

Innovation in Small Businesses: Drivers of Change and Value Use

by

C J Isom, Ceteris, Inc.

David R. Jarczyk, Ceteris, Inc.

for



Under contract no. SBAHQ07-Q-0012

Release Date: March 2009

This report was developed under a contract with the Small Business Administration, Office of Advocacy, and contains information and analysis that was reviewed and edited by officials of the Office of Advocacy. However, the final conclusions of the report do not necessarily reflect the views of the Office of Advocacy.

Innovation in Small Businesses: Drivers of Change and Value Use

by

C J Isom, Ceteris, Inc.

David R. Jarczyk, Ceteris, Inc.

for



Under contract no. SBAHQ-07-M-0409

Release Date: March 2009

This report was developed under a contract with the Small Business Administration, Office of Advocacy, and contains information and analysis that was reviewed and edited by officials of the Office of Advocacy. However, the final conclusions of the report do not necessarily reflect the views of the Office of Advocacy.

Innovation in Small Businesses: Drivers of Change and Value

C J Isom, Ceteris, Inc.

David R. Jarczyk, Ceteris, Inc.

Abstract

This paper investigates various drivers of innovation within small businesses, as well as the role that innovation plays in creating value in small businesses. The analysis suggests that additions in employee headcount increase innovation while growth in sales does not increase innovation. The analysis also finds that increases in research and development (“R&D”) expenditures enhance small business value in certain industries, but not uniformly and not in all the industries investigated. Finally, the paper finds that the number of patents owned by a small business is not a good indicator of a firm’s value.

Table of Contents

| | |
|----------------------------------------------------------------------------------|----|
| Executive Summary | 3 |
| 1. Introduction..... | 5 |
| 2. Literature Review | 7 |
| 3. Data..... | 9 |
| 3.1 Introduction..... | 9 |
| 3.2 Standard & Poor’s <i>Compustat</i> Database Review..... | 9 |
| 3.3 Patent Count Review..... | 10 |
| 3.4 <i>ktMINE</i> | 11 |
| 4. Research Methodology..... | 12 |
| 4.1 Introduction..... | 12 |
| 4.2 The Relationship between Employee Headcount and Sales and Innovation..... | 12 |
| 4.3 The Relationship between Patent Production and Market Value | 16 |
| 4.4 The Relationship between R&D Expenditures and Market Value by Industry | 17 |
| 5. Empirical Results | 19 |
| 5.1 Introduction..... | 19 |
| 5.2 The Relationship between Employee Headcount and Innovation | 19 |
| 5.3 The Relationship between Sales and Innovation..... | 20 |
| 5.4 The Relationship between Patent Count and Market Value..... | 20 |
| 5.5 The Relationship between R&D Expenditures and Market Value by Industry | 21 |
| 6. Conclusion..... | 23 |

List of Tables

- 1: Employee Headcount and Sale Coefficient Estimates
- 2: Patent Production Coefficient Estimates for Each Industry
- 3: R&D Expenditures Coefficient Estimates for Each Industry

List of Appendices

- 1: Industry Descriptions
- 2: Standard & Poor’s *Compustat* – Definitions of Relevant Information
- 3: References

Executive Summary

Innovation and firm value are key drivers for business success. Their respective roles are vital in creating and improving goods and services, developing market demand, meeting market expectations, and increasing shareholders' wealth.

In this report we examined the drivers of innovation within small businesses. We examine what drivers affect the number of patents issued to a small business by using patent production as a proxy for innovation; these drivers include employee headcount, sales, R&D expenditures, and other factors. We also examined the factors that affect firm value: R&D expenditures, patent issuance, and others.

Our first result shows that innovation increases significantly as small businesses increase employee headcount. Using a firm's patent activity as a proxy for innovative activity, our empirical results show that a one-hundred person increase in employee headcount increases innovative activity by 20 percent. Perline, Axtell, and Teitelbaum (2006) found similar results with respect to the survival rates of firms and the firm size. Wallsten (2000) also found that firms with more employees win more Small Business Innovation Research grants. Our analysis is consistent over every year for which research was performed (2004, 2005 and 2006), using a multivariate regression analysis dating back to 2000.

In our second result, we observe that changes in a firm's sales have neither a positive nor negative effect on innovation. The analysis, as before, applies to 2004 through 2006, and uses patent activity as a proxy for innovative activity.

Thirdly, we observe that empirical results reveal that there is no statistical relationship between patent count and market value. Lerner (1994) found different results when he modeled the tradeoff between patent protection and a firm's valuation. While Lerner's study focused on patents within the biotechnology industry, our analysis uses an industry-by-industry approach, focusing on five specific industries:¹

- Chemicals and Allied Products ("Chemicals");

- Industrial and Commercial Machinery and Computer Equipment (“Industrial Machinery”);
- Electronic and Other Electrical Equipment and Components, Except Computer Equipment (“Electronics”);
- Measuring, Analyzing, and Controlling Instruments; Photographic, Medical, and Optical Goods; Watches and Clocks (“Mechanical Goods”); and
- Business Services (“Business Services”).

Perhaps one explanation for this result is that patent count, per se, may be necessary to protect a position in an industry versus creating ground-breaking opportunities for a firm. Alternatively, patents may not create great leaps of technological capabilities, or some patents may have limited application. Therefore the market may not reward patent generation per se, even though patent generation is an indicator of innovation.

Finally, our results indicate that there may be as much as a three percent increase in market value for every ten percent increase in R&D expenditures. However, this relationship is dependent upon industry.

The remainder of this paper explains some of our analysis in greater detail, and concludes with areas of further research that may be warranted.

¹ Appendix 1 has a full description of each industry.

1. Introduction

Much research has been performed on the role of small businesses in the US economy. These topics include small businesses' impact on innovation (Schumpeter 1934), the effects of government grants awarded to small businesses (Wallsten 2000), and innovation impact on a small business' value (Lerner 1994). Although there is an abundance of research, the availability of data limits the extent of research that can be performed. This limit in available resources and data has led to creative studies, but with the emergence of more information researchers are able to expand their understanding.

