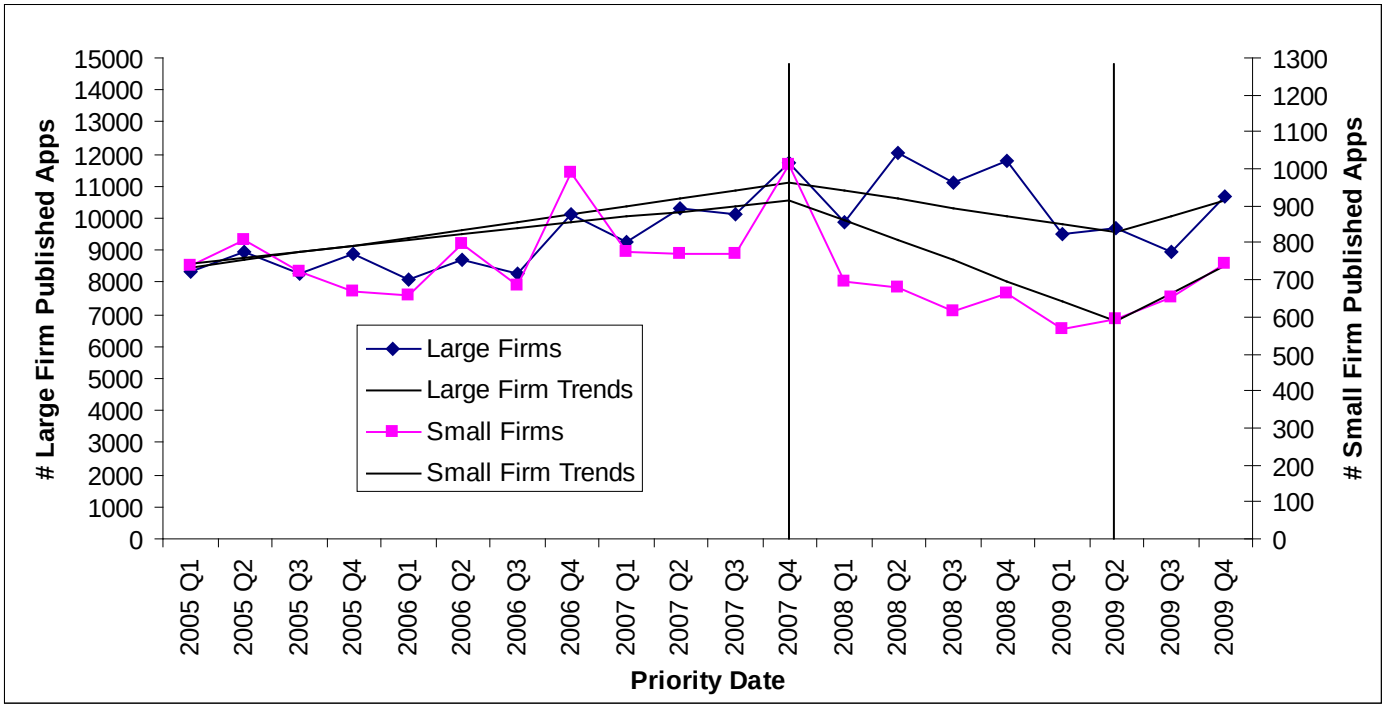
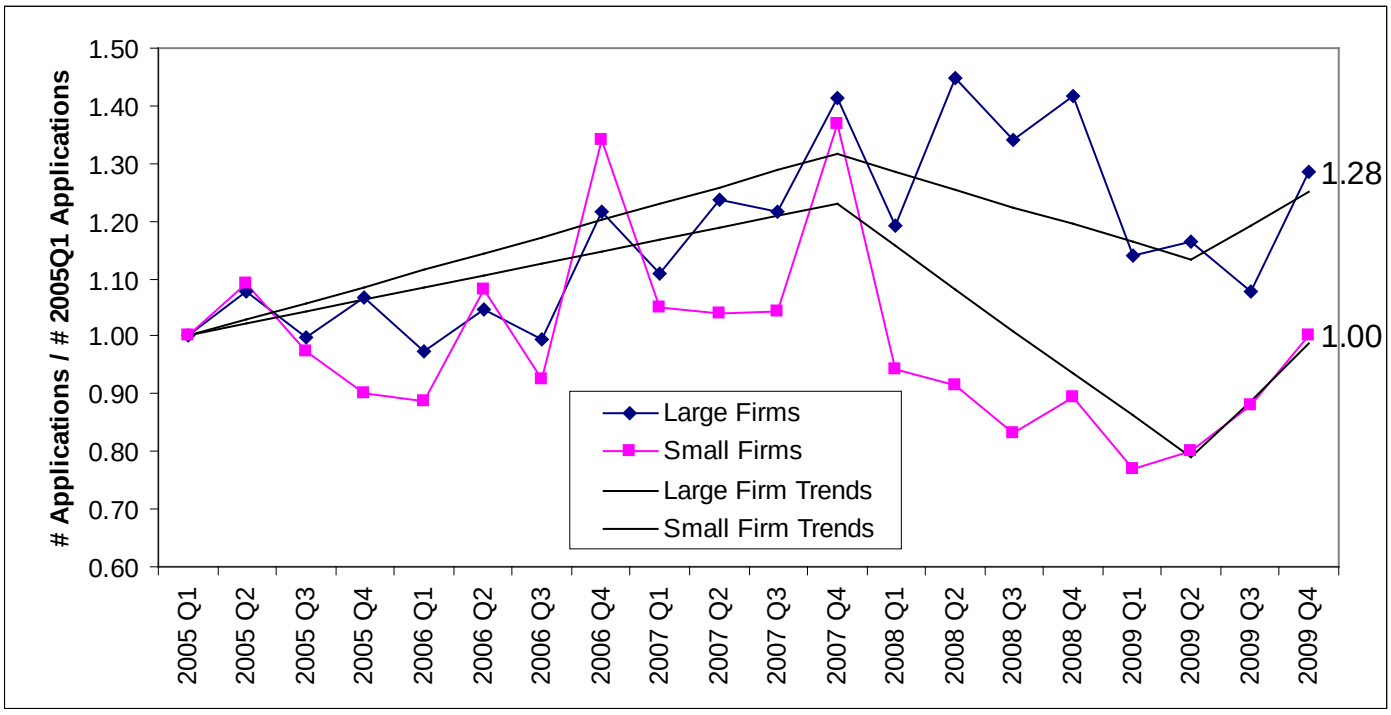


Figure III.7 offers a different view of the patent application data by plotting each trend against the number of patent applications in the first quarter of 2005. At the peak of the last business cycle (towards the end of 2007) both large and small firms were filing patents at a level nearly 40% higher than their respective filings in 2005. By the bottom of the downturn, small firms were about 20% below their 2005 levels, while large firms were still above their 2005 levels. Small innovative firms did increase their patenting after the end of the downturn. However, two quarters into the recovery, they were just back to their 2005 levels in terms of patent applications, while the large firms were 28% above their 2005 levels. These percentages should be viewed with caution given the noisy nature of the data, but the result remains clear: while large firms experienced a decline in patent applications as a result of the recession, they did not lose as much ground as their smaller counterparts.

