HOW DO GRANTS INFLUENCE FIRM PERFORMANCE?

AN ECONOMETRIC EVALUATION OF THE SBIR PROGRAM AT NIH

by

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ABSTRACT OF THE THESIS

How Do Grants Influence Firm Performance?

An Econometric Evaluation of the SBIR Program at NIH

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Dr. Andrew A. Toole

This thesis is an econometric study of the impact of Small Business Innovation Research (SBIR) grants awarded by the US National Institutes of Health (NIH). NIH is the largest biomedical research funding agency in the world, investing over $29 billion annually in medical research. The budget of SBIR at NIH reached $558.9 million in 2008. In the current economic environment, NIH administrators are interested in the relationship between their funding and health, economic growth and global competitiveness. This thesis will contribute towards an understanding of this relationship by examining sales and employment growth in firms that received SBIR awards from NIH.

Using this information, all firms are matched to the National Establishment Time-Series (NETS) Database which provides firm-level sales and employment observations, as well as information on other explanatory variables.

The main finding from the thesis is that the NIH SBIR program stimulates both sales and employment growth. Firms that received any number of Phase I and/or Phase II

awards experienced 6.82% greater sales growth, and 6.90% greater employment growth over the three years following the first year they received an award compared to firms that applied to the program but were rejected, controlling for other factors.

Firms that received one or more Phase II awards experienced 6.13% greater sales growth and 7.86% greater employment growth over the three years following the first year they received an award compared to those that applied but were rejected.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1. Introduction

This thesis is an econometric study that investigates the impact of grants awarded through the Small Business Innovation Research (SBIR) program administered by the US National Institutes of Health (NIH) on firm performance. The SBIR program is one of the funding sources at NIH that supports knowledge creation and innovation in biomedicine. NIH is the largest biomedical research funding agency in the world, investing over $29 billion annually in medical research (NIH, 2009). In the current economic environment, NIH administrators are interested in the relationship between their funding and health, economic growth and global competitiveness. This thesis will contribute to an understanding of this relationship by examining sales and employment growth of firms that received SBIR awards from NIH.

The SBIR program was established by the Small Business Innovation Development Act of 1982 and it is the largest government subsidy program intended to foster innovation in small and medium size firms with fewer than 500 employees. Operating under the Department of Health and Human Services, NIH is one of the federal agencies that participate in the SBIR program. Currently, eleven federal departments and agencies participate in SBIR: the Departments of Agriculture, Commerce, Defense, Energy, Education, Health and Human Services, Homeland Security, Transportation, and the Environmental Protection Agency, the National Aeronautics and Space Administration and National Science Foundation. A federal agency must participate in the SBIR program when its extramural research budget exceeds $100 million by setting aside 2.5% of this budget for the program. According to Wallsten (2000), total awards across all participating agencies surpassed $1 billion per year in 2000. NIH reports that its SBIR program granted $558.9 million in 2008 (NIH 2009). According to Wessner (2009), it is the second biggest SBIR-awarding agency after the Department of Defense.

When enacting the SBIR program in 1982, Congress explained its three primary rationales:

> (1) technological innovation creates jobs, increases productivity, competition, and economic growth, and is a valuable counterforce to inflation and the United States balance-of-payments deficit;
> (2) while small business is the principal source of significant innovations in the Nation, the vast majority of federally funded research and development is conducted by large businesses, universities, and Government laboratories; and
> (3) small businesses are among the most cost-effective performers of research and development and are particularly capable of developing research and development results into new products. (Small Business Innovation Development Act of 1982, p. 217)

Focused studies of the US government's efforts to foster technological innovation through the SBIR program are important because of the key role that technological innovation plays in economic growth as well as national and even international competitiveness. Speaking in 1999 at a conference organized by the Board on Science Technology and Economic Policy (STEP), United States Congressman Tom Davis (R-Va.) stated, "…The United States feels the impact both of what happens in other nations' domestic economies and of competition in the international marketplace—competition that is particularly significant in the area of technology (as cited in Wessner, 1999, p.76). Governments around the world, including the US, spend billions of dollars each year to support innovation-related activities. Evaluations of programs like SBIR give policy makers the information they need to maintain the competitive edge of the United States, and make amendments when necessary.

The SBIR program is focused primarily on small firms because they are considered a very important source of innovative talent by the US government. Tom Davis's additional comments at the 1999 STEP conference mentioned above highlighted this:

> Small businesses in general represent an extraordinary pool of competence and talent; [they] have used the…[SBIR] program to identify and develop essential, innovative products not only to their own benefit but to that of the nation, (as cited in Wessner, 1999, p. 77).

He goes on to say that it is crucial for the US government to maintain the constant flow of innovations developed by small businesses and adds, "…The health of the nation's industrialized economy is fundamentally grounded in successfully converting basic research from the laboratory into technological advancements in the marketplace," (as cited in Wessner, 1999, p. 78). He points out that SBIR achieves this goal by giving "…the government and, eventually, the private sector access to talent and leading-edge innovation for which they otherwise might not receive development funding, " (as cited in Wessner, 1999, p. 78). In addition to the superior innovation supplied by small firms, researchers have also noted that small firms contribute to job growth in the US economy, and have other favorable impacts which will be discussed at length in the following chapters.

1.2. The Contribution of this Thesis

Despite the prevalence of these ideas that small businesses are key contributors to technological innovation and the US economy, presently there is very little systematic evidence on the impact of the SBIR program and the evidence that exists is not consistent. The two most important studies in the literature are Lerner (1999) and Wallsten (2000). Lerner (1999) found that companies that receive SBIR funds show employment and sales growth above their matched counterparts. However, he noted that irregularities in the award process exist. On the contrary, Wallsten (2000) reported that SBIR grants did not have any effect on employment but they change the R&D spending behavior of the recipient firms. My thesis benefits from detailed data that was not yet published when prior studies were conducted. The data set includes firm-level observations for all firms (both recipients and rejected) that applied to the SBIR program administered by the NIH from 1994-2005. Using this information, all firms are matched to the National Establishment Time-Series (NETS) Database which provides firm-level sales and employment information, as well as information on other firm level explanatory variables.

The main control group in this study is constructed from firms who applied, but did not receive awards. (I also compared the average sales and employment growth between Phase II recipient firms and Phase I recipient firms.) Previous papers on this topic included eligible firms that did not apply for SBIR grants as part of the control group because the rejected firms' data was not available. Because my data set does not include this "eligible but did not apply" group, it does not have the same problem. Constructing the main control group out of firms that applied, but were rejected, makes sense because it helps to control for unobservable characteristics shared by both the recipients and the control group, such as the entrepreneurial spirit, the eligibility to apply, interest in technological innovation, etc.

Also, my research used a “cohort” design which compares all firms that applied to the program in the same year, some of which did not get awards. This method helps to account for unobserved reasons that led firms to apply to the program for the first time in the same year.

Further, the covariates between recipient firms (called treated firms) and firms that applied but did not receive awards (called control firms) were compared using the Imbens & Rubin (2007) rule of thumb that states, “… with a normalized difference exceeding one quarter, linear regression methods tend to be sensitive to the specifications” (as cited in Imbens and Wooldridge, 2008, p. 19). The covariates used in this thesis satisfy the Imbens and Rubin criterion by a wide margin.

This research responds to the need for effective program evaluation by making use of some of the most recent methods available in the literature. Following Imbens and Wooldridge (2008), under the assumptions of unconfoundedness, overlap and Stable Unit Treatment Value Assumption (SUTVA), regression models will estimate the causal effect of SBIR participation. Unconfoundedness means that there are no unobserved factors that influence program participation or outcomes once all of the covariates have been observed. The detailed NETS data used in this analysis along with the cohort sample design support the validity of this assumption. The overlap assumption means that the values of the covariates for SBIR recipient and non-recipient firms are similar enough to allow for valid comparison. Finally, the SUTVA assumption asserts that the SBIR “treatment” received by one firms does not affect the outcomes for another firm.

The main finding is that the NIH SBIR program stimulates both sales and employment growth. Firms that received one or more Phase I and/or Phase II awards experienced 6.82% greater sales growth and 6.9% greater employment growth over the three years after they received an award compared to firms that applied to the program but were rejected. Firms that received one or more Phase II awards experienced 6.13% greater sales growth and 7.86% greater employment growth over the three years after they received an award compared to those that applied but were rejected. These results are robust across several alternative regression models and different groups of control variables. The most important control variables were venture capital, number of establishments, multi-state locations, paydex index, the firm's sales in the year of application (sales base) and the firm's employment in the year of application (employment base). Different specifications used interaction terms with normalized differences for covariates and the treatment indicator. Using interaction terms revealed the significance of the West, Northeast and South regions of the US. Firms that are in regions West, Northeast and South grow more than Midwest.

This thesis is organized as follows. Chapter 2 presents an overview of the SBIR program, its history and procedures, with a focus on SBIR at NIH. It also explores the existing literature on government funding and SBIR evaluation. Chapter 3 presents the conceptual framework, data and methodologies applied. Chapter 4 describes the statistical evidence for an impact of NIH SBIR grants. A summary of findings and implications appears in Chapter 5.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

The United States has a long history of supporting the entrepreneurial and innovative spirit, particularly in the area of technology. Cohen and Noll (1991) gave the example that in the year of 1836, the US Congress spent $30,000 to support a prototype of Samuel Morse's telegraph. In recent years, even though some politicians claim that they want to lessen the involvement of the government in private markets, they often end up providing generous funding for certain research projects. Cohen and Noll (19991) also discussed the examples of Ronald Regan, who spent federal money on the development of breed reactors, the Space Lab and rocket planes (the Orient Express), and of Gerald Ford, Jimmy Carter and Richard Nixon, who applied billions towards finding a solution to the energy crisis in the 1970s.

Link and Ruhm (2008) presented a well-documented problem in the US Economy during the late 1970s and early 1980s, the downturn in productivity, and mentioned numerous policy programs that were enacted to fight this downturn and to stimulate innovative activity. These programs were the Bayh-Dole Act of 1980, the R&D Tax Credit of 1981, the SBIR Program of 1982 and the National Cooperative Research Act of 1984. It is important to note that SBIR was created in response to the economic conditions in these years.

2.1. Government Rationale for Interaction in R&D

Government interventions in private markets have been widely discussed by economists. The literature that most specifically pertains to the topic of this thesis, governmental support of R&D, begins with Nelson (1959), who established the theoretical background that a socially desirable level of research and development will not be realized by private companies competing with each other for profits. He emphasized the importance of government support of university and nonprofit research, but he did not discuss the idea of direct government interaction in private R&D. Arrow (1962), who also explained that pure private market conditions do not favor innovation, was the first to study government interaction in private innovation. He stated that a free market economy will invest in R&D less than the socially desirable level because of the inherent riskiness of innovation, which he called uncertainty. He noted that larger companies can sometimes absorb the risk of innovation by spreading their research and development out in several small pieces, minimizing the financial risk of any one single project. He went on to say that a company, even if it successfully absorbs the costs of innovation research, will still employ the discoveries of the innovation research much less than the ideal. Another reason that private companies invest in R&D less than optimal level is what Arrow called "inappropriability." This means that firms cannot capture all of the revenues from their R&D investment because a competing firm can easily imitate the product once it is available in the public market. So, because free market conditions do not favor innovation even though innovation has invaluable social benefit, some entity that is not driven by profit should intervene in the innovation process. Arrow (1962) explained that basic research has always been conducted by government bodies, research institutes supported by the government and universities, and there is no expected profit from these research activities. He noted that in some fields, such as agriculture, medicine, defense and aeronautics, government interactions are thought to be appropriate.