Innovation has been a constant proxy for measuring small business success. Patent production has been the most common proxy to measure innovation because data is readily accessible. Cincera (1997) concluded that R&D expenditures and technological spillovers were the result of patent production for all firms. While his research found determinants of patent production for all firms, it does not address how the size of the firm can impact patent production. Acs and Audretsch's (1988) results show that determinants of innovation are positively related to R&D expenditures and skilled labor. However, their research did show that these determinants have disparate effects on small firms.

Along with innovation, a significant body of research has looked at valuation of small businesses. Lerner's (1994) study on biotechnology firms found that the breadth of patent protection positively affects a firm's valuation. While this research provides results on the relationship between patent protection and firm value, it does not address the relationship between innovation and firm value of small businesses in different industries.

Using data from *ktMINE*, Standard & Poor's *Compustat* database, and the U.S. Patent and Trademark Office ("USPTO") databases, Ceteris constructed a dataset containing nearly 22,000 observations with detailed information from 2000 to 2006 on the size of small businesses, the industries in which they compete, the intensity of their patenting activities, and their financial performance.

While other research has addressed topics such as innovation, patent production, R&D expenditures, and firm value, no other report has performed analysis solely on small businesses using the data that we obtained.

The first thing we examined is the relationship between employee headcount and innovation within a small business. We measured innovation by patent production. This analysis is performed on an industry-wide basis and limited to small firms. Observing these firms in the years 2004, 2005, and 2006, our findings show that there is a positive relationship between employee headcount and patent production in all of the years observed.

We then explored the relationship between sales and innovation within a small business. Like the previous study, we use patent production as a proxy for innovation. The analysis shows that there is no significant relationship between sales and patent production. The years observed for this study were 2004, 2005 and 2006.

Our next analysis focused on the relationship between patent production and firm value. While Griliches' (1990) work suggests that efforts to explain the level of stock market valuations using patent measures have been disappointing, this paper is focused on the effects of patent production on the value of a small business within certain observed industries. Using data from five industries and measuring firm value as the firm's price-to-book ratio, we find that there is no significant relationship between patent production and firm value.

Finally, we examined the relationship between R&D expenditures and firm value. Continuing to use the price-to-book ratio as a proxy for firm value, we discovered that in three of the five observed industries, R&D expenditures have a positive effect on firm value.

2. Literature Review

Small firms play an instrumental role in the U.S. economy, employing half of all private sector employees and creating more than half of non-farm private Gross Domestic Product.² Further, small businesses that innovate are most likely to grow into large businesses and become a source of highly technical, high-paying jobs in the future. As such, understanding the trends of small businesses, especially patenting trends, is becoming a focal point in applied economics and policymaking. However, detailed research of this type is not readily available.

Much research has been done in the field of economics measuring patents as indicators of innovation and technological change. From a policymaking perspective, the literature focuses on how to design an optimal patent policy. From an economic perspective, studies examine the importance of innovation in the economy, the role of small firms in the innovation process, and the role of government in promoting innovation.

There are also research papers that investigate the relationship between firms' patent portfolios and their financial performance. However, these studies are often based on samples of large businesses. Small firms tend to be overlooked, because it is much more difficult to obtain detailed and reliable financial information. The difficulty lies in the fact that the majority of small firms are privately-owned. Such firms are not required to file their financial statements with the U.S. Securities Exchange Commission ("SEC"), have their statements audited by an accounting firm, or offer information publicly.

However, smaller firms play an important role in technological change. Smaller firms have many advantages as sources of innovation because they are quick to adopt new and high risk initiatives; they facilitate structures that value ideas and originality; and they have a better capacity to reap substantial rewards from market share in small niche markets. Statistically, small firms outperform large firms in terms of patents per employee by 13 to 14 times.³

² U.S Small Business Administration website: <http://app1.sba.gov/faqs/faqIndexAll.cfm?areaid=24>, as of June 22, 2007.

³ U.S Small Business Administration website: <http://app1.sba.gov/faqs/faqIndexAll.cfm?areaid=24>, as of June 22, 2007.

Theories on the role of small firms in the economy have been developed since the early 1900's. Schumpeter (1934) considered small firms an important venue for innovation and change to be incorporated into the economic system. Furthering this idea, scholars have attempted to link the size of firms with their innovation capability. However, empirical studies addressing these theories have been somewhat contradictory. While some studies have found a positive relationship between firm size and innovative capability, others have identified no relationship-or even a negative one (Audretsch and Acs 1991). The most extensive studies found a U-shaped relationship between firm size and innovative intensity in terms of innovations per employee (Audretsch and Acs 1991). That is, innovative intensity was strongly affected by small and large firms; however, in middle-size firms, the impact was weaker. This result is not robust because the results change when non-innovative firms are included in the sample. Perline, Axtell and Teitelbaum (2006) found that over longer time frames, there are fewer large growth changes within a business than observed in shorter time frames. Moreover, employment swings within a business are more likely to occur in shrinking firms than in those that are expanding.

Studies on R&D expenditures and their impact on innovation have also been analyzed. Wallsten (2000), using a multi-equation model, determined that firms with more employees who appear to do more research win more Small Business Innovation Research grants. Klette and Griliches (2000) observed that R&D expenditures are proportional to the firm's sales. Cincera (1997) suggested a positive impact on the technological spillovers on a firm's own innovation.

None of the aforementioned papers or literature, to our knowledge, provides a detailed focus on the effect that innovation has on market value, or the factors that drive innovation within firms. The approach that we take in this paper provides new analysis for understanding certain drivers and outcomes of innovative activity among small businesses, which comprise a large part of the U.S. economy.

3. Data

3.1 Introduction

This section details the data gathering activities to construct the dataset for our analysis.

Information was gathered from three primary sources:

- Standard & Poor's *Compustat* database;
- the U.S. Patent and Trademark Office's databases; and
- *ktMINE*.

3.2 Standard & Poor's *Compustat* Database Review

Ceteris examined the Standard & Poor's *Compustat* database (September 30, 2007) for public companies that are traded on U.S. stock exchanges and Over-the-Counter markets. This database provides business descriptions, financial data, and other company-specific data for these companies. Databases produced by Standard & Poor's are commonly used to analyze companies by a variety of financial industries.

In order to limit our dataset to small business results, the Standard & Poor's *Compustat* database was screened for companies that had less than 500 employees for fiscal year 2006. In order to identify the search for companies with less than 500 employees, the database was screened using the employee mnemonic⁴ "EMP," as defined by Standard & Poor's *Compustat*. This screening led to the identification of 3,659 companies classified as small businesses.