**Figure III.7 Number of Published Applications Divided by 2005 Q1 Published Applications**

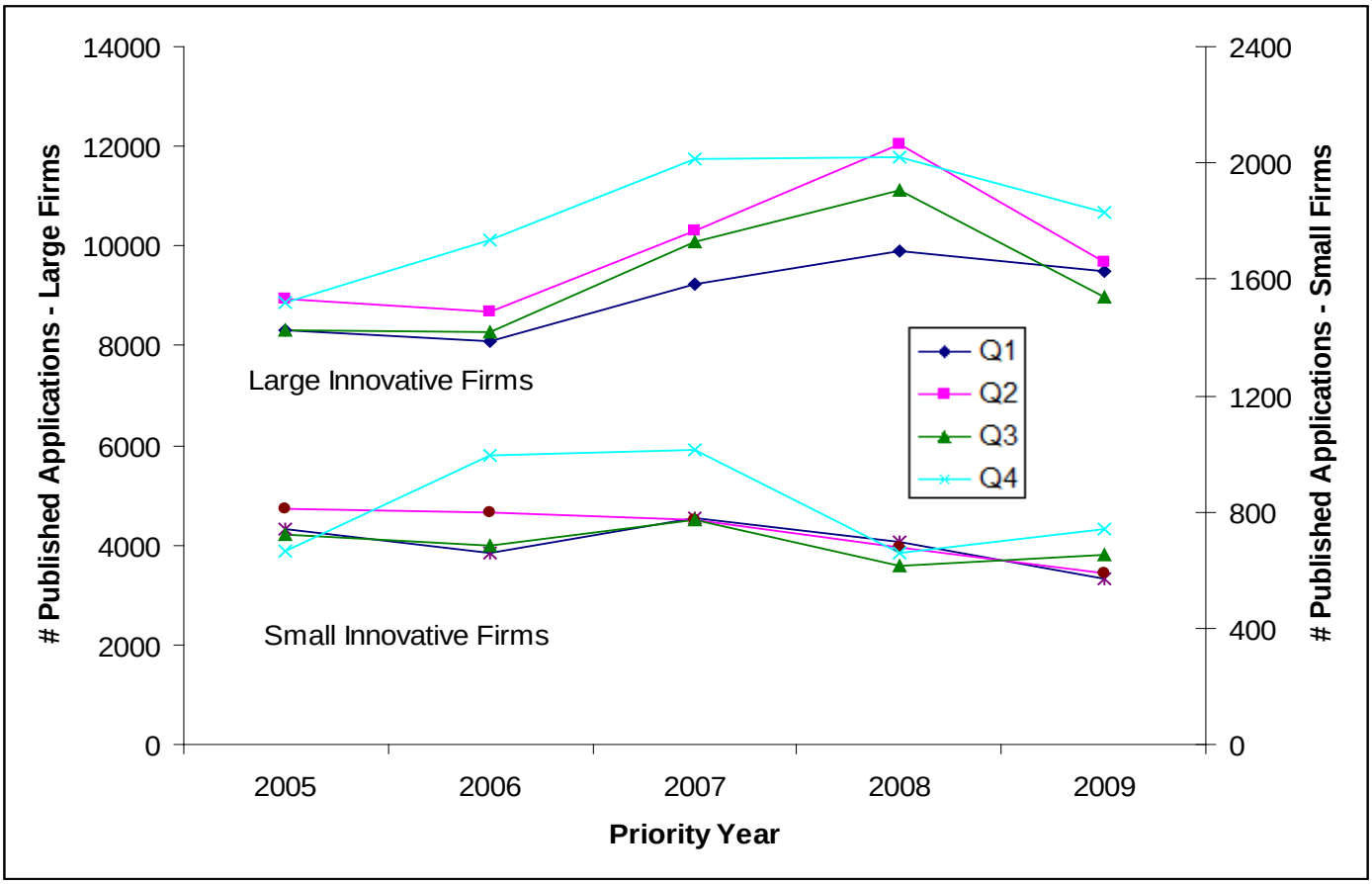



Patent applications appear to vary depending on quarter (for example, it seems small firms generally file fewer patents in the first quarter than the fourth quarter). It is therefore worthwhile comparing applications from the equivalent quarter in each year, in order to remove the effect of these differences. Figure III.8 offers such a comparison, showing patent applications for each individual quarter over a five-year period for both small and large firms.

According to Figure III.8, by 2008, large innovative firms had not significantly altered their patent application activity. By contrast, Figure III.8 further illustrates that small firms changed patent activity early in the recession period. Specifically, large firms had a significant growth in patent applications in the second and third quarters of 2008 compared to the same quarters of 2007. They then saw large declines in those same quarters in 2009. The first and fourth quarters saw the same pattern of increase in 2008 followed by decline in 2009, but the changes were less pronounced. At the same time, small firms saw a drop in patent applications in every quarter of 2008 compared to the same quarters in 2007. They then saw a modest recovery in the third and fourth quarters of 2009.

According to NBER, the recession ended in the second quarter of 2009. The third and fourth quarters of 2009 thus represent the early part of the recovery from the recession. During this period, there was an increase in small firm patent applications compared to the equivalent quarters in 2008, while large firm applications actually declined compared to 2008. During the 2007-2009 recession, small firms increased their patent activity before large firms. Further research is required to determine whether this is a consistent trend across recessions and to examine any underlying reasons for such differences. This observation may raise the question of how a 'boom and bust' pattern of patent applications might affect the ability of small firms to launch new products and taking advantage of an economic expansion following a recession.

**Figure III.8 Quarterly Published Applications for Small and Large Firms by Priority Date**




## *D. Conclusion*

In this chapter we examined patent applications filed by small and large innovative firms leading up to, during, and following the recent recession. We found that during the recession small innovative firms changed patent application activity earlier and to a greater degree than large innovative firms. Large firms also saw a decline, but it was much smaller and occurred later.

Under the assumption that patent applications are a proxy for R&D outputs, and R&D spending in general, small firms may be more sensitive to recessions. This may adversely affect their ability to launch new products following a recession in order to fully take advantage of a subsequent economic expansion. These initial theories require further analysis.

# IV. Effects of Recession on US and Non-US Invented Patent Applications

## *A. Introduction and Summary*

In this chapter, we examine US versus foreign invented patent applications to determine whether the recession affected overseas R&D in a manner similar to R&D in the US. We do this by identifying all US published applications from 2005 to July 31, 2011 and then categorizing these applications by country based on the location of their first inventor.

Some of the key findings are:

1. Patent filings from US and non-US inventors declined immediately following the start of the recession. They began to recover following the second quarter of 2009, which coincides the end of the recession according to the National Bureau of Economic Research (NBER).

2. During the recent recession, large US firms who file the most patents did not slow down their patent filing until a year after most other sectors.

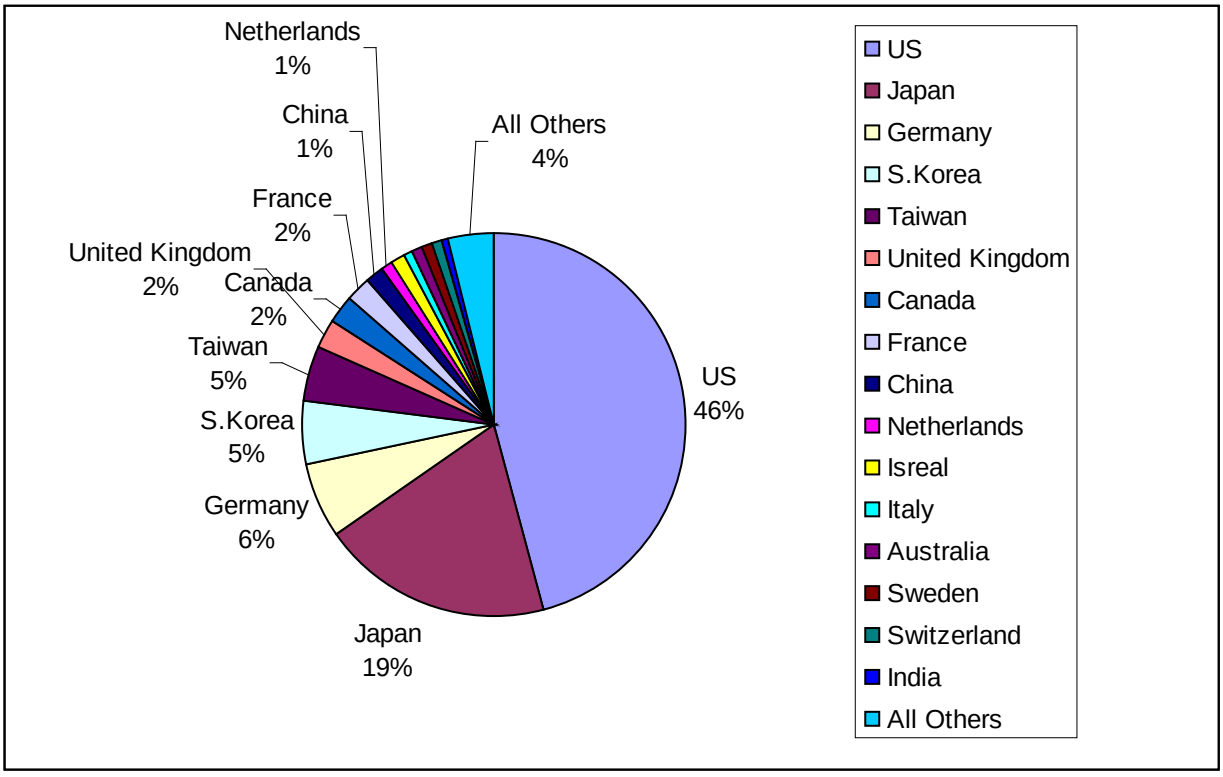
3. Small US innovative firms did slow down their patenting almost immediately after the start of the recession. However, they also increased their patenting following the recession sooner than the other sectors. When we compare quarterly patenting year over year, small innovative firms were the only sector to have upturns in the third and fourth quarters of 2009 compared to the same quarters in 2008.

4. Although foreign invented patent filings fell generally during the recession, filings from China merely leveled off, and did not decline. China currently files only about 1% of all US patents (compared to 19% for Japan, 6% for Germany, and 5% for Taiwan and South Korea). However, China has been the fastest growing country in terms of number of US patents filed over the past six years. It is also notable that India's US patent filings actually increased during the first four quarters of the recession. It then had three declining quarters but reached a peak in US patent filings in the fourth quarter of 2009.

## *B. Results*

Before analyzing how different countries reacted to the recent recession in terms of R&D, it is worth providing perspective for the analysis using some overall patent statistics. The US patent system attracts inventors worldwide, with inventors from 80+ countries filing for US patent protection. The top 16 inventor countries are shown in Figure IV.1. This figure reveals that US inventors file just under half of all US applications, followed by Japanese inventors with 19%, German inventors with 6% and South Korea and Taiwan with 5% each.