Toole and Naseem (2004) provide a three-point summary of the most widely discussed reasons in the literature for government involvement in private R&D. They stated:

> (1) increase industrial competitiveness
> (2) foster economic growth by mitigating market failures in research and innovation markets
> (3) more effectively meet agency specific mission-oriented needs through cost and risk-sharing (p.143).

Clearly, the second point above is most pertinent to this thesis. Toole and Naseem also discussed numerous rationales for private companies to seek government R&D funding. Among these is the reduction of the transaction costs of acquiring know-how and desire to avoid large financial outlays required to create new products.

2.2. Government Rationale for Supporting Small Businesses

Apart from the general rationale for government involvement in the economy, there are specific reasons for the government to pay special attention to small businesses. Van Osnabrugge and Robinson (2000) discussed five different contributions of small businesses to the US economy and society in general, namely: "innovation, employment, a shock-absorber role in declining sectors, increased competition, and flexible specialization," (p. 17). Referring to Wetzel (1982), argued that 50% of the most impactful inventions and innovations of the 20th century in the US originated from small businesses and/or independent investors (as cited in Van Osnabrugge and Robinson, 2000). They also found that small firms reduce unemployment and create jobs, especially by playing a cushioning role to maintaining jobs in declining industries when larger companies are firing large numbers of employees. Further, they saw small firms as effective competition that disciplines large firms for the greater good of society. Lastly, they highlighted the “flexible specialization” of small firms, which translates to the ability to respond more rapidly to changing market conditions than larger firms. In conclusion, they cited Wetzel (1982): “… relative to their larger established counterparts, small technology-based firms are more effective contributors to the generation of new jobs, innovative technology, productivity, price stability and favorable international trade balances” (as cited in Van Osnabrugge and Robinson, 2000, p. 19).

Another set of researchers confirmed the importance of small businesses in innovative activity. Acs, Morck and Yeung (1999) discussed the impact of property rights in large versus small firms, and concluded that when independent innovators or inventors in small firms possess property rights, they have a strong motivation to pursue riskier innovative research. Because of this, small firms are more likely to produce radical innovations.

Despite the evidence of the benefits that small businesses bring to the economy, financial markets for raising investment capital do not always work well for small businesses that need funds to conduct R&D. Czarnitzki (2002) discussed the financial problems that small businesses face when undertaking R&D. He noted that external investors often demand a higher return on R&D investments than a private firm would demand if it had enough money to make the R&D investment itself. He explained that this reluctance is due to information asymmetries, which reflect the difficulties of private investors to understand the potential success of a research project. Toole and Turvey (2007) elaborated on the information asymmetry problem: “While technical and market uncertainties are already high with early-stage technologies, imperfect information exacerbates these uncertainties. This causes external investors to delay their investment until new information arrives,"(p. 3). Czarnitzki (2002) also pointed out the difficulty that small businesses have with sunk costs. A bank or other investor often requests physical collateral for a loan or investment capital, and this type of physical collateral is often unavailable for smaller firms. Cooper (2003) found that there is a lack of funding in the private sector for the beginning R&D stages for small businesses. He stated that, "The SBIR program's Phase I and Phase II grants are often the only source of funding available to new innovative entrepreneurs" (p. 142). The US government recognizes that it should enter the market and satisfy the small firms' need for funding for R&D when it is not available in free market.

2.3. How to Measure the Effects of Government Interaction

David, Hall, and Toole (2000) moved from the question of why government would intervene in private research and development to the question of how to measure the effects of this involvement. They began by discussing the lack of systematic econometric evidence in current studies and the difficulty of comparing alternative studies in the literature. They noted that many studies found contradictory results. Ideally, a policy maker would be able to draw a general conclusion from the academic literature about the effects of government efforts on promote privating innovation and deriving policy direction. David et al. (2000) gave several suggestions for moving the body of academic literature in this direction: use better control variables that capture both cross-section and temporal sources of variation in rates of return; use international panel data; employ propensity score or sample selection methods. They concluded that there is no consensus on the measurable effect after reviewing all of the existing literature on government subsidies for private research and development.

2.4. Government-Supported R&D: Studies of Related Programs from Around the World

The SBIR program is the US example of a broader international phenomenon of supporting private R&D to stimulate innovation. For instance, there are R&D support programs in Israel, Japan, Norway, Spain and Turkey. To place the SBIR program in this broader international context, it is interesting to review studies from these countries. Generally, these studies find mixed results concerning the impact of government involvement in R&D both on the private and social levels. It is clear that the more innovative a country is, the more socially and monetarily wealthy it is.

Klette, Møen and Griliches (2000) discussed a paper given by Griliches and Regev in 1998 which studied the effect of the Israeli government's R&D support programs in the area of manufacturing. Their findings suggested that there are two benefits for the firms that received R&D support from the government. First, the participating firms benefit from having received the government support, and secondly, the R&D investments themselves produce a high rate of return. The authors assumed that when government-supported R&D creates spillovers, there is an additional elevated social benefit. However, the authors discovered a high premium on government-supported R&D projects, and this led them to consider whether the Israeli government supported projects that would have been profitable on their own.

Branstetter and Sakakibara (1998) found that Japanese research consortia in high-tech industries received an average of two-thirds of the cost of the research project from the Japanese government. Some projects were fully funded by the government, while others received subsidies covering less than half of the project cost. The Japanese government in the 1980s and 1990s preferred to support risky cutting-edge consortia projects with a greater uncertainty of outcome. Branstetter and Sakakibara's study focused on understanding whether or not participating in a research consortium increases firm-level funding devoted to R&D and innovation. They found that member firms of research consortia spend more on R&D than non-participating firms and became more productive in R&D. They suggested that there is a spillover effect from being a member of the research consortium and that this spillover explains their increased spending and productivity.

In contrast to the highly successful Japanese programs in the 1980s and 1990s, Klette and Møen (1999) studied the unsuccessful attempt of the Norwegian government to support its information technology (IT) industry during the same time period. The Norwegian government heavily supported the R&D and manufacturing of IT products, spending $620 million over the years 1987-1990. It is important to note that the grants were divided very disproportionately among the recipient firms. For example, 35% of the funds were given to 10% of the recipient firms. Klette and Møen (1999) compared the performance of recipients and non-recipients with eight measures of firm success: man-hour growth, sales growth, returns on assets, profit margin, labor productivity, total factor productivity, investment intensity and intensity in privately financed R&D. According to these measures of success, they did not find significant evidence of increased firm performance improvement for the grant recipient group. Also, the Norwegian IT industry as a whole did not show aggregate growth when compared to other Norwegian manufacturing industries during the time period. Lastly, when measuring the strength of the Norwegian IT industry against the IT industries of other OECD countries, the results were unfavorable. In the Norwegian experience, government support did not show a significant positive outcome for the IT industry.

Looking at the Spanish experience with government-supported R&D, Gonzalez, Jaumandreu and Pazo (2005) tested the R&D behavior of 2000 manufacturing companies. Their research explored the decision making process for companies when they expected government support for R&D or not. They found that generally, R&D spending increased when the firm received government support, but that the Spanish government ended up supporting projects that would have been developed without government support. Also, they found that within small companies, the decision to undertake R&D depends almost entirely on the expectation of government support for that R&D. Their results suggest that while R&D support on average encourages innovative activities, the Spanish government could do a better job selecting projects to support which would not be undertaken without that support.

In addition to these examples from developed countries, the case of Turkey demonstrates how developing economies can create successful industrial policies. Özçelik and Taymaz (2008) measured the Turkish manufacturing industry's response to government support of private R&D. Turkish R&D support programs have taken two forms since the early 1990s. First, the Technology Development Foundation of Turkey, created in 1991, provides interest-free R&D loans. Second, the Technology Monitoring and Evaluation Board of the Scientific and Technical Research Council of Turkey began awarding R&D grants in 1995, which are funded by the Undersecretariat of the Prime Ministry for Foreign Trade. The amount of the grants can be 50% of the participant firm's R&D expenditures. In 2000, the Turkish government's R&D funding had a value of nearly 100 million US dollars. Özçelik and Taymaz concluded that "…Even though overall R&D spending remains quite low in Turkey as compared to developed countries and subsidies account for less than 10% of all R&D expenditures, public R&D loans and grants are still conducive to private R&D investment" (p. 271). They also found that smaller firms in Turkey tend to more readily take advantage of R&D subsidy programs and demonstrate a greater rate of R&D investment.

2.5. Motivating Factors Leading to SBIR Creation

In order to understand why the United States government created the SBIR program, we should start by examining the acts which created and reauthorized the program. The SBIR/STTR Reauthorization Act of 2008 stated that "the federal SBIR program was created more than 25 years ago out of growing concern since the 1960s that, despite the increasing prominence of small businesses in innovation, federal research and development expenditures had disproportionately been awarded to large businesses" (p. 3). According to Wallsten (1998), science and technology support programs at the Federal level either try to further investigation in a certain research area or try to raise the total level of scientific research in the economy in general. In contrast, SBIR tries to differentiate the combination of the federal support depending on who will receive it. SBIR assures that small businesses will enjoy part of federal R&D support.

The Small Business Innovation Development Act of 1982 that established the SBIR program described the purpose of the program as:

> … to strengthen the role of the small, innovative firms in federally funded research and development, and to utilize Federal research and development as a

> base for technological innovation to meet agency needs and to contribute to the growth and strength of the Nation's economy (p.217).

Congress went on to explain its rationale for the Small Business Innovation Development Act (1982), stating first that technological innovation impacts job creation, production, competition and thus the overall growth of the economy and the reduction of inflation. Second, Congress explained that even though small businesses are excellent innovators, the large share of government-supported R&D goes to large companies and public universities and laboratories. Third, Congress stated that R&D conducted by small firms is the most cost-effective and that small firms are particularly inclined to commercialize the results of their R&D.

2.6. SBIR Legislative History

The SBIR/STTR Reauthorization Act of 2008 contained a brief summary of SBIR's legislative history. According to this document, the initial legislation authorized SBIR for six years, from 1982 to 1988, and because of the program's popularity, Congress extended it in 1986 for seven years, to 1993. In 1992, Congress again turned its attention to SBIR with a different perspective after ten years of operating the program. The NSF Assessment of SBIR (2008) explained that the 1992 reauthorization bill highlighted the importance of commercialization of technologies developed with SBIR funds. In contrast to the initial act, the 1992 amendments made commercial viability an explicit criterion for Phase I awards. Similarly, Congress directed those reviewing Phase II applications to include the possibility of the applicant receiving private third-party funds in addition to the SBIR award, and to review the applicant's history of commercialization. From that point forward, agencies were required to incorporate third-party funding commitments along with other signs of commercial potential when evaluating applications for SBIR Phase I or Phase II awards.

Archibald and Finifter (2003) studied the effects of this increased emphasis on commercialization as it pertains specifically to the SBIR program at NASA. Their research suggests that the NASA SBIR program did increase its emphasis on commercial successes, but that this increase came at a high cost: basic research support was decreased. They cautioned that the commercialization aspect of SBIR, "… is a short-sighted policy. The benefits of research at government laboratories will go up in the short run, but they may go down in the long run" (p. 618).