Next, we used the Standard & Poor's *Compustat* database to acquire the following list of financial information for the 3,659 companies:

- Employees;
- Sales – Net;
- R&D Expenditures; and

- Price to Book – Fiscal Year End.

For a complete listing of terms along with their mnemonics used to extract data for this analysis, see Appendix 2. Appendix 2 also includes the definitions and/or calculation used by Standard & Poor's Compustat for each financial item.

Lastly, we performed a final review on the employee data. For fiscal years 2005 and 2006, each company needed to have less than or equal to 500 employees. Furthermore, Compustat lists data as "@NA" if no information is available for the company for a given year. If a company had a "@NA" in the employee field, it was screened out of the total company list. This employee screen removed an additional 612 companies. As a result, we identified 3,047 companies for use in the next phase of acquiring patent counts.

3.3 Patent Count Review

Ceteris relied on databases provided by the USPTO to obtain patent count information for the 3,047 small businesses that we selected earlier. The "Advanced Search" function within the USPTO search engine allows the database to be searched by individual fields that describe each patent. These fields include Application Date, Application City, Issue Date, Patent Number, Assignee Name and more. Searches under Assignee Name and Issue Date allowed Ceteris to identify the total patents owned by the specified companies and patents issued to those companies within calendar years 2004, 2005 and 2006.⁵

Finally, after gathering the patent information, we filtered the data to keep companies that had data in each of the aforementioned categories from the S&P database dating back to 2000. This screening process removed 2,410 companies, resulting in 637 companies to form the sample of interest for this study. For each of the remaining companies, detailed company and financial information was at our disposal, including number of employees, sales, R&D expenditures and price to book value.

⁴ Mnemonics are short codes that allow a user to easily pull and analyze data contained within Compustat database.

⁵ We contacted the USPTO to confirm that this was the most appropriate method by which to gather data from the database.

3.4 *ktMINE*

ktMINE is an online tool that provides detailed information related to intellectual property. This information includes the specific detail of licensing transactions as reported by U.S. public companies and information related to the underlying intangibles, including patents, exploited through these agreements. We examined *ktMINE* to identify small businesses that license patented technologies. Then we compared the identified companies to the companies derived from the previous steps to ensure no companies were missing from the dataset. The completion of this step allowed us to be confident that the dataset compiled was accurate and complete.

4. Research Methodology

4.1 Introduction

As mentioned at the outset of this paper, our research sought to answer specific questions related to relationships between specific potential drivers of innovation – namely, employee headcount and sales, as well as the effect of different measurements of innovation (patent count and R&D expenditures) on market value. We addressed each of these questions by identifying specific forms of the relationships between the variables, and ultimately we strove to identify the best “fit” (i.e., the model with the strongest relationship to the observed data that was also theoretically sound) to address each question.

4.2 The Relationship between Employee Headcount and Sales and Innovation

While we address the relationship between employee headcount and innovation and the relationship between sales and innovation separately, our evaluations of the relationships flow from the same econometric model. This allowed us to control for any interaction or combined effects that these two variables might have on innovative activity.

In investigating the relationship between employee headcount and innovation, we posited that additions of employees in one year may not necessarily contribute to increases in innovation immediately, particularly when using patent output as a proxy for innovative activity. Other studies (Acs and Audretsch, 1988; Jaffe, 1986; Scherer, 1982; and Mansfield, 1981) have concluded that innovation output is related to innovation-inducing inputs in the previous period. We followed a similar approach, but modified it to fit our model. First, for an employee to add to the innovative process, it may take time for the employee to understand the research agenda of, and challenges faced by, the firm in which they are employed; in other words, an employee may need to move up the learning curve before adding to the innovative activity of the firm. Second, there is a lag between initial innovation and the time at which a patent is awarded.

Therefore, to account for this effect, we created a lagged model to measure the effect that employment might have on patent production and observed that innovative activity can be enhanced up to five years after employee headcount increases.

In a general regression model, marginal effects of the independent variable are one-time events. The response to the dependent variable is immediate and is completed at the end of the measuring period. For dynamic models, the marginal effects of the independent variable in any time period will affect the dependent variable in a future time period. The effect is not a one-time event, and it is not necessarily immediately observed.

A general form of a dynamic regression model can be defined as:

$$y_t = \alpha + \beta x_{t-1} + \varepsilon_t. \quad (1)$$

This model shows that a change in y is dependent on the changes in x from the previous period. By recognizing that past changes in the independent variable affect the dependent variable in this period, this function provides a better fit for the analysis.

We posited that there also might be a lag between sales and innovative activity. Increases in sales might create additional opportunities for firms, particularly smaller firms, where increases in sales may make it easier to obtain financing to fund future innovation.⁶

After determining the optimal number of lagged years to apply to our model, we used a modified moving average model applied to an ordinary least squares regression. By correcting the econometric form of the model, we were able to capture the lag effects of the coefficients while eliminating heteroscedasticity and multicollinearity.

To understand the rationale, let us observe equation (1) with more lagged variables. The model is presented as:

$$y_t = \alpha + \beta_1 x_{t-1} + \beta_2 x_{t-2} + \beta_3 x_{t-3} + \phi_1 z_{t-1} + \phi_2 z_{t-2} + \phi_3 z_{t-3} + \varepsilon_t. \quad (2)$$

Given this model, we see that the dependent variable, y_t is affected by changes in x and z in time periods $t-1$, $t-2$, $t-3$, and $t-4$. With the number of lags and cross-sectional data, there is concern of

heteroscedasticity.⁷ A moving average model is used as an alternative to the usual time-series process.⁸

Using the error term from equation (2), we can write the functional form of the error term as:

$$\varepsilon_t = \nu\varepsilon_{t-1} + u_t, \quad (3)$$

where

$$\begin{aligned} E[u_t] &= 0 \\ E[u_t^2] &= \sigma_u^2 \end{aligned}$$

In the moving-average form, “each disturbance embodies the entire past history of the u ’s (Greene 258)”. This embodiment of the past history eliminates the heteroscedasticity as well as autocorrelation.

While analyzing the effects that employee headcount and sales have on innovation, we posited that there also might be other factors that are affecting innovative activity. To eliminate any over estimation of the employee headcount and sales statistic, we included two variables that would provide the best fit for the estimation.