**Figure IV.1 Top Inventor Countries for US Patent Applications Published 2005-July 2011**




At the outset of this study, we hypothesized that foreign firms would be slower to react to the recession than US firms, but they would also be slower to react when the economic recovery began. To test this hypothesis, we compared foreign invented US patent applications from the 15 countries in Figure IV.1 with applications filed by the US large and small innovative firms included in this study. We also compared these foreign invented US applications against the universe of all US invented patent applications. The results are shown in Figure IV.2.

In Figure IV.2, US published applications by quarter from all US inventors, includes individual inventors, along with inventors from small firms, large firms, non-profits, universities, government agencies, and US-based inventors from foreign owned firms. US published applications (from the top 15 countries featured in Figure IV.1). For the most part, these inventors work at large foreign firms like Siemens, Canon, or US multinational firms with overseas locations, such as IBM. There were not large numbers of published US applications from small firms or individuals based overseas.

Against this context, Figure IV.2 also illustrates patent application activity from the large and small firms in the innovative firm database. As noted earlier, these are all US companies with 15 or more patents in the period 2005-09. Note that large firm patent applications are plotted on a main y-axis, while small firm patent applications are plotted on the secondary axis on the right hand side of the graph.

As mentioned previously, our analysis is restricted to patent applications published within 19 months of their priority date, in order to maintain consistency across different time periods for which different amounts of application data are available. Restricting the patent application data in this way is not an issue for small and large US innovative firms since, as shown earlier, 90% of their applications are published within 19 months of their priority date. It is more of an issue for foreign invented applications, since only about 60% them are

published within 19 months of their priority date. Having said this, we do not believe this will affect the shape of the trend over time for Non-US Countries Invented, but these differences would explain the downward shift relative to US Invented.

**Figure IV.2: US and Non-US Invented Published Applications**
(All Applications Published within 19 Months of Priority Date)

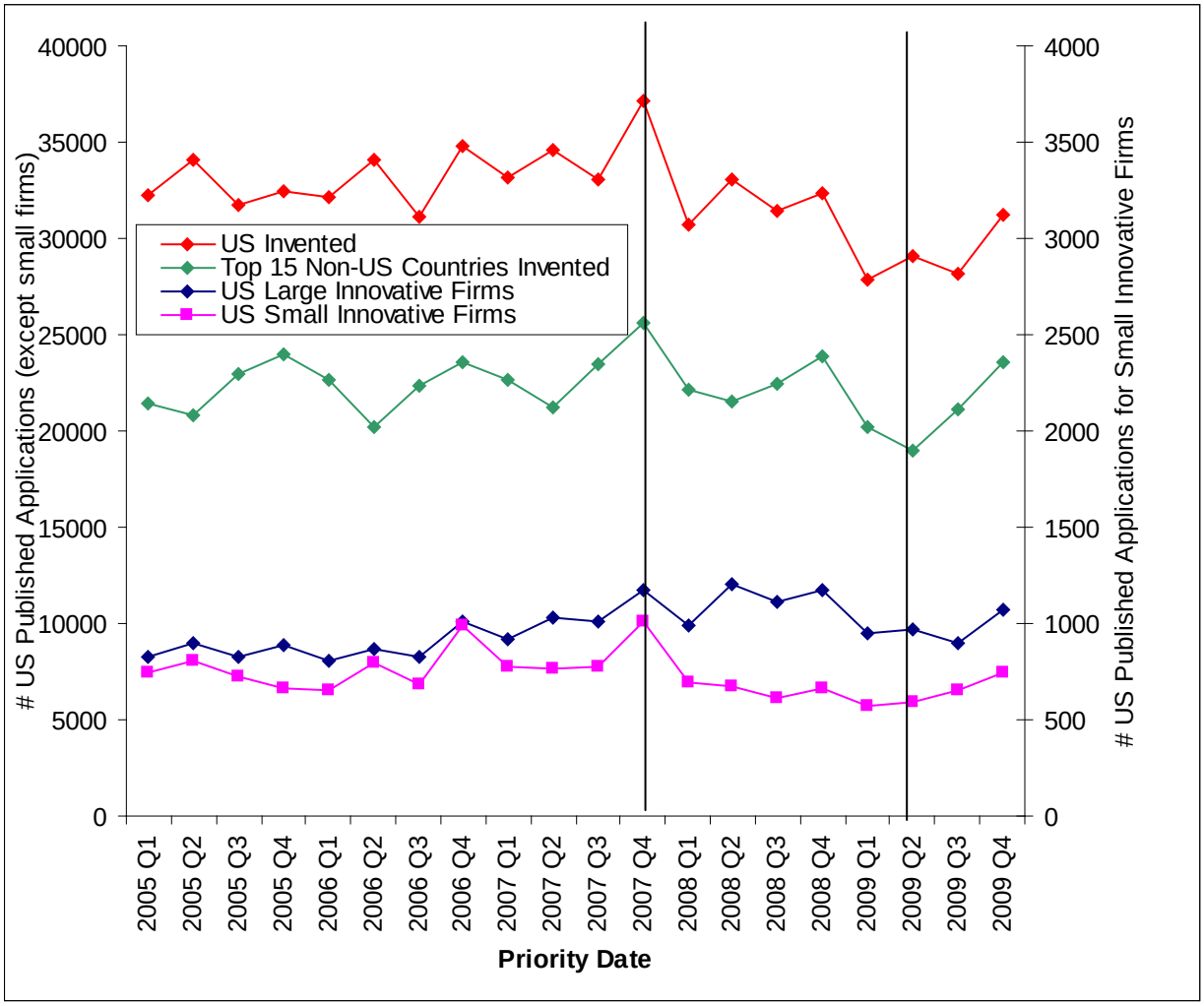



Figure IV.2 reveals that both US invented and foreign invented patent applications declined immediately after the recession began in the fourth quarter of 2007. US invented applications then recovered in the remainder of 2008. This is largely due to the fact that large innovative US firms actually reached their peak in filings in the second quarter of 2008, and these firms represent a significant subset of all US invented patent applications. Further research revealed that, during the recession, there was a significant decline in patent applications for every sector except large innovative US firms.

**Figure IV.3 US and Non-US Invented Published Applications by Quarter and Year**
(All Applications Published within 19 Months of Priority Date)

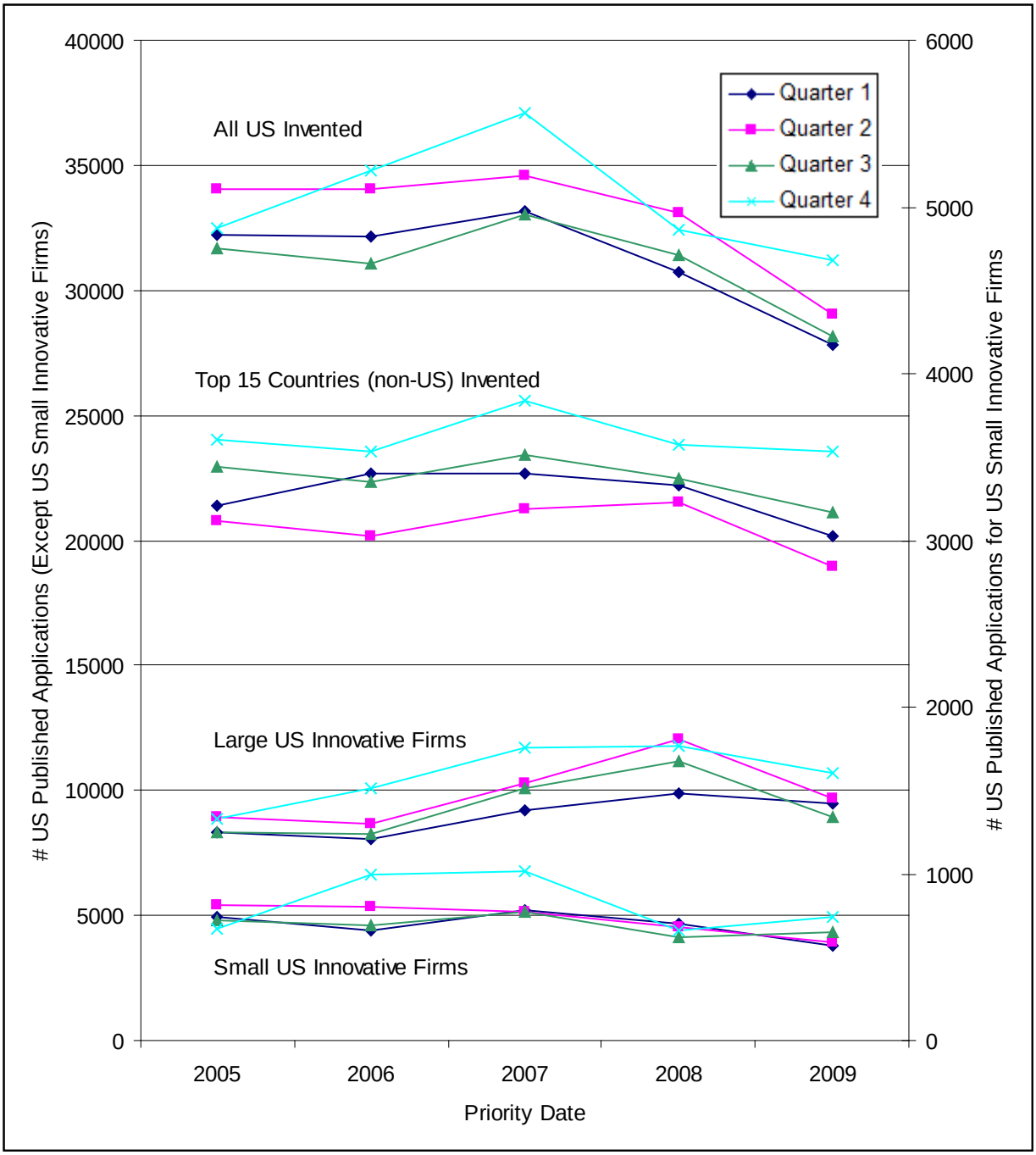



Figure IV.3 allows for year-over-year comparisons between patent application levels in equivalent quarters. This figure reveals that large innovative firms had more patent filings in each quarter of 2008 compared with the respective quarters in 2007. Meanwhile, other sectors – foreign invented applications, innovative small firm applications, and overall US applications – all declined. In 2009, even the large innovative firms declined in terms of patent applications, but less sharply than US and foreign invented applications overall. Interestingly, the small innovative US firms were the only sector to actually have an upturn in quarterly year-over-year patenting following the end of the recession in June of 2009. The other sectors did increase their