The SBIR program was reauthorized in 2000 and was supposed to be reauthorized again in 2008. Currently, the SBIR program is operating under temporary extensions and has not been reauthorized. There is a lot of disagreement and debate about the role of venture capital firms in the program.

2.7. Goals and Impact of the SBIR Program

The Small Business Innovation Development Act of (1982) stated several specific goals for the SBIR program:

> (1) to stimulate technological innovation;
> (2) to use small business to meet Federal research and development needs;
> (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and
> (4) to increase private sector commercialization of innovations derived from Federal research and development

In addition to these official goals, numerous "indirect" impacts of the program have been noted. Cooper (2003) provided and extensive discussion of these unofficial effects. He highlighted Lerner's "certification effect" in which an SBIR award plays a role in attracting private investors. Lerner (1999) discovered that those companies that received government funding have better chances to find venture capital in the future. So, in effect, receiving an SBIR grant "certifies" that the company is a worthwhile investment for venture capital firms. Toole and Turvey (2009) developed a two-stage net present value model of a new technology in order to understand how initial government investment changes the incentives for follow-on private investment. Using data on SBIR recipient firms, they also found evidence supporting a certification effect.

Audretsch, Weigand and Weigand (2000) mentioned several additional indirect effects based on their small study of SBIR in Indiana. While they recommended that their findings be confirmed by a larger test, their preliminary conclusions are fascinating. In their study

1. A significant number of the firms would not have been started in the absence of SBIR.
2. A significant number of the scientists and engineers would not have become involved in the commercialization process in the absence of SBIR.
3. A significant number of other firms are started because of the demonstration effect produced by the efforts of scientists to commercialize knowledge.
4. As a result of the demonstration effect by SBIR-funded commercialization, a number of other scientists alter their careers to include commercialization efforts (p. 161).

Building on the research of Audretsch et al. (2000), Toole and Czarnitzki (2007) examined the role of the SBIR program in fostering faculty (or academic) entrepreneurship. They analyzed a sample of NIH-supported academic biomedical scientists who commercialized their research using the SBIR program. They pointed out two features of the SBIR program that facilitate entrepreneurship. First, the SBIR program offers early stage financing for promising, but unproven technologies. Second, the SBIR program requires the academic scientists to commit 51% of their time to commercialization which insures their active involvement. They found that the academic scientist-led firms in the SBIR program performed better than non-academic-led firms.

Duncan Moore, speaking as a recipient of SBIR grants from the Department of Defense and the National Science Foundation at the 1999 STEP conference, noted the strength of the small business community in providing jobs to the US economy. He cited Small Business Administration statistics demonstrating that, "… companies with fewer than 500 employees contributed 10.5 million jobs to the US economy from 1991 to 1995. In the same time period, employment in companies with more than 500 employees fell by 3.2 million," (as cited in Wessner, 1999, pp. 39-40). The SBIR objective to support the innovative activities of small businesses also indirectly supports the ability of small businesses to hire and retain employees.

2.8. Eligibility for the Program and Application Process

To be eligible for an SBIR grant, a firm must be at least 51% American-owned, operate for profit, and must have fewer than 500 employees. Grants are awarded in three phases: the feasibility study phase, the product development phase, and the commercialization phase. Phase I, testing the feasibility of the proposed idea, is the starting point for all applicants and lasts between six and twelve months. Phase I awards run between $100,000 and $150,000. There is typically a high rate of failure in Phase I, but if the results are positive, a firm is eligible to apply for a Phase II product development grant. Phase II grants can be as much as $750,000 over a two-year period. In the third and final phase, the recipient must commercialize their product without any further SBIR funding. At the end of Phase II, it is expected that a firm will receive follow-on private financing from sources such as venture capital funding to take their product to the market.

According to the National Research Council (NRC) assessment of the SBIR program at the NIH (2009), each NIH agency collects a list of problematic areas in need of creative technological solutions on an annual basis. The agencies publish "solicitations" on these R&D topics. Small businesses can then choose from among these solicitations and submit a proposal; the format of the proposal varies from agency to agency. The NIH agencies each have different systems for evaluating these SBIR proposals, and also for selecting the grant recipients.

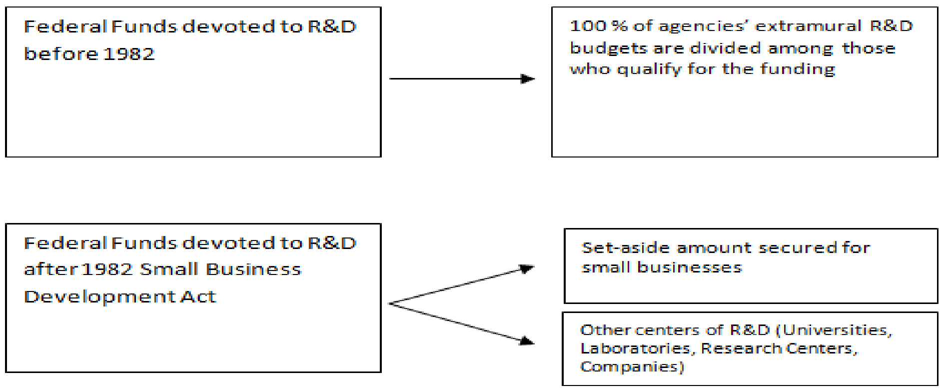
2.9. How SBIR is Funded

Wallsten (2000) summarized how SBIR is funded: "SBIR has no budget, per se. Instead, certain federal agencies are required to set aside a percentage of their extramural (contract and grants) R&D budgets for the program. This set-aside percentage increased in FY 1997 by 25 percent to 2.5 percent of an agency's extramural budget, meaning that SBIR funding will exceed $1 billion per year, making it the largest federal technology program aimed at product commercialization"(p. 194). The original set aside amount was 1.25%; by increasing this percentage, the government gave small businesses a bigger share of the overall R&D opportunities. When the program was reauthorized in 2000, there was no alteration to this set-aside budget.

By creating this funding set-aside, the US government found the funds to support small businesses without having to create a new budgetary item for the program. To visualize the process before and after SBIR was created, we can examine Figure 1 below.

The budget set-aside was a clever way for the US government to find the funding to support innovation in small businesses.

Figure1: Changes in R&D Budget Diversification after 1982



Source : Author

2.10. The National Institutes of Health and the SBIR Program

NIH was founded in 1887, and since then has grown to include 27 different institutes and centers. NIH states its mission as follows:

> … foster fundamental creative discoveries, innovative research strategies, and their applications as a basis to advance significantly the Nation's capacity to protect and improve health; develop, maintain, and renew scientific human and physical resources that will assure the Nation's capability to prevent disease; expand the knowledge base in medical and associated sciences in order to enhance the Nation's economic well-being and ensure a continued high return on the public investment in research; and exemplify and promote the highest level of scientific integrity, public accountability, and social responsibility in the conduct of science (NIH, 2009).

The budget of NIH is currently over $29 billion per year. NIH spends the majority of its budget on grant-giving to various research bodies such as universities, medical schools, and laboratories throughout the United States and around the world. Under the set-aside criteria of SBIR, the budget of SBIR at NIH reached $558.9 million in 2008 (NIH, 2009).

In contrast to the general research mission of NIH as a whole, the NIH SBIR program focuses on commercialization. As the NRC assessment (2009) indicates, "… Most NIH programs generally do not seek to develop products and services for the marketplace. The SBIR program does,"(p. 3). Link and Ruhm (2008) highlighted the importance of product development out of the NIH SBIR program: "…Commercialized technologies that result in improvements in health are particularly likely to have high rates of return (social and private)"(p. 3). The social return on products developed through SBIR at NIH may be higher than the social return of products developed through other agencies' SBIR programs, such as DoD and NASA, that routinely purchase the products that were developed in their own SBIR programs.

2.11. SBIR Studies

There are several published studies that attempt to evaluate the impact of SBIR grants. Audretsch (2003) analyzed the SBIR program to determine why SBIR became an important policy tool. He believed the answer has to do with globalization: developed countries lose their comparative advantage by having an expensive workforce. As a result, most developed countries have faced corporate downsizing and have moved their manufacturing facilities to lower cost geographies. This leads to increasing unemployment in the developed country. SBIR helps to solve this problem and to regain the lost comparative advantage as that comes from globalization. Audretsch expressed in his paper that SBIR reached its stated goal to help high technology small firms play a significant role in rebuilding the competitiveness of the United States.

In another study, Audretsch, Link and Scott (2002) did not discuss the usefulness of the SBIR program, but they emphasized the program's outcomes from grants and contracts awarded by the Department of Defense (DoD). According to Cahill (2000), their data was collected by the National Academy of Sciences (NAS) and consists of 112 responses to a survey mailed to 379 companies that received a Phase II SBIR grant from the DoD between 1992 and 1996. In their statistical analysis, their model was

$$ActSales_i = f(\mathbf{X_i})$$

where ActSales stands for actual sales which came from the project that received a Phase II award, measured in dollars, and *X* stands for independent variables related to each firm. Because their dependent variable ActSales in 78 cases out of 112 total respondents had a value of 0, they were not able to use an ordinary least squares method for estimating their model. Instead, they used the Tobit to model the value of sales that can be attributed to the SBIR grant. They concluded that SBIR, in its specific relationship with the DoD, meets its mission. It enhances both technological innovation and private industry commercialization that come from federal R&D grants.

Lerner's (1999) argued that although researchers have published studies on government involvement in private research and development in general, government interaction with the research and development efforts of small firms had not been studied extensively prior to his work in 1999. Lerner said that government grants to subsidize small high technology firms have two motivations: First, social returns that may come from firm's R&D investments will be greater than the firm's private return. Social returns often come in the form of spillover effects such as the profit enjoyed by a competing company that introduces a “me too” product or complementary product. Secondly, by giving a grant, the government may play a matchmaking role between small technology firms and private venture capitalists.

Lerner did not have continuous annual data, but instead compared the employment and sales growth of Phase I and Phase II recipients and their respective control groups (1435 firms in total), using two separate years, 1985 and 1995. Lerner worked with data generated by the Government Accounting Office (GAO), a sample of 933 firms that received SBIR awards from 12 participating agencies. This group consisted of firms that received Phase II awards and also firms that only received a Phase I awards. The GAO surveyed this group of 933 in 1986 and 1988, and after being surveyed, 835 firms responded. Out of these 835 firms that answered, 541 received Phase II awards, and 294 received Phase I awards. Lerner’s “treated” group consisted of the 541 Phase II recipients, and he reserved the 294 that received only Phase I awards as a “control” group. He also constructed two additional control groups matched to Phase II recipients using the Corporate Technology Information Services’ Corporate Technology Directory (1996). The first group included firms with the same industrial classification code and the same sales level as the Phase II recipients. The second matching group included firms in the same geographic location with similar sales levels to the Phase II recipients. Both matching groups had 300 firms. His final sample looked like this: 541 Phase II awardees from the GAO survey, 294 matching firms from the survey that received Phase I awards and the two matched groups of 300 firms from the Corporate Technology Directory. After constructing the data sample he compiled the sales and employment figures for both Phase II recipients and matching firms in the year 1995.