The first variable that we added to the regression was R&D expenditures. Previous studies have shown that there is a direct correlation with R&D expenditures and innovation (Bound, Cummins, Griliches, Hall and Jaffee 1984). We find it necessary to include R&D expenditures in the regression, given our use of patent count as a proxy for innovation.

⁶ There may be a “chicken and the egg” problem that is not explored in this paper: Do revenues create opportunities for more innovation, or does innovation create more opportunities for revenue? We have focused on the former causality at this juncture.

⁷ Engle (1982, 1983) and Cragg (1982) found evidence that for some kinds of data, the disturbance variances in time-series models were less stable than usually assumed. Engle’s results “suggested that in models of inflation, large and small forecast errors appeared to occur in clusters, suggesting a form of heteroscedasticity in which the variance of the forecast error depends on the size of the previous disturbance” (Greene 2000).

⁸ Other research that used the moving average model include Coulson and Robins (1985), Engle, Hendry, and Trumbull (1985), Domowitz and Hakkio (1985), and Bollerslev and Ghysels (1996).

The second variable we included is the ratio of price to book value. The price to book value ratio is a measurement of a firm's market value. We saw it appropriate to control for changes in innovation while measuring the market value of the firm. Because the ratio of price to book value measures the market's valuation of a firm, it provides information on what the market believes each firm is worth as well as the premium the market is willing to pay for the embedded intangible property, including efficiencies, within the firm. Efficient behavior directly impacts a company's value.⁹

The moving-average form is one that embodies the entire past history of the disturbances of the independent variables with the most recent observations, with greater weights given to recent observations versus the distant past (Greene 2003). The form we used for this study differs in that an equal weight is placed on the disturbances. By allowing for this distribution across the disturbances, we can use the average of the independent variable to provide consistent and efficient estimates. This is based on the assumption that past shocks will not vary across time.¹⁰ For example, the effect that R&D expenditures in year $t-3$ has on patent production in year t is not necessarily less than the effect that R&D expenditures in year $t-2$. In fact, one could argue that the effect is greater in year $t-3$ than in year $t-2$. The alternate could be argued for employee headcount. Because of the ambiguity of past shock effects, we applied equal weights across all shocks, which will not affect the consistency of the regression. After taking the average of the variables, we apply an ordinary least squares regression to produce consistent estimates.

The model used in the analysis is as follows:

$$Patents_{i,t} = \beta_0 + \beta_1 \overline{employee}_{i,n} + \beta_2 \overline{sales}_{i,n} + \beta_3 \overline{research}_{i,n} + \beta_4 \overline{book}_{i,n} + \varepsilon_{i,n} \quad (4)$$

Where,

- $Patents_t$ is the number of patents issued in the United States for firm i in year t ;

⁹ Literature shows that public and private information is fully embedded in market value, i.e. stock prices. Efficiency within a firm is included when valuing a firm. References for this topic include Harris & Gurel (1986) and Mitchell & Mulherin (1994).

¹⁰ After performing analysis to measure the effects of the lag variables, the results produced were inefficient and did not provide information on which lag structure would be optimal.

- $\overline{employee}$ is the five-year average of employee headcount for firm i for the period n ;
- \overline{sales} is the five year average of net total sales in firm i for the period n ;
- $\overline{research}$ is the five year average of R&D expenditures in firm i for the period n ;
- \overline{book} is the five year average of price to book values in firm i for period n ;
- β_0 is the intercept and β_1 , β_2 , β_3 , and β_4 are the coefficient estimates; and
- $\varepsilon_{i,n}$ is the error term.

Sections 5.2 and 5.3 explain the results as applied to this model.

4.3 The Relationship between Patent Production and Market Value

Our third analysis focuses on the relationship between innovation and firm market value, using patent production as a proxy for innovation and the price to book value ratio of firms as the measure of market value. As previously stated, measurement of market value provides signals of the embedded intangible property, including efficiencies, of the firm. The efficiency is representative of the firm's management and production capabilities. The price to book value signals the capabilities of the firm.

We posited that increases in patent production might have a positive effect on market value. Our evaluation of the data led to our belief that the dependent variable, the price to book value ratio, fits a non-linear function. Specifically, we applied a semi-log regression to measure the elasticity of the price to book value with changes in patent production. The primary result for the semi-log regression estimate is that it retains its consistency, efficiency, and asymptotic normality.

Because we used a non-linear model, we assumed that there was an underlying probability distribution for the observable y_i and a true parameter vector, β . We use the functional form:

$$\frac{y_i^\lambda - 1}{\lambda} = \alpha + \beta x_i + \varepsilon_i \quad (5)$$

Where y_i is the dependent variable, α is a constant, β is the parameter estimate, and λ is a given value. By applying this form to the study, the model corrects for heteroscedasticity and autocorrelation.¹¹

For our model, the ratio of patents issued in year t to the total patent count per company is regressed against the price to book ratio. This ratio of patent production provides the percentage change of patent production for a given firm in a given year.¹²

The specific model¹³ applied is:

$$\ln book_{i,j,t} = \gamma_0 + \gamma_1 pratio_{i,j,t} + \varepsilon_{i,j,t} \quad (6)$$

Where

- $\ln book_{i,j,t}$ is the natural logarithm of the price to book value for firm i , in industry j , for year t ;
- $pratio_{i,j,t}$ is the ratio of patents issued in year t , divided by total patents for firm i , in industry j ; and
- γ_0 is the intercept and γ_1 is the coefficient estimate for this model.

Section 5.4 presents the results as applied to this model.

4.4 The Relationship between R&D Expenditures and Market Value by Industry

For the final application, we used R&D expenditures as a proxy for innovative activity to determine how market value might be affected. We used the price to book value as a proxy for the

¹¹ A more detailed discussion of how the functional form corrects for heteroscedasticity and autocorrelation is found in Judge et al. (1985), Amemiya (1985), and Davidson and MacKinnon (1993).

¹² The lags of patent counts were not used because research by Mitchell and Mulherin et al. (1994) shows that markets are very efficient. Public and private information instantly impacts the value of a firm. Because of these findings, we believe that the current year's patent production would most immediately impact the price to book value for the given year. Previous years' patent count would be reflected in its respective years.