patenting in the second and third quarters of 2009 relative to the first quarter of 2009, but their patent application levels were still lower than the equivalent second and third quarters of 2008.

It is also worth noting that the analysis reported here combines all foreign invented patents into a single group. There are actually significant differences among the countries included in this group. Appendix A contains 16 individual graphs (one for each country) similar to Figure IV.3. These graphs reveal that most of the 16 countries were affected by the recession, and showed a decline in patent filings in both 2008 and 2009. There are, however, some notable exceptions. For example, Australia had peak filings in each quarter of 2008 compared to same quarters in other years, while Switzerland's only slow quarter seems to be the fourth quarter of 2009. China's patent activity shows a leveling off, but no real decline. China is also the fastest growing country overall, with patent filings at approximately twice the rate of 2005. India is also among the fastest growing countries. India's US patent applications rose in 2008 and then fell in the first three quarters of 2009, before recovering to their highest level overall in the fourth quarter of 2009.

## *D. Conclusion*

In this chapter, we examined US versus foreign invented patents to see if the R&D patterns in foreign countries during the recent recession behaved in a similar manner to the US. Initial observations indicate that it did. Patent filings from US and non-US inventors declined immediately following the recession start and began recovering following the second quarter of 2009. As noted earlier, highly innovative large US firms were slower to change their patent activity during the recession than small innovative firms. These firms did not slow down their patent filing until a year after most other sectors. Small US firms did slow down their patenting, but they also increased their patenting quickest following the end of the recession in June 2009.

# V. Regional Effects of Recession on Innovative Firms

## *A. Introduction*

In Chapter III we compared the patent filings of small and large innovative firms leading up to and following the recent economic recession. In this section, we drill down into these data to determine whether there are any differences in patent application trends related to the US regions in which inventors are located.

## *B. Summary*

In this chapter we examine inventors from four US census regions and several states to see if innovative firms in different regions react in different ways to economic declines. Some key findings are:

1. As reported above, in the period immediately after the recession started, large firms continued to file patent applications at high levels, while small firms quickly reduced their filings. This finding holds for all four US Census Regions (Northeast, Midwest, South, West). The end of the economic expansion came in the fourth quarter of 2007, but large firms in all four regions continued to file patents in large numbers through 2008, with some reaching all time highs during that year. In most regions, large firms only started to reduce their patent filing activity in early 2009. On the other hand, small firms in all regions reduced their patent filing activity immediately after the recession started. Indeed, small firms in the Midwest actually reduced filing activity even earlier than the fourth quarter of 2007.

2. The results are similar at state level, with large firms in most states maintaining their R&D for several quarters into the recession, and then showing a decline in 2009. Meanwhile, small innovative firms repeat their pattern of reducing their patent filings immediately and sharply in the first quarter of 2008. California is an interesting exception to this. Large firms in California not only increased their patent applications in 2008, they did not show major declines in 2009 like in most regions and states.

3. The small firms in California, on the other hand, reduced their patent filings in the first quarter of 2008, immediately after the recession started. The same happened in most other states, but the drop in California was particularly dramatic. Indeed, much of the overall difference between small firm and large firm patent filings during the downturn can be explained by differences in small and large firm behavior in California.

4. This reflects the importance of California to the overall level of US innovation. Based on inventor addresses, 22% of all patents from large innovative firms in our database come from California, while 40% of all the patents from the innovative small firms are invented in California. Moreover, 25% of all large innovative firms and 68% of all small innovative firms in the database have their major R&D operations in California.

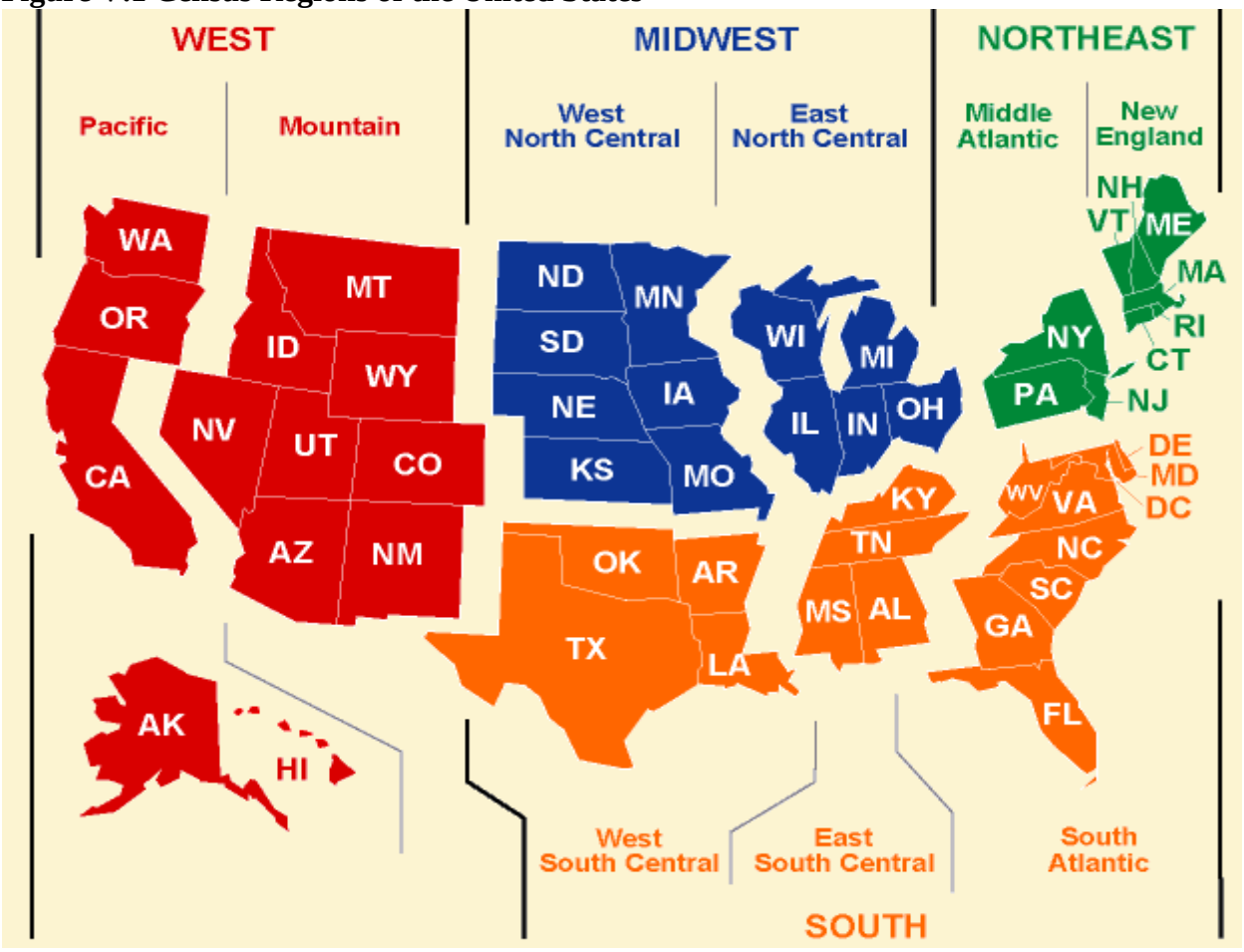
## *C. Method*

In the database of innovative firms used throughout this project, we identified the address of the first inventor of each patent application, and used this address to assign each patent to a state and census region.

## *D. Results*

The first part of our analysis is by US Census Region. Figure V.1 shows which states make up each of these regions (Northeast, Midwest, South, West).

**Figure V.1 Census Regions of the United States**




Source: Energy Information Administration http://www.eia.gov/emeu/reps/maps/us_census.html (Last accessed February 13, 2013.)

We analyzed trends over time in patent applications filed by large and small innovative firms in the four census regions. The results are shown in Figure V.2 (for large companies) and Figure V.3 (for small companies). Note that the western region has many more patent applications than the other regions, so we use a secondary Y-axis on the graph to allow for direct comparison of trends between the west and other regions.