Lerner started his analysis using mean comparisons between the Phase II recipient group and the control groups. His basic findings showed that recipient firms have greater average sales and employment growth than matching firms between 1985 and 1995. Later he used same analysis to compare venture capital activity between regions. Then he moved to regression analysis using OLS to test the SBIR grant effect. His model was

$$\Delta sales = f(\boldsymbol{X_i}) \quad \text{and} \quad \%\Delta sales = f(\boldsymbol{X_i})$$

$$\Delta employment = f(\boldsymbol{X_i}) \quad \text{and} \quad \%\Delta employment = f(\boldsymbol{X_i})$$

where X stands for his independent variables that includes sales and employment figures in 1985, a dummy variable depending on whether or not a firm received a Phase II award, a dummy variable about venture capital activity in a firm's geographic area, and an interaction term between the award dummy variable and the venture capital activity dummy variable. With this model he concluded that the effect of receiving an SBIR award is limited to employment and sales growth. Then he used median regression to eliminate outliers' effect, and as a result of this, the differences between sales and employment for awardees and matching firms became more significant.

After this, he employed another OLS model using sales and sales percentage change as a dependent variable and as independent variables he chose 1985 sales figures, a dummy variable indicating whether or not a firm received a Phase II award, a dummy variable about whether the geographical region had an above-average level of venture capital financing activity between the years 1983 and 1985, and an interaction term between the last two. He calculated his regressions under several assumptions, firstly overlap, meaning that his control groups and his recipient groups were similar enough to compare. Secondly, he also assumed unconfoundedness, meaning that there were no unobservable factors affecting the dependent variable. His last assumption is that the benefits of receiving an SBIR award were only experienced by the award recipient firm, in other words, the Stable Unit Treatment Value Assumption (SUTVA). His results suggested that the difference in sales growth between the recipient group and the matched group was more pronounced in states with an above-average level of venture capital activity.

Lerner went on to test for the interaction between "certification effect" and the tendency of government officials to give awards to visible projects regardless of whether or not the project would be funded privately. To test the certification effect, he re-estimated the first OLS model described above, but divided the sample into two groups. For sales growth, he divided his firm-level sample at the median of the industry ratio of intangible to total assets. Similarly, for the employment dependent variable, he divided his firm-level sample at the median of the industry ration of average R&D spending to sales. He estimated separate regressions for firms above and below these industry medians. He rejected the null hypothesis that there is no difference between SBIR recipients and rejected firms for both regressions, suggesting that there was a certification effect by SBIR to the participating firms. He also tested the effect of a firm receiving multiple SBIR awards using this same regression model with a new dummy variable indicating the receipt of more than one Phase II award, and an interaction term between this new dummy and the value of venture capital in the zip code where the firm is located. He found that the receipt of more than one SBIR award had little effect on recipients. Similarly, he also looked at the correlation between a firm being an SBIR recipient and the firm's likelihood of receiving venture capital. His univariate comparison showed that the probability of receiving first time venture capital funding increased after a firm received an SBIR award. Then, he used a Logit model to estimate the probability of an SBIR recipient's chance to capture venture capital. His results showed that the likelihood of securing venture capital for a non-recipient was 0.8%, but for an SBIR recipient, this increased to 3.1%.

So, in conclusion, Lerner found that firms that received government grants showed increases in employment and sales compared with firms that did not receive grants. He also noted that recipient firms experienced a boost in the possibility of receiving private venture capital after being an SBIR recipient. However, these positive effects were limited to recipient firms in geographic regions where there is significant venture capital activity, and multiple awards did not increase performance. Also, the greater amount of the subsidy did not lead to greater performance in a recipient firm. His study also supported irregularities in the award process.

Another important SBIR study done by Wallsten (2000) began by describing the government's rationale for subsidizing commercial R&D: private enterprises do not invest in R&D at a desirable level. He argued that government funding truly leads to enhanced R&D efforts only when that funding supports a project that would otherwise produce a financial loss. He noted that most attempts to measure the outcome of government regress some aspect of innovation or productivity on the award. This approach may detect a link between government grants and firm-level R&D, but it cannot tell us the direction of causality. SBIR grants may lead to increased R&D in the recipient firm or recipient firms that invest more in R&D may be awarded more grants from SBIR.

Wallsten agreed with the common concept that the economic rationale for government subsidy programs is to support research with a high value to society, but low profitability. The government's role in this is to lower the expenses of the companies conducting the R&D, thereby making these projects privately feasible. Wallsten tried to understand if the SBIR program behaves according to this rationale by supporting research projects that produce benefits for society, but are privately cost-prohibitive.

He documented that the SBIR program does not act according to the rationale stated above. Instead, he found that the funding goes towards projects where concrete commercial success is feasible. These findings led him to design econometric tests to determine if SBIR grants encourage innovation in recipient companies. He also cautioned that since being chosen for a grant may be related to a firm's already existing R&D activity, any econometric test of the impact of subsidies on firm R&D should control for the agency's decision concerning which projects to select.

Wallsten's group of recipient firms consisted of 367 firms that won at least one Phase I award between 1990 and 1992. He constructed his control group from 90 firms that applied to NASA and DoD, but were rejected, and added 22 additional firms taken from Compustat that did not apply to SBIR, but had the same industrial classification and size as the recipients and therefore were eligible to apply. Wallsten's data set was not ideal. Even though Wallsten's study addressed SBIR awards from the eleven participating agencies, his rejected group only came from two federal agencies, and the rejected firms from the nine other agencies that participated in SBIR are not represented. Additionally, Wallsten's eligible firms that did not receive awards were all publicly traded, but this was not a characteristic of the overall population of eligible firms. Also, the proportion of Wallsten's award winners to rejected firms to eligible firms is not representative of the actual population.

He first used an OLS model that regressed employment on awards with a set of control variables. In his OLS model,

$$Employment = f\,(\textbf{\textit{subsidy, X, Z, G}})$$

he used log of employment in 1993, subsidy stands for number of Phase II awards, X is a vector of firm characteristics such as minority owned, firms' age, and so on, Z is a vector of industry dummies, and finally, G is vector for four geographic regions. His OLS results showed that more Phase II awards led to more employment in recipient firms. Nevertheless, his OLS regression does not account for endogeneity in the award selection process.

In order to account for endogeneity in the award process, he employed a three-stage least square system of equations which instrumented the endogenous award variable, using the "potentially awardable budget" (see below for a description) as the instrumental variable as follows:

$$Phase\ I\ awards = f\,(\textbf{X, Z, G, budget})$$

$$Phase\ II\ awards = f\,(\textbf{X, Z, G, budget})$$

He chose as his key instrumental variable the "potentially awardable" portion of the Federal SBIR budget which was available to be granted to a firm depending on the type of R&D that it performed. Stock and Watson (2006) supplied the two conditions necessary for an instrumental variable to be valid: first, "instrument relevance," that the instrumental variable should be correlated with the endogenous award variable and second, “instrument exogeneity,” that the instrumental variable be uncorrelated with the error term. Wallsen’s “potentially awardable budget” satisfies these two requirements.

Since the award process happens in stages over time, a simultaneous equation system also allowed Wallsten to capture the resulting change in the recipient firm’s behavior. An additional benefit of the 3SLS system is that it accounts for error correlation among the equations. Using this method, he discovered that the more employees and patents a company has, the greater its likelihood of receiving an SBIR grant, even though receiving an SBIR grant did not seem to enhance employment levels in the company. He also found results that indicated that SBIR awards crowd out a company’s financing of R&D at a ratio of one to one.

One possible interpretation Wallsten offered was that SBIR grants had essentially no effect on a recipient firm’s R&D. He added that it was possible to interpret his findings in another way, that while an SBIR grant did not increase a firm’s level of R&D, it may have allowed the firm to continue or not cut back on existing R&D projects.

CHAPTER 3: CONCEPTUAL FRAMEWORK AND DATA

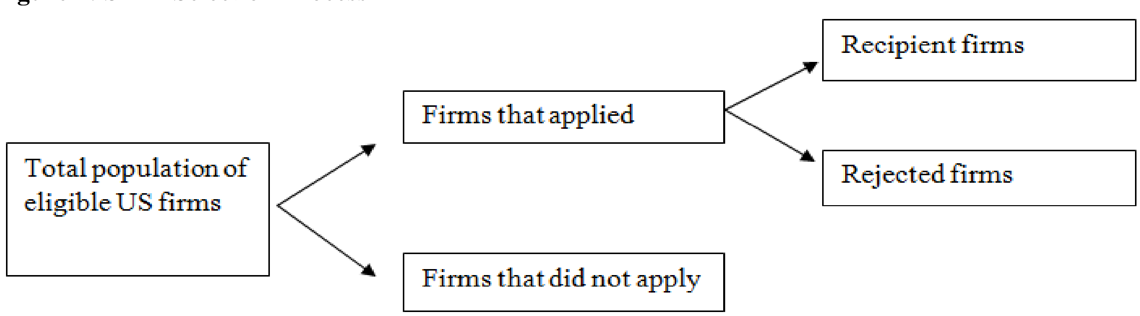
3.1. The Evaluation Problem

This research will use econometric methods commonly applied in the field of labor economics to evaluate the NIH SBIR program. These methods, discussed by Angrist and Krueger (1999), Blundell and Dias (2002) and others, were developed to measure the effect of training programs on employment outcomes for those individuals who participated in the job training. In my research, receipt of an SBIR grant will indicate participation in the SBIR program. This simple redefinition allows the econometric methods for program evaluation to be applied directly to technology programs such as my application to the SBIR program administered by the NIH.

For many social programs the choice of who participates is not made through random selection. This complicates the analysis of program effects. If SBIR grants were randomly assigned, the receipt of grants would not be systematically related to any of the characteristics of the recipient firms. Standard statistical methods could be applied as with randomized clinical trials used to evaluate new medicines. However, SBIR grant awards are not randomly assigned. For instance, all applications to the NIH SBIR program undergo peer review to evaluate the merit of the proposed research. Subject to a budget constraint, only those applicant firms with the “best” project applications will be awarded SBIR grants. Non-random selection requires additional assumptions in order to estimate the effect of the SBIR program and these are described below.

Figure 2 below illustrates the various stages of selection that occur in the SBIR program. The first box identifies the broadest population of firms relevant to the SBIR program. This group consists of all firms that meet the eligibility requirements and are potential applicants and recipients in the SBIR program. The second set of boxes show the "first-level" of non-random selection. Firms self-select into the groups of SBIR program applicants and non-applicants. There could be many reasons underlying a firm's choice to apply to the SBIR program, but data limitations prevent me from addressing first-level selection in this thesis. Among the second set of boxes, the top box in Figure 2 shows the population of SBIR applicant firms. This thesis studied a subpopulation of these applicant firms. Specifically, it examined all applicant firms to the NIH SBIR program, which is the second largest of the eleven Federal Agencies that administer the SBIR program. As the third set of boxes illustrates, applicant firms are further divided into program recipients (firms that received a grant) and non-recipients (firms whose applications were rejected and did not receive a grant). This "second-level" selection results from the screening process of the SBIR agency. In order to draw conclusions about how SBIR grants influence outcomes among the subpopulation of NIH applicant firms, the influence of NIH screening process must be purged.

Figure 2: SBIR Selection Process



Source : Author

A second challenge in program evaluation, regardless of whether a program uses random or non-random selection, is a missing data problem. Speaking to this missing data problem, Blundell and Dias (2002) write,

> At the heart of this kind of policy evaluation is a missing data problem since, at any moment in time, an individual is either in the program under consideration or not, but not both. If we could observe the outcome variable for those had they not participated then there would be no evaluation problem of the type we discuss here, (p.92).