¹³ For this model, we explored other possible determinants of the price-to-book ratio. These determinants included net sales revenues, operating profit, research and development expenses, earnings before depreciation, shares outstanding, and closing stock price for the year. We found that there were no significant relationship between any of the above determinants and the price-to-book ratio.

intangible value of a firm, as the book value of a firm captures only the value of assets on the balance sheet of a firm, and internally created intangibles would not appear as an asset under generally accepted accounting principles. Therefore, we would expect R&D expenditures to increase the price to book value of a firm, provided the R&D activities were successful in creating intangibles, such as patents, trade secrets, enhanced production processes, etc., that investors would expect to increase a firm's market value in the marketplace. In our regression, we use the ratio of R&D expenditures to total net sales to correct for the relative scale of innovative activity. It also allowed us to eliminate outliers in the data.

Finally, we applied our analysis by industry, as different industries would be expected to have different expected levels of R&D expenditures. This also allows us to compare the relative benefits of R&D expenditures across industries.

We applied a log-linear model for this relationship, which provides consistent and efficient estimates.¹⁴

$$\ln book_{i,t,j} = \varphi_0 + \varphi_1 \ln r_d_sales_{i,j,t} + \varepsilon_{i,j,t}, \quad (7)$$

Where:

- $\ln book_{i,j,t}$ is the natural logarithm of the price to book value for firm i , in industry j , for year t ;
- $r_d_sales_{i,j,t}$ is the natural logarithmic value of the percentage change in R&D expenditures over net sales for firm i in industry j in year t ; and
- φ_0 is the intercept and φ_1 is the coefficient estimate for this model.

Section 5.5 presents the results as applied to this model.

¹⁴ Similar to equation (6), we applied the same determinants to this equation. In our results, none of the determinants had any significant effect on the model.

5. Empirical Results

5.1 Introduction

This section presents the empirical results of the regression analyses presented in the prior section. Full details of our results are provided in the tables and appendices at the end of this report.

5.2 The Relationship between Employee Headcount and Innovation

Coefficient estimates of the independent variables are contained in Table 1, along with the t-statistic. The model controls for employee headcount, sales, R&D expenditures, and the price to book value ratio.¹⁵

Table 1 lists the results. As noted previously, employee headcount, which is based on a five-year average, increases innovative activity in a significant manner. We have evaluated this every year from 2004 to 2006 and have noted a positive relationship in each regression. Moreover, the relationship grew stronger over time.

In 2005 and 2006, increasing average employee headcount by one individual within a small business increases patent production by 0.002. It is important to note that, while this is a small value in itself, it is the significance of the value that matters. First, one must remember that there is great value in the production of one patent, and one also would assume that there also is additional non-patentable but innovative activity that likely goes with the production of a patent.

A study done by Breitzman and Hicks (2008) shows that small firms develop more patents per employee than larger ones. Breitzman and Hick's results differ from our results because their analysis compares smaller firms to large firms.

Other results such as Perline, Axtell and Teitelbaum (2006) and Wallsten (2000) show that increases in employee headcount have a positive effect on innovation. Our results differ in that we

¹⁵ While we are measuring for employee headcount and revenues, it is necessary to include the other variables because they provide a better fit for the model, giving consistent and efficient estimates.

focused only on small firms. Within the sample of small firms, the more employees a firm has, the more patents will be produced.

5.3 The Relationship between Sales and Innovation

Our analysis of the relationship between sales and innovation provided very different results from the preceding section. Specifically, one finds that there is an insignificant effect between sales and patent production, as shown in Table 1.

The model we used for this estimate measured for the lagged effects that sales may have on innovation. However, it did not produce significant results.

One possible reason for this effect is that there is a high degree of variation in sales across firms relative to patent production. While we investigated many different forms of sales relative to patent production, we were unable to find a meaningful correlation within our dataset. If the conclusion that sales do not have a predictable effect on innovative activity is correct, this might imply that innovative activity would be greater in economies pursuing strategies of low unemployment versus high sales growth, *ceteris paribus*. Such a conclusion, however, would require additional research beyond the scope of this paper.

5.4 The Relationship between Patent Count and Market Value

The results of our analysis of patent production on market value for each observed industry are found in Table 2. The results show that patent issuance does not have any significant statistical effect on market value, as measured by the price to book ratio, within any industry.

From a statistical standpoint, these results may imply that market value is driven by factors other than patent count. Particularly because this analysis controls for variations across industries, the results of this conclusion may be that patents might not necessarily create enhanced value for firms. For example, a firm might create patents in order to maintain a competitive position or to block future long-term competition. This type of activity might not generate incremental earnings for a firm but would simply maintain the firm's status quo in an industry. Therefore, the market would not likely pay a premium for such activity.

An earlier study by Lerner (1994) found that there was an increase in a firm's value with an increase in patent scope. While these results examined the breadth of patent protection, our results focused solely on the production of patents.

5.5 The Relationship between R&D Expenditures and Market Value by Industry

The results for our analysis presented in Table 3 show that for the years considered, R&D expenditures in the Industrial Machinery industry had the largest effect on firms' values. Firms in this industry engage in the manufacture of engines and turbines; farm and garden machinery; construction; mining; and oil field machinery; elevators and conveying equipment; industrial trucks and tractors; computer and peripheral equipment; and office machinery. In 2006, for every one percent increase in the percentage change in R&D expenditures to net sales, the price to book value increased by 0.3 percent for a given firm in this industry.

Another industry whose R&D expenditures had a large effect on firms' values is the Mechanical Goods industry. In 2006, for every one percent increase in the percentage change in R&D expenditures to net sales, the price to book value increased by nearly 0.2 percent for a given firm in this industry. The Electronics industry price to book value increased by 0.15 percent and 0.12 percent in 2005 and 2004, respectively.

The Chemicals industry and the Business Services industry did not produce statistically significant results. These two industries produced low coefficient estimates in nearly every year of the study. One can say that because of the low coefficient estimates and the insignificant t-statistics, the Chemicals industry and the Business Services industry does not reward a firm for R&D expenditures in a significant manner.

These results suggest that the relationship between R&D expenditures and market value are industry specific. While we limited our analysis to five industry classifications, we should note that the industries that are typically associated with rapid technological improvements benefit from greater R&D expenditures. Industries with more mature activity or that are service-oriented may not reap as much benefit from greater R&D expenditures.