Figure V.2 reveals that large firms did not react immediately to the recession in terms of filing patent applications. For example, large firms in the western and southern regions peaked in terms of applications in the second quarter of 2008, which was two quarters beyond the start of the recession according to the National Bureau of Economic Research. The northeast region was also near its all time high in the second quarter of 2008, while the Midwest region reached its peak in the third quarter of 2008.

**Figure V.2 Number of US Published Applications for Large Innovative Firms by Region of Inventor**

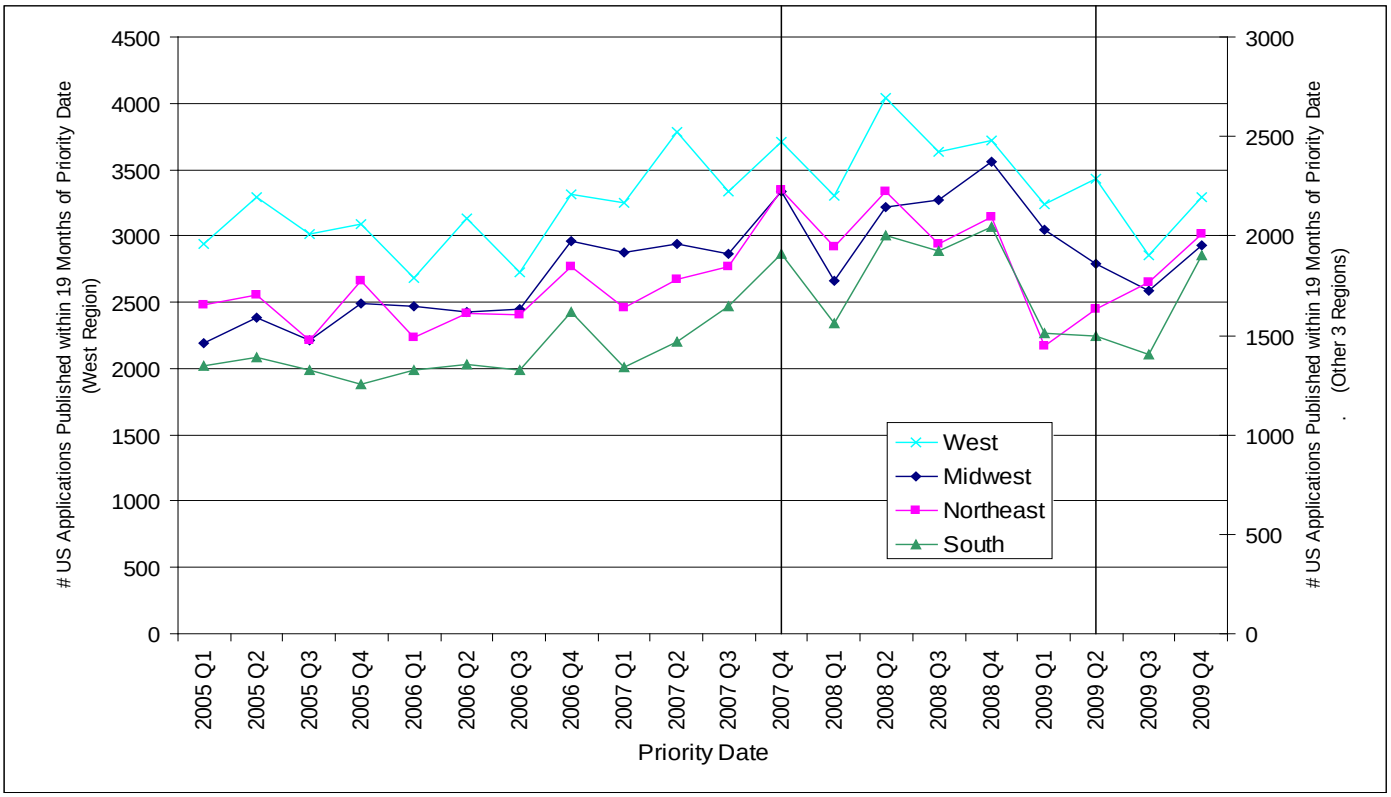



**Figure V.3 Number of US Published Applications for Small Innovative Firms by Region of Inventor**

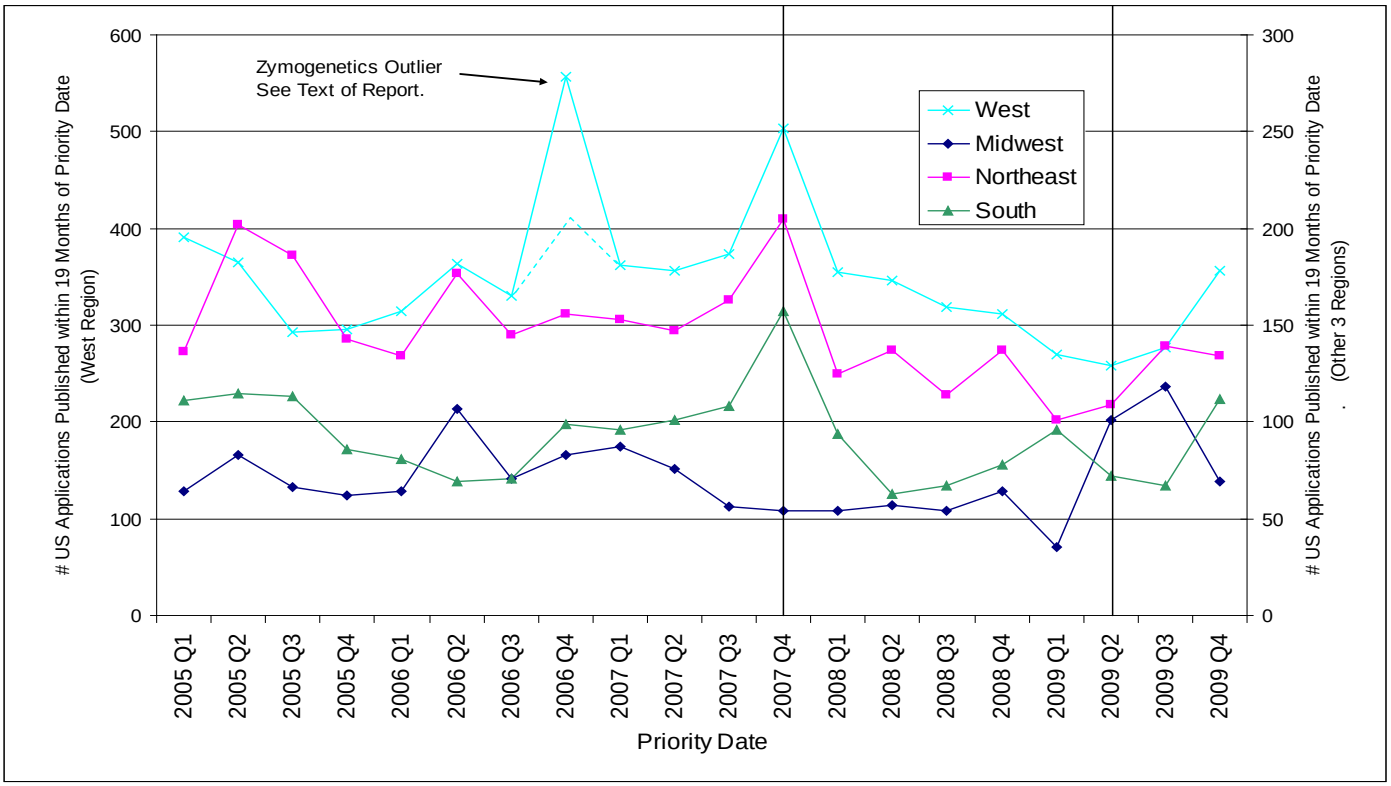


Figure V.3 reveals that the number of applications declined immediately and sharply for small companies in the western, southern and northeastern regions during the recession. Midwest patenting had actually declined prior to the recession, and remained roughly constant throughout most of the recession. It then dropped again in the first quarter of 2009, before recovering sharply in the second quarter of 2009.

Figure V.3 does have one unusual data point in the fourth quarter of 2006. The count of applications in this quarter is inflated significantly due to applications filed by Zymogenetics. This company typically files one to ten patent applications per month. However, in October of 2006, Zymogenetics filed 153 applications, most of which were variations of one another. For example it filed 31 individual applications with the title 'Homogenous preparations of IL-28 and IL-29', 12 applications with the title 'Methods of treating cancer using IL-21' and nine with the title "Methods for treating viral infection using IL-28 and IL-2'. If we remove the extraordinary month for Zymogenetics, the number of small company patent applications in the fourth quarter of 2006 drops from 557 to 413. This is shown in Figure V.3 using a blue dashed line.