Ideally, we would observe the outcomes of interest for each program recipient in two different circumstances. First, we would observe the outcomes after a firm has participated in the SBIR program. These data are available. Second, we would observe the outcomes of this same firm in the counterfactual situation of not receiving an SBIR grant. In effect, this second set of data on outcomes for each recipient firm is missing.

Table 1: The Fundamental Problem of Casual Inference

Potential Outcome	Y_1	Y_0
Group		
Treatment Group (D=1)	Observable as Y_1	Counterfactual
Control Group (D=0)	Counterfactual	Observable as Y_0

Source: Morgan and Winship (2007)

Following Morgan and Winship (2007), we can visualize the missing data problem in program evaluation using Table 1 above, where Y is defined to be the variable representing the outcome such as sales or employment growth. Define D as the program participation indicator so that D=1 means the firm received an SBIR grant and D=0 means the firm did not. If the firm participates in the SBIR program (D=1), we observe the outcome Y_1 For this same firm, there is a counterfactual outcome that is not observed, Y_0, which would be the firm's sales or employment growth if it had not received and SBIR award (D=0). The outcome we actually observe can be written as:

(1) $$Y=DY_1 + (1-D)Y_0$$

Before discussing the assumptions that allow estimation when faced with non-random selection and missing data, it is important to first define the program effect to be estimated. In the program evaluation literature, different quantities are estimated depending on the population or subpopulation of interest. The most common quantity is called the "Population Average Treatment Effect" (PATE). This quantity measures the average effect of participating in the program on any randomly picked firm from the population. As Imbens and Wooldridge (2009) state, PATE is most interesting "if the policy under consideration is a mandatory exposure to the treatment versus complete elimination" (p. 16). Using the notation introduced above, PATE is:

(2) $$PATE = E[Y_1 - Y_0]$$

Another quantity of interest is called the "Population Average Treatment on the Treated" (PATT). This is the effect of the program on those firms that participated. PATT is considered the most interesting quantity when considering a voluntary program that will never require participation by all firms. PATT can be represented as:

(3) $$PATT = E[Y_1 - Y_0 \mid D = 1]$$

While PATT is the most interesting quantity for studying the effect of the SBIR program, the assumptions used throughout most of the thesis imply PATE and PATT are equal.

3.2. The Econometric Assumptions and Model

The main assumption needed to eliminate potential bias from non-random selection and missing data is called "unconfoundedness" (Imbens & Wooldridge, 2009). They state "… it assumes that beyond the observed covariates X_i , there are no (unobserved) characteristics of the individual associated both with the potential outcomes and the treatment," (p. 26). This assumption can be represented as:

(4) $$D_i \perp (Y_{1i}, Y_{0i}) \mid X_i$$ where *i* represents the firm

This means that we can observe enough information as represented by the explanatory variables, X_i, such that the potential outcomes for firm i, (Y_{1i}, Y_{0i}), will be independent of that firm's selection into the SBIR program, D_i.

In the context of this thesis, this assumption has two important implications. First, it implies that private information used by the NIH peer review committees does not have any additional influence on both SBIR award selection and commercial success after the observable characteristics of the firm are taken into account. This assumption might be violated if SBIR applications reveal something about the firm's quality that is not already captured by the other covariates, but this unobserved quality would need to influence *both* SBIR selection and the outcomes. For instance, the scientific or technical merit of a proposal, which is unobserved outside the review process, is likely to be positively correlated with the decision to award an SBIR grant. However, even though the technical merit of the proposal influences the probability of award, there is no evidence that technical merit is correlated with commercial success. Second, it implies that the counterfactual outcome for the SBIR recipient firm, Y_0, can be estimated using data from a control group of similar firms that did not participate in the SBIR program.

To assure the comparability of SBIR recipients (treatment group) and non-recipients (control group), two additional assumptions must be added to the unconfoundedness assumption. The first of these is called "overlap" and relates to the values of the explanatory variables. This assumption requires that for every SBIR recipient firm, there is a non-recipient firm that shares the same distribution of the explanatory variables. Neither PATE nor PATT can be calculated unless there is a non-recipient firm in the control group with similar characteristics to the SBIR recipient. The second assumption is called the Stable Unit Treatment Value Assumption (SUTVA). Morgan and Winship (2007) explain that SUTVA "is a basic assumption of causal effect stability that requires that the potential outcomes of individuals be unaffected by potential changes in the treatment exposures of other individuals" (p. 37). In other words, SBIR grants do not have any spillover effects on the outcomes of other firms in the population.

With these assumptions, regression analysis can be used to estimate PATE and PATT for SBIR recipient firms. Based on Imbens and Wooldrige (2009) and Wooldridge (2002), two types of regression models are estimated in this thesis. To understand the regression models, assume the potential outcomes introduced above, Y_1 and Y_0, can be decomposed into the sum of their means and an unobserved random component with zero mean:

(5) $$Y_1 = \mu_1 + \upsilon_1 \qquad E[\upsilon_1] = 0$$

(6) $$Y_0 = \mu_0 + \upsilon_0 \qquad E[\upsilon_0] = 0$$

Plugging these into the observed outcome for a firm in equation (1) gives,

(7) $$Y = \mu_0 + (\mu_1 - \mu_0)D + \upsilon_0 + (\upsilon_1 - \upsilon_0)D$$

The observed outcome for every firm given in equation (7) has four parts. The first part is its outcome without an SBIR grant. The second part is PATE, the contribution from participation in the SBIR program that is common across all firms. The third part is the firm's idiosyncratic component in the circumstance of not participating in the SBIR program. The fourth part is the firm-specific gain from participation in the SBIR program. With this formulation, PATT is the sum of PATE and the firm-specific gain when the firm participates in the SBIR program:

(8) $$PATT = PATE + E[\upsilon_1 - \upsilon_0 \mid D = 1]$$

In the first regression model used in this thesis, I assume that the expected firm-specific gain from participation in the SBIR program is zero, conditional on the explanatory variables. This means the second part of equation (8) above is zero and that PATT equals PATE:

(9) $$E[\upsilon_1 - \upsilon_0 \mid X] = E[\upsilon_1 \mid X] - E[\upsilon_0 \mid X] = 0$$

(10) $$PATT = PATE$$

Based on equation (7) the regression model for firm i can be written as:

(11) $$Y_i = \beta_0 + \alpha D_i + \mathbf{X_i}\boldsymbol{\gamma}$$

Using ordinary least squares on a random sample provides a consistent estimator of alpha, α , which is the SBIR program effect, both PATE and PATT. The vector of explanatory variables, $\mathbf{X}_i$, is called a "control function" and is a model of the idiosyncratic component υ_0. It guarantees that enough control variables have been included such that the SBIR program selection indicator, D, and any unobservables affecting potential outcomes (Y_1, Y_0) are appropriately unrelated. The variables in **X** are acting as proxy variables for the unobservables.

A second regression model relaxes the assumption made in (9) that the expected firm-specific gain from participation in the SBIR program is zero, conditional on the explanatory variables. Without this assumption, PATT is no longer equal to PATE, but a regression model can still be used as long as $E[v_1]$ and $E[v_0]$ are deterministic functions of the observed explanatory variables. In this case the regression equation becomes:

(12) $$Y_i = \beta_0 + \alpha D_i + \mathbf{X_i}\boldsymbol{\gamma} + D_i(\mathbf{X_i} - \bar{\mathbf{X}})\boldsymbol{\delta}$$

Using OLS provides a consistent estimator of alpha, α , which is the SBIR program effect PATE.

3.3. Data

3.3.1. General Data Description

This thesis used data on firms that applied to the NIH SBIR program. As indicated in Figure 2 above, the NIH funding decisions divide the pool of applicant firms into those with winning applications and with losing applications. Data was downloaded from the NIH website for all applicant firms that won an SBIR award. These data include the name and address of the firm, the title of the project, the NIH component that sponsored the award, the SBIR phase, the year of award, the dollar amount of the award, and other information. Data that identified firms with rejected applications were obtained through a special request to the NIH. Those data identified the firm name and address, the application year, the application phase, the title of the project. These databases were combined to identify all firms that applied to the NIH SBIR program *for the first time* in the years 1994-1997.

To supplement the NIH data, two other databases were matched to the NIH data by firm name and address. The first was the SDC VenturExpert database. This database identified all SBIR firms that received venture capital investment between 1970 and 2005. Venture capital is a very competitive form of financial capital. Firms that received venture capital could have especially promising products on the market or in their pipeline. The second database was the National Establishment Time-Series (NETS) database compiled by a private company, Walls & Associates. The NETS database was constructed from annual versions of the Dun & Bradstreet (D&B) proprietary database which is the most comprehensive publicly available data on small private firms and their establishments in the US. The NETS database is a panel of establishments observed between 1990 and 2007 created from combining the annual D&B data. As discussed below, this database has detailed firm-level data and provided most of the explanatory variables used in the analysis.

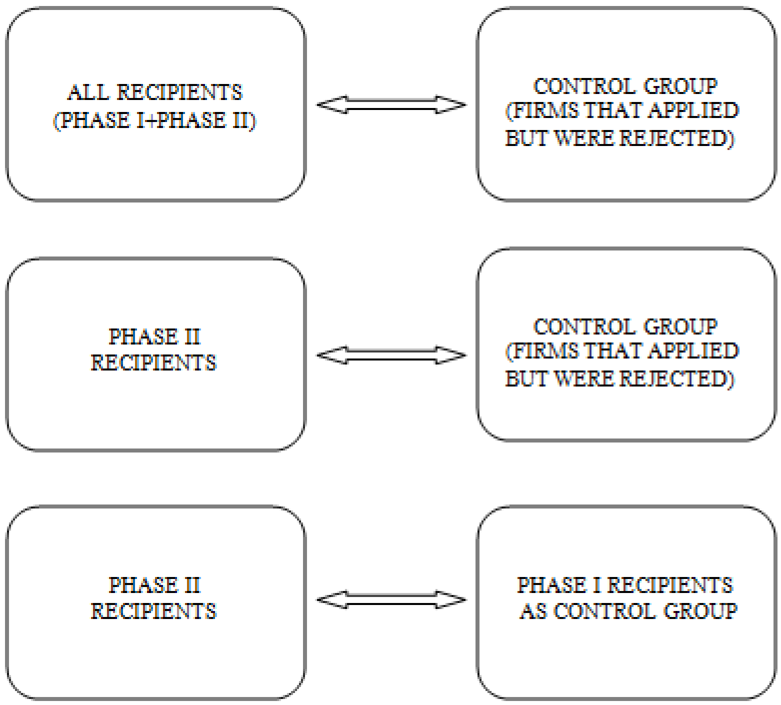
3.3.2. Definitions of Treatment and Control Groups

Recall that the unconfoundedness assumption relies on observing enough covariates so that selection into the NIH SBIR program and other unobservables are unrelated to the outcomes, sales and employment growth. Because the SBIR program involves active agency solicitation of proposals on topics of interest, an important part of the research design in this thesis is to group applicant firms by "application cohorts." All firms that applied to the SBIR program for the first time in the same year are grouped into "cohorts." This is important because there could have been unobservable events such as particular SBIR solicitations topics or informational events that induced firms to apply to the NIH SBIR program in the same year. Further, all of the firms in the annual cohorts are "first time" SBIR applicants. This eliminates any unobserved experience with the application process that might influence selection and outcomes. Along with a rich set of covariates, the cohort research designs should bolster the validity of the unconfoundedness assumption.