Other studies that focus on R&D expenditures have shown a positive relationship between government and private sector R&D expenditures and economic growth (BJK Associates 2002).

Klette and Grilliches (2000) found a positive relationship between firm growth and R&D expenditures. While these results show the effects that R&D expenditures have on the economy and firm growth, our results are consistent with the theoretical suggestions that R&D expenditures have a positive impact on firms. The impact that we examine is on firm value.

6. Conclusion

We investigated certain drivers and outcomes of innovative activity among small businesses, which comprise a large part of the U.S. economy. Our analysis of a dataset compiled from large databases demonstrated that increasing employment within small businesses enhances innovative activity, while increases in small business sales do not. There may be many conclusions that we can draw from this interrelationship, including further investigations into how policy should be shaped concerning employment growth versus sales growth when focusing on innovative activity.

We also found that increases in R&D activities enhance the value of small businesses in certain industries. It would seem that R&D expenditures account for a wide assortment of innovative activities and are better measures for capturing value-creating innovative activities than more pinpointed statics such as patent-count.

This paper also leads to many additional topics that would benefit from future research. Such topics include understanding what other industries benefit from enhanced R&D expenditures, finding other metrics to measure innovation, and the relationship between investment in innovative activities and the success of small businesses.

Such questions are beyond the scope of this paper, yet an understanding of such questions would likely be fruitful areas of research to benefit those interested in how small businesses innovate and how innovation affects small businesses.

Table 1: Employee Headcount and Sales Coefficient Estimates

| Variable | 2006 | | 2005 | | 2004 | |
|--------------------|----------|-------------|----------|-------------|----------|-------------|
| | Estimate | T-Statistic | Estimate | T-Statistic | Estimate | T-Statistic |
| Employee Headcount | 0.0028 | 2.38 | 0.00245 | 2.36 | 0.0011 | 1.21 |
| Sales | 0.00162 | 0.86 | 0.015 | 0.81 | 0.00283 | 1.18 |

Table 2: Patent Production Coefficient Estimates for Each Industry

| Industry | 2006 | | 2005 | | 2004 | |
|---------------------------------------------------------------------------------------------------------------|---------------------|-------------|---------------------|-------------|---------------------|-------------|
| | Estimate* | T-Statistic | Estimate* | T-Statistic | Estimate* | T-Statistic |
| Chemicals and Allied Products | -1.73 (0.6564) | -0.26 | 0.2084 (0.8749) | 0.24 | 0.558 (0.4944) | 1.13 |
| Industrial and Commercial Machinery and Computer Equipment | 0.6564 (0.7819) | -0.83 | -1.254 (1.384) | -0.91 | -0.331 (0.75) | -0.44 |
| Electronic and Other Electrical Equipment and Components, Except Computer Equipment | -0.7556 (0.5845) | -1.29 | 1.073 (0.736) | 1.46 | -0.4422 (0.7819) | -0.57 |
| Measuring, Analyzing, and Controlling Instruments: Photographic Medical and Optical Goods; Watches and Clocks | -0.4932 (0.6884) | -0.72 | 2.909 (0.8847) | 0.33 | 0.2909 (0.8847) | 0.33 |
| Business Services | 0.06263 (4.5930) | 0.14 | -0.7551 (0.8232) | -0.92 | 0.0978 (0.6527) | 0.15 |

*Standard errors in parenthesis

Table 3: R&D Expenditures Coefficient Estimates for Each Industry

| Research and Development | 2006 | | 2005 | | 2004 | |
|---------------------------------------------------------------------------------------------------------------|---------------------|--------------------|----------------------|--------------------|----------------------|--------------------|
| | Estimate* | T-Statistic | Estimate* | T-Statistic | Estimate* | T-Statistic |
| Chemicals and Allied Products | 0.0631 (0.3780) | 1.67 | 0.0479 (0.0348) | 1.38 | 0.5287 (0.0318) | 1.66 |
| Industrial and Commercial Machinery and Computer Equipment | 0.3143 (0.0741) | 4.24 | 0.2062 (0.0733) | 2.81 | 0.1826 (0.0570) | 3.21 |
| Electronic and Other Electrical Equipment and Components, Except Computer Equipment | 0.1224 (0.0436) | 2.81 | 0.1534 (0.0588) | 2.61 | 0.1217 (0.0606) | 2.01 |
| Measuring, Analyzing, and Controlling Instruments: Photographic Medical and Optical Goods; Watches and Clocks | 0.1928 (0.0635) | 3.04 | 0.1 (0.0514) | 1.94 | 0.091713 (0.0504) | 1.82 |
| Business Services | -0.0717 (0.0931) | -0.77 | -0.00169 (0.0582) | -0.03 | -0.0797 (0.0746) | -1.07 |

*Standard errors in parenthesis

Appendix 1: Industry Descriptions

Chemicals and Allied Products

This major group includes establishments producing basic chemicals and establishments manufacturing products by predominantly chemical processes. Establishments classified in this major group manufacture three general classes of products: (1) basic chemicals, such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture, such as synthetic fibers, plastics materials, dry colors, and pigments; and (3) finished chemical products to be used for ultimate consumption, such as drugs, cosmetics and soaps; or to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives. The mining of natural alkalies and other natural potassium, sodium, and boron compounds, of natural rock salt, and of other natural chemicals and fertilizers are classified in Mining, Industry Group 147. Establishments primarily engaged in manufacturing nonferrous metals and high-percentage ferroalloys are classified in Major Group 33; those manufacturing silicon carbide are classified in Major Group 32; those manufacturing baking powder, other leavening compounds, and starches are classified in Major Group 20; and those manufacturing artists' colors are classified in Major Group 39. Establishments primarily engaged in packaging, repackaging, and bottling of purchased chemical products, but not engaged in manufacturing chemicals and allied products, are classified in Wholesale or Retail Trade industries.

Industrial and Commercial Machinery and Computer Equipment

This major group includes establishments engaged in manufacturing industrial and commercial machinery and equipment and computers. Included are the manufacture of engines and turbines; farm and garden machinery; construction, mining, and oil field machinery; elevators and conveying equipment; hoists, cranes, monorails, and industrial trucks and tractors; metalworking machinery; special industry machinery; general industrial machinery; computer and peripheral equipment and office machinery; and refrigeration and service industry machinery. Machines powered by built-in or detachable motors ordinarily are included in this major group, with the exception of electrical household appliances. Power-driven handtools are included in this major group, whether electric or otherwise driven.