As reported in Chapter III, both small and large firms tend to file more patents in the fourth quarter of each year than they do in the first quarter, regardless of the business cycle. We therefore plotted year-over-year quarterly filings for each region. The eight figures (one for each region for large firms, and one for each region for small firms) are contained in Appendix B. Plotting the data this way shows that large innovative firms in each region continued to file patent applications at a high level for nearly a year after the recession started before showing a downturn. Meanwhile, the small innovative firms show a downturn in patent applications immediately after the start of the recession, followed by a slight upturn in the third and fourth quarters of 2009 – i.e. after the recession ended. Once again, the Midwest region appears to have its downturn well before the other regions. For the other three regions, the fourth quarter of 2008 saw the largest drop in patent applications compared to the fourth quarter of 2007, which coincided with the absolute peak in the business cycle (see Figure III.1 in Chapter 3).

Beyond census regions, we also examined trends in patent applications at the level of individual US states. This provides a greater level of detail for each region. For example, while the western region has three times as many patent applications as the other regions, most of these come from California and Washington, while very few come from Wyoming.

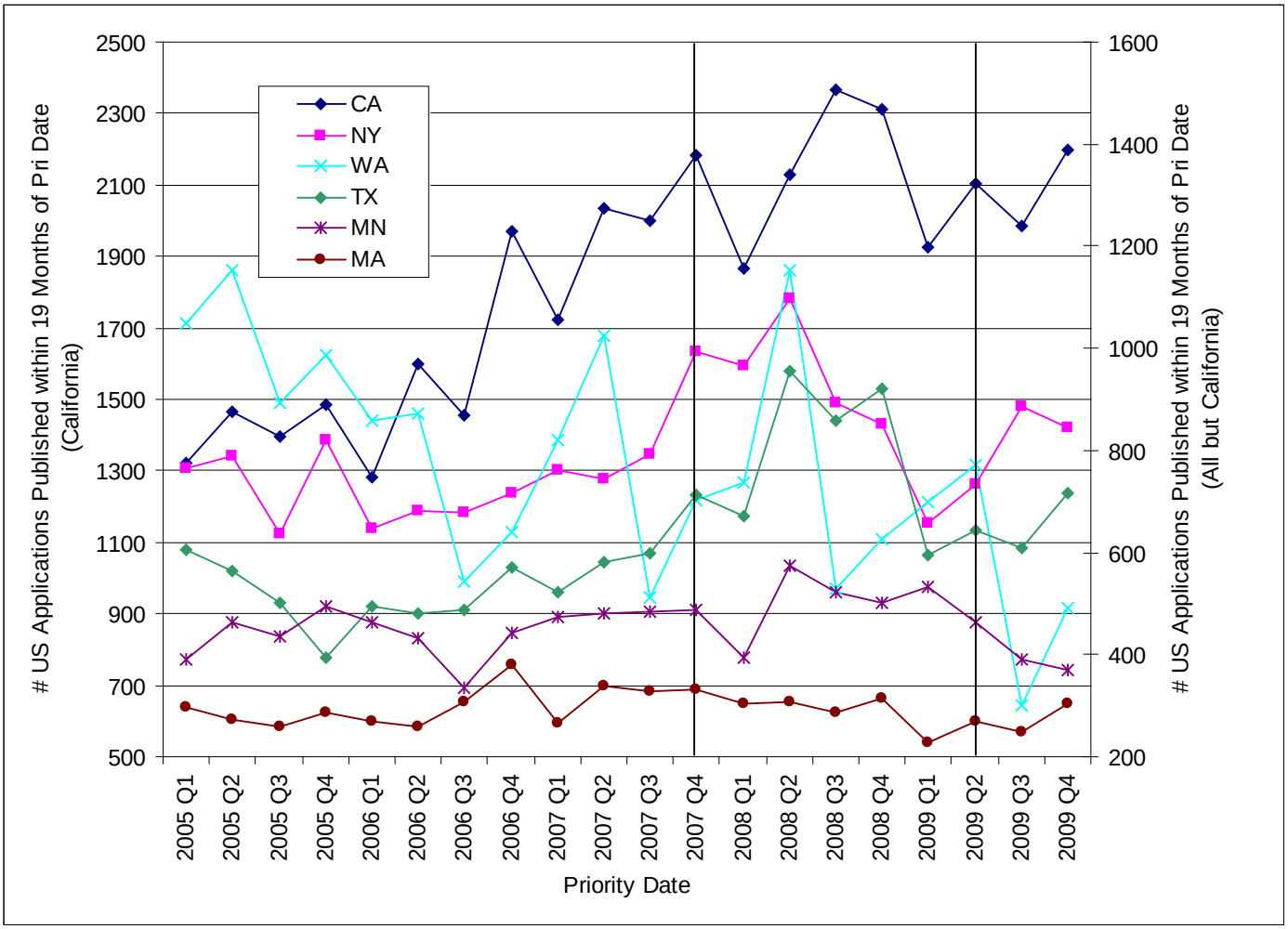
Table V.1 shows the number of patent applications by state filed by small and large innovative companies between 2005 and July 2011. This table reveals that, for large firms, California inventors have the most patent filings, followed by New York and Washington State. For small firms, it is California followed by New York and Massachusetts. Note that California inventors working at large firms have roughly twice as many patent filings as their counterparts from second place New York, but California inventors working at small firms have six times as many filings as their New York counterparts. In fact, California inventors are responsible for 22% of all patent filings from innovative large firms and 40% of all patent filings from innovative small firms.

In Figure V.4, we examine trends over time in large firm patent applications from the leading states in Table V.1 (highlighted in yellow). This figure reveals that, in each of the top five states, large companies had their peak in patent applications in 2008, by which point the economy had entered the recession. It is also interesting to note the trend for California inventors from large firms compared to their counterparts in Washington State, whose patent filings had been generally trending downwards since 2005.

**Table V.1 Number of Published Applications by Inventor State for Small and Large Innovative Firms**
(All US Applications Published within 19 months of Priority Date)

| | # Large Firm Published Apps | # Small Firm Published Apps | Combined | Large Firm Rank | Small Firm Rank | Combined Rank |
|---|---|---|---|---|---|---|
| California | 36794 | 5314 | 42108 | 1 | 1 | 1 |
| New York | 15953 | 840 | 16793 | 2 | 2 | 2 |
| Washington | 15365 | 700 | 16065 | 3 | 4 | 3 |
| Texas | 12484 | 555 | 13039 | 4 | 5 | 4 |
| Minnesota | 9133 | 307 | 9440 | 5 | 12 | 5 |
| Michigan | 8235 | 138 | 8373 | 6 | 19 | 6 |
| Illinois | 6924 | 458 | 7382 | 7 | 8 | 7 |
| Massachusetts | 5862 | 768 | 6630 | 8 | 3 | 8 |
| New Jersey | 4362 | 474 | 4836 | 10 | 7 | 9 |
| North Carolina | 4541 | 285 | 4826 | 9 | 13 | 10 |
| Pennsylvania | 4008 | 514 | 4522 | 12 | 6 | 11 |
| Ohio | 4228 | 104 | 4332 | 11 | 23 | 12 |
| Arizona | 3304 | 120 | 3424 | 13 | 21 | 13 |
| Colorado | 2969 | 328 | 3297 | 14 | 11 | 14 |
| Florida | 2881 | 334 | 3215 | 17 | 9 | 15 |
| Georgia | 2896 | 189 | 3085 | 15 | 14 | 16 |
| Connecticut | 2887 | 172 | 3059 | 16 | 16 | 17 |
| Wisconsin | 2801 | 147 | 2948 | 18 | 18 | 18 |
| Oregon | 2497 | 331 | 2828 | 19 | 10 | 19 |
| Indiana | 2229 | 31 | 2260 | 20 | 30 | 20 |
| Idaho | 2189 | 9 | 2198 | 21 | 39 | 21 |
| Virginia | 1606 | 59 | 1665 | 22 | 27 | 22 |
| Tennessee | 1403 | 94 | 1497 | 23 | 24 | 23 |
| Iowa | 1350 | 128 | 1478 | 24 | 20 | 24 |
| Maryland | 1265 | 178 | 1443 | 25 | 15 | 25 |
| South Carolina | 1229 | 22 | 1251 | 27 | 31 | 26 |
| Vermont | 1241 | 3 | 1244 | 26 | 43 | 27 |
| Missouri | 1158 | 60 | 1218 | 28 | 26 | 28 |
| Utah | 1021 | 114 | 1135 | 30 | 22 | 29 |
| New Hampshire | 975 | 158 | 1133 | 31 | 17 | 30 |
| Nevada | 1080 | 41 | 1121 | 29 | 29 | 31 |
| Oklahoma | 885 | 1 | 886 | 32 | 47 | 32 |
| Kentucky | 682 | 16 | 698 | 33 | 33 | 33 |
| Kansas | 613 | 44 | 657 | 35 | 28 | 34 |
| Delaware | 614 | 8 | 622 | 34 | 40 | 35 |
| New Mexico | 406 | 19 | 425 | 36 | 32 | 36 |
| Nebraska | 269 | 3 | 272 | 37 | 44 | 37 |
| Rhode Island | 237 | 11 | 248 | 38 | 37 | 38 |
| Alabama | 167 | 75 | 242 | 41 | 25 | 39 |
| Maine | 208 | 3 | 211 | 39 | 45 | 40 |
| Louisiana | 181 | 2 | 183 | 40 | 46 | 41 |
| North Dakota | 165 | 0 | 165 | 42 | 50 | 42 |
| Mississippi | 127 | 16 | 143 | 43 | 34 | 43 |
| Arkansas | 76 | 0 | 76 | 44 | 51 | 44 |
| Montana | 71 | 1 | 72 | 45 | 48 | 45 |
| District of Columbia | 57 | 10 | 67 | 46 | 38 | 46 |
| West Virginia | 52 | 12 | 64 | 48 | 36 | 47 |
| Hawaii | 55 | 8 | 63 | 47 | 41 | 48 |
| Wyoming | 33 | 14 | 47 | 49 | 35 | 49 |
| South Dakota | 13 | 5 | 18 | 50 | 42 | 50 |
| Alaska | 12 | 0 | 12 | 51 | 49 | 51 |

**Figure V.4 Number of US Published Applications for Large Innovative Firms by State of Inventor**




Due to the sharp decline for Washington State in patent applications since 2005, and the simultaneous ascent for California, we looked at applications from these states in more detail. Table V.2 shows the top 12 large US firms with inventors based in California. Table V.3 shows similar data for Washington State.