With these data I am able to define two versions of "treatment" in the SBIR program. The first "treated group" consists of firms that received at least one Phase I award. A firm that received any SBIR grant at all, and/or multiple Phase I awards, and/or any number of Phase I and Phase II awards, is eligible to be part of this group. The second "treated group" contains firms that received one or more Phase II awards. Figure 3 below shows these groups.

I defined two control groups. Because NIH recently made the identities of its rejected firms available, my primary control group consists of those firms that applied, but were rejected. These firms are quite similar to the recipient firms in all other respects. My second control group contains firms that received one or more Phase I award.

Figure 3: Treatment Groups versus Control Groups



Source : Author

In the two prior studies most relevant to this thesis, Lerner (1999) and Wallsten (2000), the treated groups were defined in a variety of ways. Lerner's treated group consisted of 541 firms that received one or more Phase II awards from any of the 12 participating agencies in the first three program cycles of the SBIR program (1982-1985). Wallsten's treated group was made up of 367 firms that received at least one award (Phase 1 and/or Phase 2) from any of the participating agencies between the years of 1990 and 1992. Lerner's control group was constructed of 294 firms that received only Phase I awards, plus 600 matched firms selected for their similarity to his Phase II recipient firms. Even though Wallsten's study addressed all SBIR awards from the eleven participating agencies during 1990-1992, his control group of 90 firms came from only two federal agencies, NASA and DoD. The rejected firms from the nine other agencies were not represented.

As described earlier, it is important that the treatment and control groups are comparable. In particular, Imbens and Wooldridge (2009) suggest looking at the normalized difference between the explanatory variables between the treatment and control groups. This normalized difference is calculated as:

$$\Delta_x = \frac{\overline{x}_1 - \overline{x}_0}{\sqrt{{s_0}^2} + \sqrt{{s_1}^2}} \tag{13}$$

Where the subscript 1 indicates the SBIR “All Recipients” treatment group and the subscript 0 represents the primary control group of firms that applied, but did not receive SBIR grants. The s_i^2 represent the sample variances for each group, respectively. They point out that the normalized difference should be less than one quarter to assure the regression results are not sensitive to the specification.

Table 2 below shows the results for normalized differences between the “All Recipients” treatment group and the control group of firms that applied, but were rejected. The normalized differences (Δ_X) across the independent variables are all smaller than one quarter. This indicates that the treatment and control groups are similar enough to limit sensitivity of my regression results to the regression specification used.

Table 2: Calculations of Mean Differences

	Treatment Group			Control Group			Calculations			
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Mean Diff.	$S_0^2 + S_1^2$	$(S_0^2 + S_1^2)^{1/2}$	Δ_X
Venture Capital Before SBIR	208	0.07	0.26	195	0.02	0.12	0.06	0.08	0.29	**0.20**
Paydex Index	208	28.57	36.18	195	31.18	36.17	-2.61	2617.20	51.16	**-0.05**
Employment in Application Year	208	20.24	34.77	195	23.81	54.34	-3.57	4161.60	64.51	**-0.06**
Log of Sales in Application Year	208	13.37	1.49	195	13.34	1.47	0.03	4.36	2.09	**0.01**
Woman-owned	208	0.08	0.27	195	0.11	0.32	-0.04	0.17	0.41	**-0.09**
Minority-owned	208	0.00	0.07	195	0.01	0.10	-0.01	0.02	0.12	**-0.04**
Location Change	208	0.55	0.50	195	0.62	0.49	-0.07	0.49	0.70	**-0.10**
Industrial Classification Change	208	0.31	0.46	195	0.32	0.47	-0.01	0.44	0.66	**-0.02**
Multiple State	208	0.02	0.15	195	0.04	0.19	-0.01	0.06	0.24	**-0.05**
Number of Establishments	208	0.63	1.07	195	0.42	0.95	0.21	2.06	1.43	**0.15**
Midwest	208	0.10	0.30	195	0.11	0.32	-0.02	0.19	0.43	**-0.04**
Northeast	208	0.34	0.47	195	0.29	0.46	0.04	0.43	0.66	**0.07**
South	208	0.22	0.41	195	0.26	0.44	-0.05	0.36	0.60	**-0.07**
West	208	0.35	0.48	195	0.33	0.47	0.02	0.45	0.67	**0.03**
Chemicals and Allied Products	208	0.13	0.34	195	0.09	0.29	0.04	0.20	0.45	**0.09**
Instruments & Related Products	208	0.02	0.15	195	0.04	0.19	-0.01	0.06	0.24	**-0.05**
Engineering & Management Services	208	0.75	0.43	195	0.80	0.40	-0.05	0.35	0.59	**-0.08**
Other Industrial Classifications	208	0.09	0.28	195	0.07	0.26	0.01	0.15	0.38	**0.04**

3.3.3. Summary of the Regression Data

The regression analysis used a cross-sectional database composed of 403 firm observations. The construction of the regression data took place in four steps. The first step prepared the NIH application data. The second step identified the NIH applicants that received venture capital backing at any point in their history. The third step involved matching the NIH application data at the firm-level to the NETS data. The final step involved calculating the firm-level outcomes and explanatory variables used in the models.

To prepare the NIH data, all of the project-level applications had to be grouped by firm and each firm had to be given a unique identifier. Most firms have multiple applications because they are allowed to apply for multiple SBIR grants and the program has been ongoing since 1983. After all the applications were grouped by firm, the earliest application year for each firm was identified. This allowed me to groups firms into “cohorts” based on the first year the company applied to the NIH SBIR program. Table 3 shows the number of firms in each NIH cohort, 1994-1997, and the break out by awardees versus rejected.

Table 3: Applicant, Recipient and Rejected Firms by Cohort

Cohort	Applicants	Recipient	Rejected
1994	944	81	863
1995	1,095	65	1,030
1996	824	50	774
1997	731	47	684
Total	3,594	243	3,351

The second and third steps involved matching NIH applicant firms by name and address to the VenturExpert and NETS databases. As shown in the descriptive statistics Table 8, only 7% of the NIH SBIR applicant firms ever received venture capital backing. The NETS matching process was the most limiting. Table 4 shows the percentage of NIH applicant firms matched to the NETS database by cohort. Only 427 firms, or about 11%, of all NIH applicants appeared in the NETS database. This percentage was unexpectedly low, but it is not the result of the matching process. It seems to reflect the fact that most NIH SBIR applicant companies are small, young private firms. For the statistical analysis, I assume the unmatched firms are missing at random so the matched firms are a representative sample of the population of NIH SBIR applicant firms. This assumption applies to both SBIR recipient firms and rejected firms.

Table 4: Percent of NIH Applicant Firms Matched to NETS

Cohort	Number of NIH	Number of	Percentage of
1994	944	111	11.7%
1995	1095	127	11.6%
1996	824	92	11.2%
1997	732	97	13.3%

Out of the 427 firms matched to NETS, twenty-four additional firms were dropped from the analysis. Three firms showed total employment greater than 500 employees in their first year of application to the SBIR program. This violates the one of the eligibility requirements for the program so these firms were dropped. Seven matched firms contained errors in the NIH application data. Fourteen firms were dropped because the NETS data showed the firm as having more than five establishments. These firms had to be dropped because the version of the NETS database available for this analysis did not contain all the information for the firm's other establishments. In the final cross-sectional regression sample, there were 403 firms. 52% of these firms won at least one SBIR award (treated) and the remainder applied, but never received a grant (controls).

The Outcome Variables:

Employment and sales growth rate: For this thesis, the annual average sales and employment growth rates are taken as good indicators of firm performance. The firm-level growth rates are calculated for three different time intervals: 3-years, 5-years, and 8-years. For example, for a firm that first received an SBIR grant in 1994, the average 3-year annual average growth rate of sales is the result of taking the log of sales in 1997 and subtracting the log of sales in 1994 and dividing by 3. The calculation for the employment growth rate over three years used a similar formula. By doing this, the dependent variables are already in the log format. This portion of the data comes from the NETS database.

Covariates:

<u>Award</u>: This is a dummy variable that indicates whether the firm received an NIH SBIR grant or not. Award = 1 if the firm received an SBIR grant; Award = 0 otherwise. This portion of the data comes from NIH.

<u>Venture Capital Before SBIR</u>: This variable shows whether or not a firm received venture capital before the first year it applied for an SBIR grant. This portion of the data comes from the SDC VenturExpert database.

Paydex Index: This variable shows us how well a firm pays its bills and serves an indicator of the firm's financial health. It is considered that a Paydex number over 75 is an indicator of good financial health. This portion of the data comes from the NETS database.

Employment: This variable shows us the number of employees a firm had when it first applied to SBIR. I used this as a control for firm size before applying to the program. This portion of the data comes from the NETS database.

Log of Sales: This variable shows us the real sales a firm had during the first year that the firm received an SBIR award. I use this as a control for firm size before applying to the program. Real sales is calculated by dividing the nominal sales of the company by the price index (GDP deflator). By doing this, I have controlled for the effect of inflation. In the analysis, I am going to use the log of this variable. This portion of the data comes from the NETS database.

Woman-Owned: This variable shows whether the company was owned by a woman in 2005. I assume that a company owned by a woman in 2005 was likely to have been owned by the same woman in the first year that the company received an SBIR award. I am also ruling out the company's receipt of an SBIR award had any effect on the gender ownership, and I would like to control for this variable. This portion of the data comes from the NETS database.

Minority-Owned: As above, this variable shows whether company was owned by a minority person in 2005. I make the same assumptions as above. This portion of the data comes from the NETS database.

Location Change: This variable shows whether or not a firm or any of its establishments moved at least one time between 1990 and 2005. This variable is particularly important because geographical location has a strong effect on sales and employment. This portion of the data comes from the NETS database.

Industrial Classification Change: This variable shows whether a company changed its industrial classification between 1990 and 2005. This portion of the data comes from the NETS database.

Multiple State: This variable shows whether or not a firm has establishments in more than one state. The same geographical location consideration above applies also to this variable. This portion of the data comes from the NETS database.

Number of Establishments: This variable shows the total of active establishments for the firm in the first year of application, including its headquarters. This portion of the data comes from the NETS database.

Region Dummy Variables: These variables, listed below in Table 5, show us where the headquarters of the company is located. This portion of the data comes from the NETS database.

Midwest includes these states: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

Northeast includes these states: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

<u>South includes these states</u>: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

<u>West includes these states</u>: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Table 5: Applicant, Recipient and Rejected Firms by Region

Region	Applicants	Recipient	Rejected
Midwest	42	20	22
Northeast	127	70	57
South	96	45	51
West	138	73	65
Total	403	208	195

<u>Industrial Classification:</u> These variables, shown in Table 6 below, tell us the industrial classifications of the firms. I have divided them into four groups: Chemicals and Allied Products, Instruments and Related Products, Engineering and Management Services, and Other Industrial Classifications. This portion of the data comes from the NETS database.