Electronic and Other Electrical Equipment and Components, Except Computer Equipment

This major group includes establishments engaged in manufacturing machinery, apparatus, and supplies for the generation, storage, transmission, transformation, and utilization of electrical energy. Included are the manufacturing of electricity distribution equipment, electrical industrial apparatus, household appliances, electrical lighting and wiring equipment, radio and television receiving equipment, communications equipment, electronic components and accessories, and other electrical equipment and supplies.

Measuring, Analyzing, and Controlling Instruments; Photographic, Medical, and Optical Goods; Watches and Clocks

This major group includes establishments engaged in manufacturing instruments (including professional and scientific) for measuring, testing, analyzing, and controlling, and their associated sensors and accessories; optical instruments and lenses; surveying and drafting instruments; hydrological, hydrographic, meteorological, and geophysical equipment; search, detection, navigation, and guidance systems and equipment; surgical, medical, and dental instruments, equipment, and supplies; ophthalmic goods; photographic equipment and supplies; and watches and clocks.

Business Services

This major group includes establishments primarily engaged in rendering services, not elsewhere classified, to business establishments on a contract or fee basis, such as advertising, credit reporting, collection of claims, mailing, reproduction, stenographic, news syndicates, computer programming, photocopying, duplicating, data processing, services to buildings, and help supply services.

Appendix 2: Standard & Poor's Compustat – Definitions of Relevant Information

1.1 Employees

Mnemonic: EMP

Units: Thousands

This item represents the number of company workers as reported to shareholders. This is reported by some firms as an average number of employees and by some as the number of employees at year-end. No attempt has been made to differentiate between these bases of reporting. If both are given, the year-end figure is used. This item, for banks, always represents the number of year-end employees.

This item includes:

1. All part-time and seasonal employees; and
2. All employees of consolidated subsidiaries, both domestic and foreign.

This item excludes:

1. Contract workers;
2. Consultants; and
3. Employees of unconsolidated subsidiaries.

1.2 Sales-Net

Mnemonic: SALE

Units: Millions of dollars

This item represents gross sales (the amount of actual billings to customers for regular sales completed during the period) reduced by cash discounts, trade discounts, and returned sales and allowances for which credit is given to customers.

This item is scaled in millions. For example the 1999 annual sales for GM are 173215.000 (or 173 billion, 215 million dollars).

This item includes:

1. Any revenue source that is expected to continue for the life of the company;
2. Other operating revenue;
3. Installment sales; and
4. Franchise sales (when corresponding expenses are available).

Special cases (by industry) include:

1. Royalty income when considered operating income (such as, oil companies, extractive industries, publishing companies, etc.);
2. Retail companies' sales of leased departments when corresponding costs are available and included in expenses (if costs are not available, the net figure is included in Nonoperating Income [Expense]);
3. Shipping companies' operating differential subsidies and income on reserve fund securities when shown separately;
4. Finance companies' earned insurance premiums and interest income for finance companies, the sales are counted only after net losses on factored receivables purchased;
5. Airline companies, net mutual aid assistance and federal subsidies;
6. Cigar, cigarette, oil, rubber, and liquor companies' net sales are after deducting excise taxes;
7. Income derived from equipment rental is considered part of operating revenue;
8. Utilities' net sales are total current operating revenue;
9. For banks, this item includes total current operating revenue and net pretax profit or loss on securities sold or redeemed;
10. Life insurance, and property and casualty companies' net sales are total income;
11. Advertising companies' net sales are commissions earned, not gross billings;
12. Franchise operations' franchise and license fees;
13. Leasing companies' rental or leased income;
14. Hospitals' sales net of provision for contractual allowances (will sometimes include doubtful accounts); and
15. Security brokers' other income.

This item excludes:

1. Nonoperating income;
2. Interest income (included in Nonoperating Income [Expense]);
3. Equity in earnings of unconsolidated subsidiaries (included in Nonoperating Income [Expense]);
4. Other income (included in Nonoperating Income [Expense]);
5. Rental income (included in Nonoperating Income [Expense]);
6. Gain on sale of securities or fixed assets (included in Special Items);
7. Discontinued operations (included in Special Items);
8. Excise taxes (excluded from sales and also deducted from Cost of Goods Sold); and
9. Royalty income (included in Nonoperating Income [Expense]).

1.3 Research and Development Expense

Mnemonic: XRD

Units: Millions of dollars

This item represents all costs incurred during the year that relate to the development of new products or services. This amount is only the company's contribution.

This item includes:

1. Software expenses; and
2. Amortization of software costs

This item excludes:

1. Customer or government-sponsored R&D (including reimbursable indirect costs) ;
2. Extractive industry activities, such as prospecting, acquisition of mineral rights, drilling, mining, etc.;
3. Engineering expense—routine, ongoing efforts to define, enrich, or improve the qualities of existing products;
4. Inventory royalties; and
5. Market research and testing.

This item is not available for banks and utilities.

1.4 Price to Book

Mnemonic: MKBK

Units: Percentage

Price to Book Ratio is defined as Market Value - Monthly divided by Quarterly Common Equity - Total, which represents the common shareholder's interest in the company, including common stock, capital surplus, retained earnings and treasury stock adjustments. (If Common Equity for the current quarter is not available, the values for the previous quarter will be used.)

1.5 Price to Book Fiscal Year End

Mnemonic: MKBKF

Units: Percentage

Price to Book Ratio - Fiscal Year-End is Market Value - Fiscal Year-End (or the close price for the fiscal year) multiplied by the company's common shares outstanding, divided by Common Equity as Reported, which represents the common shareholders' interest in the company.