Table V.2 reveals that Qualcomm's inventors based in California increased their patent filings from 228 in 2005-06 to 2,431 in 2008-09. Similarly, Apple's California inventors increased applications from 299 to 1,072 over the same period. Several other firms also saw increases, albeit less marked, resulting in the overall upward trend for California shown in Figure V.4. In Washington State, meanwhile, Microsoft reduced its patent applications by more than 30% over the same period (from 5,900 to 4,097). Given that Microsoft is responsible for over 81% of the Washington State patent filings in Figure V.4, this explains much of the decline shown for Washington in this figure. For example, while AT&T's Washington inventors increased their patent filings by 354% between 2005-06 and 2008-09, the numbers of applications involved were too low to offset Microsoft's decline to any great extent.

**Table V.2 Firms with Most Patents Filed from California Inventors (Filing Date 2005-09)**

| Rank | Company | Total Published Applications Filed 2005-09 | # Published Applications Filed 2005-06 | # Published Applications Filed 2008-09 | % Change 2005-06 to 2008-09 |
|---|---|---|---|---|---|
| 1 | Qualcomm Inc | 3172 | 228 | 2431 | 966% |
| 2 | Broadcom Corp. | 2050 | 676 | 853 | 26% |
| 3 | Oracle Corporation | 1822 | 561 | 859 | 53% |
| 4 | Apple Inc | 1778 | 299 | 1072 | 259% |
| 5 | Applied Materials Inc. | 1649 | 781 | 579 | -26% |
| 6 | Yahoo Inc | 1367 | 378 | 570 | 51% |
| 7 | International Business Machines Corp | 1346 | 426 | 657 | 54% |
| 8 | Cisco Systems Inc. | 1227 | 619 | 368 | -41% |
| 9 | Abbott Laboratories | 1011 | 210 | 556 | 165% |
| 10 | Microsoft Corporation | 859 | 437 | 288 | -34% |
| 11 | Xerox Corp | 791 | 296 | 361 | 22% |
| 12 | Medtronic Inc | 770 | 262 | 331 | 26% |

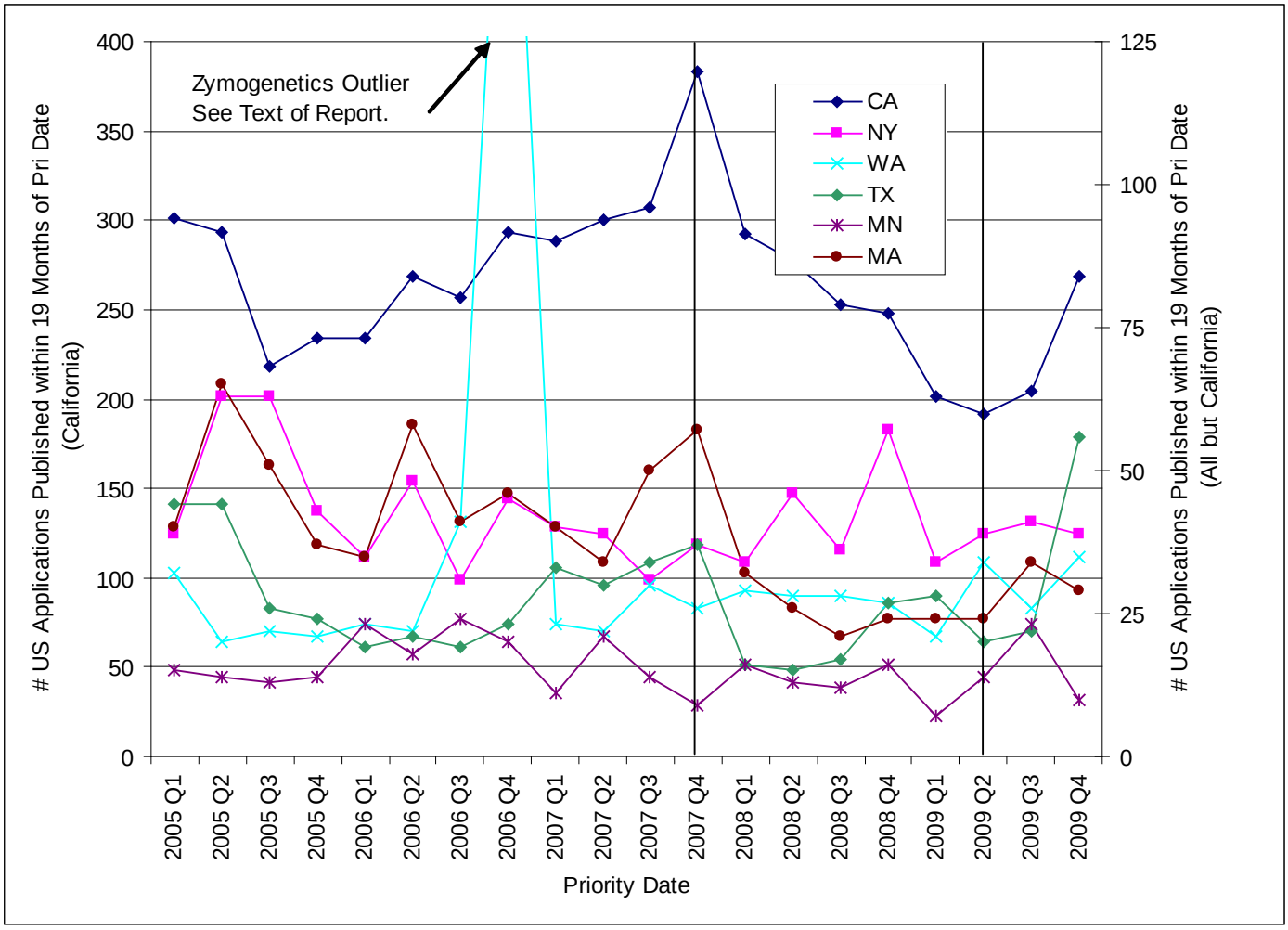
**Table V.3 Firms with Most Patents Filed from Washington State Inventors (Filing Date 2005-09)**

| Rank | Company | Total Published Applications Filed 2005-09 | # Published Applications Filed 2005-06 | # Published Applications Filed 2008-09 | % Change 2005-06 to 2008-09 |
|---|---|---|---|---|---|
| 1 | Microsoft Corporation | 12445 | 5900 | 4097 | -31% |
| 2 | Boeing Co. (The) | 981 | 393 | 404 | 3% |
| 3 | Honeywell International Inc. | 216 | 84 | 96 | 14% |
| 4 | AT&T Inc | 174 | 28 | 127 | 354% |
| 5 | Weyerhaeuser Co. | 140 | 31 | 65 | 110% |
| 6 | Amgen Inc | 105 | 40 | 34 | -15% |
| 7 | Intel Corporation | 58 | 44 | 8 | -82% |
| 8 | Intermec Inc | 58 | 26 | 19 | -27% |
| 9 | International Business Machines Corp | 56 | 8 | 34 | 325% |
| 10 | Danaher Corp. | 39 | 4 | 29 | 625% |
| 11 | Leviton Manufacturing Co. Inc. | 39 | 15 | 16 | 7% |
| 12 | Paccar Inc. | 37 | 11 | 8 | -27% |

Figure V.5 reveals a very different trend for small innovative firms than Figure V.4 did for large innovative firms. Specifically, while large California firms maintained their patent filings during the recession, small California firms saw an immediate and sharp reduction in their filings. Other states including Texas and Massachusetts had similar reductions, although the numbers of applications involved were much lower. It is also interesting to note that small companies in Washington State and New York largely maintained their level of patent applications during the recession.

We plotted patent applications from large and small innovative firms on a year-over-year quarterly basis for each of the leading states, and the results can be found in Appendix C. These results again show that large firms generally continued to file patent applications at a high level through 2008, and did not show a downturn until a year into the recession. Large firms in California had a generally flat 2009, rather than a downturn, while those in Massachusetts saw a slight decline in both years. The small innovative firms reacted completely differently. Small firms in New York peaked in 2008 and declined in 2009, similar to the large firms in most states. Meanwhile, small firms in California, Texas, Minnesota, and Massachusetts all declined throughout 2008, with most seeing an uptick in the third and fourth quarters of 2009. Texas small firms seemed to rebound from the recession the earliest.