Table 6: Applicant, Recipient and Rejected Firms by Industrial Classification

Industrial Classification	Applicants	Recipient	Rejected
Chemicals and Allied Products	46	28	18
Instruments and Related Products	12	5	7
Engineering and Management Services	313	157	156
Other Industrial Classifications	32	18	14
Total	403	208	195

Table 7: Summary of Variable Descriptions

Variables	
Outcome Variables	
Sales Growth	Average sales growth rate over 3 years
Employment Growth	Average employment growth rate over 3 years
Covariates	
Award	=1 if firm received an SBIR award, 0 otherwise
Venture Capital Before SBIR	=1 if firm received venture capital prior to its first application to
Paydex Index	Paydex of first year of SBIR award
Employment in Application Year	Number Employees in first year of SBIR award application
Log of Sales in Application Year	Log of sales of first year in SBIR award application
Woman-owned	=1 if firm is woman-owned in 2005, 0 otherwise
Minority-owned	=1 if firm is minority-owned in 2005, 0 otherwise
Location Change	=1 if firm or one of its establishments changed its location
Industrial Classification Change	=1 if firm changed its industrial classification code between
Multiple State	=1 if firm has establishments in multiple states, 0 otherwise
Number of Establishments	No. of active firm locations in first year of application
Midwest	Region dummy
Northeast	Region dummy
South	Region dummy
West	Region dummy
Chemicals and Allied Products	Industrial classification: chemicals and allied products
Instruments & Related Products	Industrial classification: instruments and related products
Engineering & Management Services	Industrial classification: engineering and management services
Other Industrial Classifications	Industrial classification: others

3.3.4. Descriptive Statistics

Table 8 presents summary statistics of the variables for the “All Recipients” treatment group and the control group of firms that applied, but were rejected. It is evident that the growth rate of both sales and employment is greater among recipient firms. Only 7% of SBIR awardees received venture capital funding before their first year application to the program, while the rate for non-recipient firms is lower at 2%. According to my results, firms in the classification Engineering and Management Services are the most active in applying to SBIR at NIH, and this is to be expected considering the type of research NIH does.

Table 8: Summary Statistics

	Treatment Group					Control Group				
Outcome Variables	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
3-year Sales Growth	188	0.18	0.36	-0.97	1.67	165	0.09	0.25	-0.68	1.18
5-year Sales Growth	175	0.13	0.26	-1.33	1.11	154	0.07	0.22	-0.89	1
8-year Sales Growth	160	0.08	0.2	-0.85	0.71	127	0.05	0.16	-0.43	0.64
3-year Employment Growth	188	0.14	0.25	-0.47	1.46	165	0.06	0.19	-0.6	0.87
5-year Employment Growth	175	0.13	0.21	-0.92	0.82	154	0.04	0.16	-0.59	0.58
8-year Employment Growth	160	0.08	0.17	-0.58	0.51	127	0.04	0.11	-0.37	0.35
Covariates	**Treatment Group**					**Control Group**				
Venture Capital Before SBIR	208	0.07	0.26	0	1	195	0.02	0.12	0	1
Paydex Index	208	28.57	36.18	0	89.5	195	31.18	36.17	0	86.5
Employment in Application Year	208	20.24	34.77	1	223	195	23.81	54.34	1	400
Log of Sales in Application Year	208	13.37	1.49	8.38	18.53	195	13.34	1.47	10.08	17.46
Woman-owned	208	0.08	0.27	0	1	195	0.11	0.32	0	1
Minority-owned	208	0	0.07	0	1	195	0.01	0.1	0	1
Location Change	208	0.55	0.5	0	1	195	0.62	0.49	0	1
Industrial Classification Change	208	0.31	0.46	0	1	195	0.32	0.47	0	1
Multiple State	208	0.02	0.15	0	1	195	0.04	0.19	0	1
Number of Establishments	208	0.63	1.07	0	5	195	0.42	0.95	0	5
Midwest	208	0.1	0.3	0	1	195	0.11	0.32	0	1
Northeast	208	0.34	0.47	0	1	195	0.29	0.46	0	1
South	208	0.22	0.41	0	1	195	0.26	0.44	0	1
West	208	0.35	0.48	0	1	195	0.33	0.47	0	1
Chemicals and Allied Products	208	0.13	0.34	0	1	195	0.09	0.29	0	1
Instruments & Related Products	208	0.02	0.15	0	1	195	0.04	0.19	0	1
Engineering & Management Services	208	0.75	0.43	0	1	195	0.8	0.4	0	1
Other Industrial Classifications	208	0.09	0.28	0	1	195	0.07	0.26	0	1

CHAPTER 4: ECONOMETRIC TESTS AND RESULTS

The presentation of my results is divided into three sections according to the treatment group and control groups analyzed. (The three treatment groups and two control groups were described in Chapter 3.) The first section presents the analysis of my "All Recipients" treatment group versus the control group that includes firms that applied to the NIH SBIR program, but were rejected and never subsequently won an SBIR award. The "All Recipients" group includes all firms that received an NIH SBIR grant, either or both Phase I and Phase II. To be part of this group, the number of awards does not matter as long as the firm received at least one. The second section presents the analysis of my "Phase II Recipients" treatment group versus the same control group of firms that applied, but were rejected. The "Phase II Recipients" treatment group includes only those firms that received at least one Phase II SBIR award. The third section of my analysis compares Phase II recipient firms as the treated group versus Phase I recipient firms as the control group.

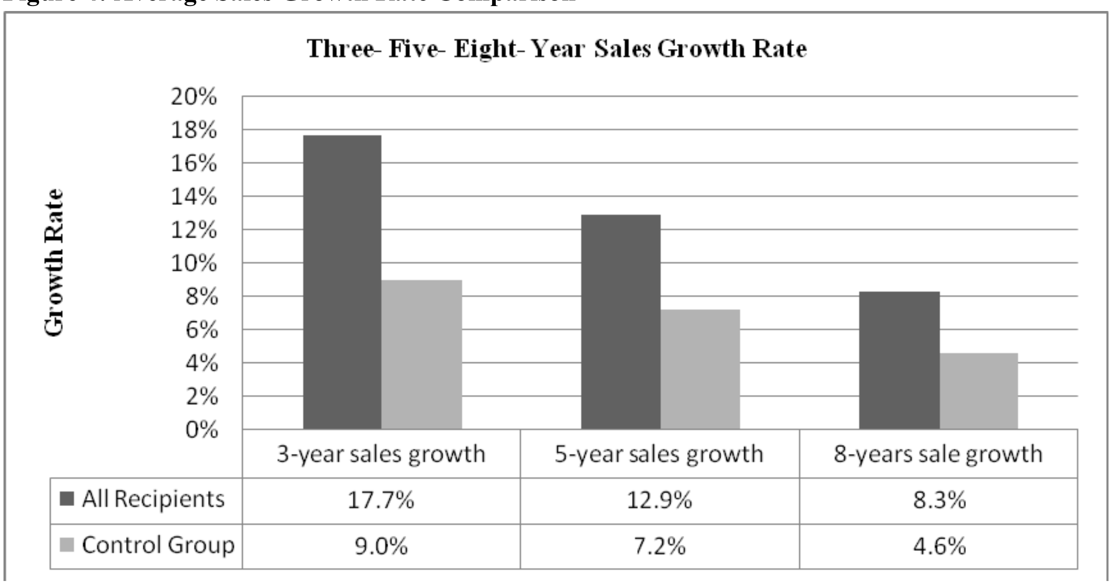
4.1. Results: All Recipients versus Control Group

4.1.1. Overall Effects of SBIR Awards: Mean Comparison

I started my analysis of the effects of SBIR grants by looking at the differences in average sales and employment growth between recipient firms and non-recipient firms. Figures 4 and 5 below compare the average 3-year, 5-year and 8-year sales and employment growth rates, where the non-recipients serve as the control group.

As evident in Figure 4 below, recipients had a higher average sales growth rate in all time ranges. To find out whether these differences were statistically significant, I used a t-test between the means of the groups. The t-values show that the mean differences are statistically significant for three- and five-year growth rates. The t-value for the 3-year sales growth rate was 2.58 and was significant with a 1% level. The t-value for the 5-year sales growth rate was significant at 2.11 with a 5% level. The t-value for the 8-year sales growth rate was1.66 and was signficant at a 10% level. These results show us that the differences of means among recipients and control group are not due to chance or random variation, at least for the three- and five-year time periods.

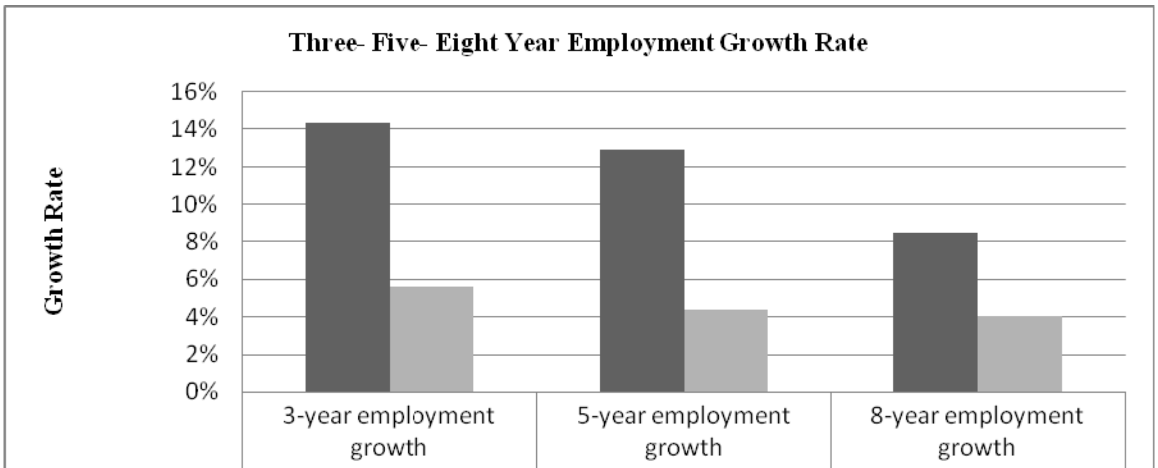
Figure 4: Average Sales Growth Rate Comparison



Source : Author

I took a similar approach to compare the mean employment growth rates. Just as with the sales growth rates, employment growth rates are higher for recipients than non-recipients. As shown in Figure 5 below, recipient firms grew by 14% on average, while non-recipient firms grew by 5% on average over 3 years. The mean growth rates over 5 years are 12% for recipients versus 4% for non-recipients. Similar to the results for sales growth, the 8-year growth rate for employment is smaller for both groups of firms, but unlike the 8-year sales growth rate, the difference is statistically significant. The t-test results for the 3-year, 5-year and 8-year employment growth rate are 3.64, 4.06, 2.58, respectively, and are significant at a 1% level.

Figure 5: Average Employment Growth Rate Comparison



	3-year employment growth	5-year employment growth	8-year employment growth
All Recipients	14.34%	12.89%	8.48%
Control Group	5.58%	4.38%	4.06%

Source : Author

4.1.2. General Description of OLS Model for Sales and Employment

This subsection presents the regression results using the "All Recipients" treatment group along with the group of control firms. Both of the regression models discussed in Chapter 3, equations (11) and (12), were estimated. Recall that the regression model shown in equation (11) does not include interaction terms and it assumes that the firm-specific gain from participation and nonparticipation are equal. In this case, the population average treatment effect (PATE) is equal to the population average treatment effect on the treated (PATT). For the regression model shown in (12), the firm-specific gain from participation and nonparticipation are not assumed to be equal and this means that PATE and PATT and not equal. In this case, I estimate PATE.