Appendix 3: References

- Amemiya, T. (1985). *Advanced Econometrics*. Cambridge: Harvard University Press.
- Arrellano, M. & S. Bond (1991). "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations," *Review of Economic Studies*, 58, 277-297.
- Audretsch, D. & Z. Acs (1998). "Innovation in Small and Large Firms: An Empirical Analysis" *American Economic Review*, 78(4), 678-90.
- Audretsch, D. & Z. Acs (1991). "Innovation and Size at the Firm Level," *Southern Economic Journal*, Vol. 57, No. 3, 739-744.
- BJK Associates (2002). "The Influence of R&D Expenditures on New Firm Formation and Economic Growth," *Small Business Administration, Office of Advocacy*, Contract Number SBAHQ-00-M-0491.
- Bound, J., C. Cummins, Z. Griliches, B.H. Hall & A. Jaffee (1984). "Who Does R&D and Who Patents in R&D." *Parents, and Productivity*, edited by Zvi Griliches. Chicago: University of Chicago, 21-54.
- Bollerslev, T., & E. Ghysels (1996). "Periodic Auto-regressive Conditional Heteroscedasticity," *Journal of Business and Economic Statistics*, Vol. 14, 139-151.
- Blundell, R., R. Griffith & J. Van Reenen (1995). "Dynamic count data models of technological innovation," *Economic Journal*, 105, 333-344.
- Breitzman, Anthony & Hicks Diana (2008). "An Analysis of Small Business Patents by Industry and Firm Size," *Small Business Administration, Office of Advocacy*, Contract Number SBAHQ-07-Q-0010.

Cincer, M. (1997). "Patents, R&D, and Technological Spillovers at the Firm Level: Some Evidence from Econometric Count Models for Panel Data," *Journal of Applied Econometrics*, Vol. 12, No. 3, 265-280.

Cragg, J. (1982). "Estimation and Testing in Testing in Time Series Regression Models with Heteroscedastic Disturbances," *Journal of Econometrics*, Vol. 20, 135-157.

Crepon, B. & E. Duguet (1997). "Estimating the Innovation Function from Patent Numbers: GMM on Count Panel Data," *Journal of Applied Econometrics*, this issue.

Coulson, N. & Robins, R. (1985) "Aggregate Economic Activity and the Variance of Inflation: Another Look," *Economics Letters*, Vol. 17, 71-75

Davidson, R. & Mackinnon J. (1993). *Estimation and Inference in Econometrics*. New York: Oxford University Press.

Domowitz, I. & Hakkio, C. (1985). "Conditional Variance and the Risk Premium in the Foreign Exchange Market," *Journal of International Economics*, Vol. 19, 47-66.

Engle, R. (1982) "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica*, Vol. 50, 987-1008.

Engle, R. Hendry, D, & Trumble, D. "Small Sample Properties of ARCH Estimators and Tests," *Canadian Journal of Economics*, Vol. 18, 66-93.

Gourieroux, C., A. Monfort & A. Trognon (1984a). "Pseudo Maximum Likelihood Methods: Theory," *Econometrica*, 52, 68 1-700.

Greene, William A. (2003). *Econometric Analysis: Fifth Edition*. Pearson Education, Inc. Upper Saddle River.

Griliches, Z. (1979). "Issues in Assessing the Competition of R&D to Productivity Growth," *Bell Journal of Economics*, 10, 92-116.

Hausman, J., B. H. Hall & Z. Griliches (1984). "Econometric models for count data with an application to the patents-R&D relationship," *Econometrica*, 52, 909-938.

Hausman, J., B. H. Hall & Z. Griliches (1986). "Patents and R&D: Is There a Lag?" *International Economic Review*, 27, 265-283.

Jaffe, A. B. (1986). "Technological opportunity and spillovers of R&D," *American Economic Review*, 76, 984-1001.

Jaffe, A. B. (1988). "R&D intensity and productivity growth," *Review of Economics and Statistics*, 70, 431-437.

Judge, G, Griffiths, W. Hill, C. & Lee, T. (1985). "*The Theory and Practice of Econometrics*," New York: John Wiley and Sons

Lerner J. (1994). "The Importance of Patent Scope: An Empirical Analysis," Vol. 25, No. 2, 319-333

Loury, G. (1979). "Market Structure and Innovation," *Quarterly Journal of Economics*, 93, 395-410.

Lucas, R. (1978). "On the Size Distribution of Business Firms," *Bell Journal of Economics*, 9(2), 508.

Mairesse, J. & B. H. Hall (1996). "Estimating the Productivity of Research and Development: An Exploration of GMM Methods Using Data on French and United States Manufacturing Firms," *NBER Working Paper 5501*, National Bureau of Economic Research, Cambridge.

Pakes, A, & Z. Griliches (1984). "Patents and R&D at the Firm Level: A First Look," Z. Griliches (ed.). *R&D, Patents and Productivity*, University of Chicago Press, Chicago.

Perline, R, Axtell, P, & Teitelbaum, D. (2006). "Volatility and Asymmetry of Small Firm Growth Rates Over Increasing Time Frames," *Small Business Administration, Office of Advocacy*, No. 285, Contract No. SBAHQ-05-Q-0018,

Pianta, M. & A. Vaona (2006). "Innovation and Productivity in European Industries," *Kiel Working Papers 1283*, Kiel Institute for the World Economy.

Rogers, M. (2000). "Understanding Innovative Firms: An Empirical Analysis of the GAPS," *Melbourne Institute Working Paper Series wp2000n08*, Melbourne Institute of Applied Economic and Social Research, The University of Melbourne.

Scherer, F. M. (1965). "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions," *American Economic Review*, LV , 1097-1125. (b)

Scherer, F. M. (1983). "The Propensity to Patent," *International Journal of Industrial Organization*, 107-28.

Scherer, F. M. (1984). *Innovation and Growth: Schumpeterian Perspectives*. Cambridge, Mass.: MIT Press.

Scherer, F. M. (1991). "Changing Perspectives on the Firm Size Problem", *Innovation and Technological Change: An International Comparison*, edited by Zoltan J. Acs and David B. Audretsch. Ann Arbor: University of Michigan Press, 1991.

Schumpeter, J. A. (1934). *Theory of economic development*. Cambridge: Harvard University Press.

Van Dijk, B. et al, 1997. "Some New Evidence on the Determinants of Large- and Small-Firm Innovation," *Small Business Economics*, Springer, vol. 9(4), pages 335-43, August.

Wallsten, S. (2000). "The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program," *The RAND Journal of Economics*, Vol 31, No 1, 82-100.

Winkelmann, R, & K. F. Zimmerman (1995). "Recent Developments in Count Data Modeling: Theory and Application," *Journal of Economic Surveys*, 9, 1-24.