**Figure V.5 Number of US Published Applications for Small Innovative Firms by State of Inventor**




Before leaving this section, it is worth highlighting California's importance to innovation in the US. As discussed earlier, 22% of patent applications from innovative US large firms between 2005 and July 2011, and 40% of applications from innovative US small firms over this period, were invented in California. This is largely a reflection of how many large and small innovative firms have their major operations in California. Table V.4 shows the 15 US states with the largest number of highly innovative large firms (where company location is determined based on where they invent the largest proportion of their patent applications). This table reveals that 25% of the large innovative firms in our database are located in California. Meanwhile, New York and Washington State have only 4% and 2% of large firms respectively, but each state is responsible for 9% of large firm patent applications. The high percentage of patent applications from these states, relative to their number of innovative large companies, is due largely to the extensive filings by IBM (based in New York) and Microsoft (based in Washington).

Table V.5 shows the 15 US states with the largest number of highly innovative small firms. This table reveals that over two-thirds (68%) of small innovative firms in our database are located in California. This is six times as many firms as the second placed state in Table V.5 (Massachusetts, with 11% of the small companies), showing how central California is to innovation by small US firms.

**Table V.4 15 US States with Most Highly Innovative Large Firms**

| Rank | State Where Majority of Patent Applications Invented | # Firms | % Firms |
|---|---|---|---|
| 1 | California | 176 | 25% |
| 2 | Michigan | 44 | 6% |
| 3 | Illinois | 42 | 6% |
| 4 | Minnesota | 35 | 5% |
| 5 | Texas | 35 | 5% |
| 6 | Massachusetts | 35 | 5% |
| 7 | Ohio | 32 | 4% |
| 8 | New York | 32 | 4% |
| 9 | Pennsylvania | 30 | 4% |
| 10 | New Jersey | 24 | 3% |
| 11 | Wisconsin | 20 | 3% |
| 12 | Colorado | 19 | 3% |
| 13 | Washington | 16 | 2% |
| 14 | Indiana | 16 | 2% |
| 15 | Georgia | 16 | 2% |

**Table V.5 Top 15 States with Most Highly Innovative Small Firms**

| Rank | State Where Majority of Patent Applications Invented | # Firms | % Firms |
|---|---|---|---|
| 1 | California | 203 | 68% |
| 2 | Massachusetts | 32 | 11% |
| 3 | Texas | 25 | 8% |
| 4 | Illinois | 20 | 7% |
| 5 | Minnesota | 18 | 6% |
| 6 | Pennsylvania | 16 | 5% |
| 7 | Colorado | 16 | 5% |
| 8 | North Carolina | 15 | 5% |
| 9 | New York | 15 | 5% |
| 10 | Washington | 13 | 4% |
| 11 | New Jersey | 13 | 4% |
| 12 | Connecticut | 12 | 4% |
| 13 | Florida | 10 | 3% |
| 14 | Maryland | 10 | 3% |
| 15 | Oregon | 9 | 3% |

## *E. Conclusion*

In this chapter, we examined patent applications from four US census regions and several US states during the recent economic recession. We reaffirmed the finding from Chapter III that large firms continued to file patent applications at high levels after the recession started, while small firms reduced their patent filings almost immediately. We also found that this finding holds true for each of the four US census regions individually. The start of the economic recession was in the fourth quarter of 2007, but large firms in the four major regions continued to file patents in large numbers through 2008, with some reaching all time highs in that year. In most regions, large firms did not start to reduce their patent filings until early 2009. Small

firms, on the other hand, reduced their patent activity almost immediately after the start of the recession, with small firms in the Midwest actually reducing their filings even earlier than the fourth quarter of 2007.

Similar results were found at state level for the most patent intensive US states. California is a particularly interesting example, because it is responsible for by far the largest percentage of large and small firm patent applications. In California, large firms continued to file patent applications at a high level during the recession, while small firms reduced their filings dramatically and immediately. Indeed, much of the overall gap between trends in small firm and large firm patenting during the downturn (reported in Chapter III) can be explained by small firm behavior versus large firm behavior in California.

# VI. Closing Summary

The main body of this report consists of four somewhat self-contained sections. The first section describes the construction of our database of innovative US firms, and provides an overview of the database via summary statistics. The remaining sections of the report use this database to compare patent applications from highly innovative US small and large firms prior to, during, and following the recent economic recession. First we compare these US firms against each other, and then against patent applications filed by overseas inventors. Finally, we compare large and small firm patent applications by major US regions and within several key US states.

The main data resource developed for this project is a database of innovative firms described in Chapter II - Overview of Small Business Patent Database. This database contains all firms with 15+ patents granted between 2005 and 2009. There are 1,279 firms in the database, which are referred to as 'innovative firms' because of their high level of patent activity. These firms were researched further in order to categorize them as small firms (those with 500 or fewer employees) and large firms (those with more than 500 employees). In total, we identified 532 small firms and 728 large firms, plus 19 firms where no employee information could be located (these latter firms are very likely to be additional small firms).

Given the difficulty and expense of filing patents, it is somewhat surprising that a full 42% of US innovative firms (that is, those with 15+ patents between 2005 and 2009) are small firms with 500 or fewer employees. Perhaps even more surprising is that 57% of all the firms, and 29% of the small firms, in the database are publicly listed on major US exchanges (i.e. not including companies whose stock is traded over the counter). We estimate that less than 0.1% of all firms are publicly traded on major US exchanges. The large share of publicly traded firms in the database for this project is therefore notable. It suggests that firms of all sizes with patented technology are more likely to become successful enough to go public than firms that do not produce patents.

In Chapter II, we also confirmed a result from one of our earlier SBA studies, (Breitzman and Hicks, 2008) where we showed that small innovative firms are much more productive than large innovative firms from a patents-per-employee perspective. In the updated database for the current project, we found that small innovative firms produce 15 times as many inventions per 100 employees as do large innovative firms.

We also confirmed our earlier finding that small innovative firms outperform their larger counterparts based on patent impact measures. In the current study, patents from small innovative firms are cited 57% more frequently by recent patents than is typical for patents of the same age and patent classification. Meanwhile, patents from large innovative firms are cited just slightly above average. Numerous validation studies have shown a relationship between patent citations and positive outcomes such as inventor awards, licensing revenue, increases in sales and profits, etc.

Chapter III of the report showed that small innovative firms changed patent application activity early and to a considerable degree during the 2007-2009 recession. Large firms also saw a decline in patent applications, but it was much smaller and later. The net result is that, two quarters into the recovery, small firms had only just got back to their patent application rate from 2005. Large firms, meanwhile, were well above their 2005 level in terms of patent applications, and indeed had almost reached pre-recession levels.

Patent applications can be a proxy for R&D outputs and R&D spending in general, and small innovative firms changed patent application patterns during the recent recession. This may adversely affect their ability to launch new products following a recession in order to fully take advantage of a subsequent economic expansion in the short term. Since small firms have been shown to develop high impact technologies, and a higher percentage of green and leading edge technologies, this result has significant policy implications.

Chapter IV examined US versus foreign invented patent filings to determine whether the recession affected overseas R&D in a manner similar to the US. The simple answer to this question is that it did. Patent filings from US and non-US inventors declined immediately following the start of the recession, and began to recover following the second quarter of 2009. That is, the large US firms who file the most patents did not slow down their filing rate until a year after most other sectors. Small US firms did slow down their patent application rate, but they also increased their rate soonest following the end of the recession in June 2009.

Chapter V examined patent applications from four US census regions and several US states to see if small and large innovative firms in different regions reacted in different ways to the recent economic recession. We reaffirmed the finding from Chapter III that large firms continued to file patent applications at high levels after the recession started, while small firms reduced their patent filings almost immediately. We also found that this holds true for each of the four US census regions individually. The end of the economic expansion was in the fourth quarter of 2007, but large firms in the four major regions continued to file patents in large numbers through 2008, with some reaching all time highs in that year. In most regions, large firms did not start to reduce their patent filings until early 2009. Small firms, on the other hand, reduced their patent applications almost immediately after the start of the recession, with small firms in the Midwest actually reducing their filings even earlier than the fourth quarter of 2007.

These results were found to be the same at the state level for the most patent intensive states. California is a particularly interesting example, because it is responsible for by far the largest percentage of large and small firm patent applications. In California, large firms continued to file patent applications at a high level during the recession, while small firms reduced their filings dramatically and immediately. Indeed, much of the overall gap between the trends in small firm and large firm patenting during the downturn (reported in Chapter III) can be explained by small firm behavior versus large firm behavior in California.

Overall, the findings of this report reinforce those from our earlier reports, namely that small firms participate extensively in the patent system, they produce large numbers of patents relative to their size, and these patents tend to have very strong quality metrics. This project also extends those earlier reports to reveal the different patterns of innovative small and large US firms during the recent recession. Specifically, we found that during the 2007-2009 recession small firms changed patent application activity much more quickly and extensively than large firms in terms of their patent filings.

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