For each of these regression models, I will estimate four alternative specifications using the sales and employment growth rates for the different time periods as the dependent variables. The first specification, Model A, is a simple linear regression in which the only explanatory variable is the SBIR award indicator. The second specification, Model B, adds explanatory variables about firm characteristics. In particular, the following covariates are added: employment, log of sales, woman-owned, minority-owned, multiple state and number of establishments. The third specification, Model C, adds explanatory variables related to the firm's financial health, changes in location, and changes in industry. These variables are: venture capital before SBIR, paydex index, location change, and industrial classification change. The fourth specification, Model D, adds dummy variables for the firm's location and industry classification.

Although my tables show results according to the four different specifications described above, my discussion of interesting covariates in the following sections focuses on the results from Model D. I believe that it is most valuable to talk about the model that controls for the greatest number of explanatory variable.

4.1.3. Effects of SBIR Awards on Sales Growth (OLS)

Table 9, Model D, presents the regression results using equation (11) with the firms' 3-year sales growth rate as a dependent variable. The treated group shows a 6.9% higher 3-year sales growth rate than what they would have experienced if they had not received the grants, all other factors held constant. It is significant at a 5% level. Among the control variables, there are three explanatory variables that hold constant any effects due to firm size in the initial year of application to the SBIR program. As described in Chapter 3, *employment* measures the total number of employees at the firm in the first year of application, *sales* measures the initial volume of sales in the year of application, and *number of establishments* is the total number of active locations for the firm in the first year of application. All of these variables are statistically significant at a 1% level. Firms with more employees in the year of application have higher expected growth in sales, all else constant. Firms with a higher initial volume of sales and locations in multiple states have lower expected sales growth. Firms with a greater number of establishments have higher expected sales growth rate, all else constant. Having venture capital backing before applying to NIH SBIR program is expected to increase sales over the first three years by 15.9% increase holding other factors constant. This is significant at a 10% level. Increased sales growth is expected from firms that had a better initial credit rating or a better initial financial situation, all else constant. It is significant at a 1% level. The sales growth rate is expected to fall over three years if there is a change in the location of one or more of a firm's establishments, all else constant. It is significant at a 5% level. Adding the interaction terms does not produce any large changes to the covariate estimates compared to Table 9. Table A.1 in the Appendix shows 3-year sales growth rate as a dependent variable using equation (12), which includes interaction terms.

Table 10, Model D, presents the regression results using equation (11) with the firms' 5-year sales growth rate as a dependent variable. The treated group shows a 4.2% higher 5-year sales growth rate than what they would have experienced if they had not received the grant, all other factors held constant. This is significant at the 10% level. Firms with initial larger sales are expected to experience slower sales growth. Being minority-owned leads to a 34.9% expected increase in the sales growth rate over 5 years compared to non-minority owned firms and this is significant at a 1% level. Firms with a greater number of establishments have a higher expected sales growth rate, all else constant. This is significant at a 1% level. However, the growth rate is expected to decrease for firms with locations in multiple states. Increased sales growth is expected from firms that had a better initial credit rating or a better initial financial situation. Additionally, firms that belong to the industrial classification group Instruments and Related Products show a greater expected sales growth rate than the firms in the benchmark industrial classification group, called "other."

Adding the interaction terms according to equation (12) made the award variable statistically insignificant. Regional differences also appeared when interaction terms were part of the equation. Sales by firms that were headquartered in the Northeast are expected to grow 10.8% more over five years than the benchmark region, Midwest, and this is significant at a 10% level. Similarly, firms in the West are expected to grow 13.7% more than the benchmark (significant at a 5% level), and firms in the South are expected to grow 11.9% more than the benchmark (significant at a 10% level). The regression results using 5-year sales growth as the dependent variable and the specification from equation (12) can be found in the Appendix.

Table 11, Model D, presents the regression results using equation (11) with the firms' 8-year sales growth rate as a dependent variable. The t-value for the award variable becomes statistically insignificant for 8-year sales growth rate. Increased sales growth over 8 years is expected from firms that had a better initial credit rating or a better initial financial situation. This is significant at a 1% level. Interestingly, companies that are part of the Instruments and Related Products industrial classification group are expected to show an 11% higher 8-year sales growth rate than the benchmark group (significant at the 5% level). As shown in Table A.3 in the Appendix, adding the interaction terms according to equation (12) did not produce any important changes in the results that came from equation (11).

Table 9: Three Year Sales Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.091***	4.60	1.400***	5.31	1.589***	5.49	1.531***	5.14
Award (All Recipients)	0.087***	2.65	0.070**	2.27	0.067**	2.21	0.069**	2.29
Employment in Application Year			0.001***	2.87	0.001***	3.22	0.001***	3.20
Log of Sales in Application Year			-0.102***	-5.03	-	-5.12	-0.120***	-5.05
Woman-owned			-0.030	-0.61	0.006	0.12	0.002	0.04
Minority-owned			0.042	0.45	0.010	0.11	0.013	0.11
Multiple State			-0.255**	-2.30	-0.251**	-2.16	-0.258**	-2.15
Number of Establishments			0.062***	3.71	0.047***	2.71	0.050***	2.79
Venture Capital Before SBIR					0.163*	1.75	0.159*	1.74
Paydex Index					0.001**	2.54	0.001***	2.68
Location Change					-0.057*	-1.92	-0.059**	-1.97
Industrial Classification Change					0.041	1.22	0.055	1.47
Northeast							-0.020	-0.38
South							0.021	0.36
West							0.051	0.97
Chemicals and Allied Products							0.056	0.65
Instruments & Related Products							0.019	0.20
Engineering & Management Services							0.061	0.97
Number of Observation	353		353		353		353	
F statistic	7.01		5.97		4.73		3.52	
Probability > F	0.0085		0		0		0	
R^2	0.0187		0.1765		0.2297		0.2411	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 10: Five Year Sales Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.072***	4.11	1.046***	5.93	1.163***	6.14	1.164***	5.65
Award (All Recipients)	0.056**	2.14	0.037	1.45	0.037	1.43	0.042*	1.65
Employment in Application Year			0.000	0.97	0.000	0.89	0.000	0.9
Log of Sales in Application Year			-0.074***	-5.58	-0.086***	-5.77	-0.088***	-5.72
Woman-owned			-0.051	-1.52	-0.029	-0.85	-0.037	-1.05
Minority-owned			0.317***	2.96	0.291***	2.88	0.349***	3.19
Multiple State			-0.163	-1.55	-0.162	-1.54	-0.183*	-1.73
Number of Establishments			0.060***	4.24	0.051***	3.38	0.051***	3.31
Venture Capital Before SBIR					0.111	1.29	0.098	1.16
Paydex Index					0.001***	2.82	0.001***	2.99
Location Change					-0.021	-0.81	-0.020	-0.76
Industrial Classification Change					0.014	0.51	0.008	0.25
Northeast							-0.005	-0.1
South							0.018	0.38
West							0.056	1.23
Chemicals and Allied Products							0.021	0.37
Instruments & Related Products							0.100*	1.75
Engineering & Management Services							0.000	0
Number of Observation	329		329		329		329	
F statistic	4.59		.		.		.	
Probability > F	0.0328		.		.		.	
R^2	0.0136		0.1841		0.2209		0.2385	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 11: Eight Year Sales Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.047***	3.36	0.891***	6.65	0.983***	7.1	1.012***	6.41
Award (All Recipients)	0.036*	1.71	0.019	0.97	0.017	0.86	0.019	0.99
Employment in Application Year			0.000	1.41	0.000	1.17	0.000	1.21
Log of Sales in Application Year			-0.065***	-6.37	-0.074***	-6.84	-0.076***	-6.59
Woman-owned			-0.032	-1.01	-0.017	-0.58	-0.020	-0.66
Minority-owned			-	-	-	-	-	-
Multiple State			-0.079	-1.04	-0.079	-1.07	-0.101	-1.38
Number of Establishments			0.051***	4.49	0.044***	3.67	0.043***	3.61
Venture Capital Before SBIR					0.108*	1.73	0.090	1.48
Paydex Index					0.001***	3.23	0.001***	3.21
Location Change					-0.011	-0.56	-0.012	-0.57
Industrial Classification Change					0.003	0.13	-0.002	-0.06
Northeast							-0.017	-0.55
South							-0.019	-0.6
West							0.019	0.67
Chemicals and Allied Products							0.043	0.9
Instruments & Related Products							0.110**	2.28
Engineering & Management Services							-0.003	-0.08
Number of Observation	287		287		287		287	
F statistic	2.94		8.91		6.79		4.6	
Probability > F	0.0877		0		0		0	
R^2	0.0097		0.2179		0.2651		0.2906	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

4.1.4. Effects of SBIR Awards on Employment Growth (OLS)

Table 12, Model D, presents the regression results using equation (11) with the firms' 3-year employment growth rate as a dependent variable. The treated group shows a 6.9% higher 3-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 1% level. Firms with a higher initial volume of sales and locations in multiple states have lower expected employment growth and firms with a greater number of establishments have a higher expected employment growth rate, all else constant. Firms that had venture capital before first applying to SBIR are expected to show a 14.2% increase in employment growth over three years, all else constant. All of these variables are statistically significant at a 1% level. The employment growth rate is expected to fall over three years if there is a change in the location of one or more of a firm's establishments, all else constant. It is significant at a 5% level. The employment growth rate over 3 years is expected to grow in firms that change their industrial classification, all else constant. It is significant at 10% level. As reported in Table A.4 in the Appendix, when interaction terms were included, recipients showed a 6.3% greater 3-year employment growth rate compared to the control group, all other factors held constant. It is significant at 1% level.

Table 13, Model D, presents the regression results using equation (11) with the firms' 5-year employment growth rate as a dependent variable. The treated group shows a 6.9% higher 5-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 1% level. Firms with a higher initial volume of sales and locations in multiple states have lower expected employment growth. Firms with a greater number of establishments have a higher expected employment growth rate over 5 years, all else constant. All these variables are significant at a 1% level. Firms that are minority-owned are expected to show a 12.5% increase in the employment growth rate over 5 years compared to non-minority owned firms, all else constant. This is significant at a 10% level.

Table A.5, found in the Appendix, presents the regression results using equation (12) with the firms' 5-year employment growth rate as a dependent variable and interaction terms. The treated group shows a 6.4% higher 5-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. This is significant at a 1% level. Regional differences also appeared when interaction terms were part of the equation. Employment in firms that were headquartered in the Northeast is expected to grow 9.9% more over five years; the South 10.8% more and the West, 9.9% more compared to the benchmark region, Midwest. These regional coefficient estimates are all significant at a 5% level.

Table 14, Model D, presents the regression results using equation (11) with the firms' 8-year employment growth rate as a dependent variable. The treated group shows a 2.8% higher 8-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 10% level.

Firms with a higher initial volume of sales have lower expected employment growth, firms that changed one or more of their establishments are expected to have lower employment growth rate, and firms with a greater number of establishments have a higher expected employment growth rate over 8 years, all else constant. All are significant at a 1% level. When the interaction terms are added in equation (12), recipients showed a 3.1% 8-year employment growth rate as compared to the control group. It is significant at a 5% level. No other significant changes came from adding the interaction terms for 8-year employment growth rate. Table A.6, found in the Appendix, presents the regression results using equation (12) with the firm's 8-year employment growth rate as a dependent variable and interaction terms

Table 12: Three Year Employment Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.056***	3.78	0.452***	2.81	0.524***	3.23	0.547***	3.18
Award (All Recipients)	0.088***	3.71	0.071***	3.08	0.069***	2.98	0.069***	2.98
Employment in Application Year			0.000	-1.21	0.000	-1.16	0.000	-1.05
Log of Sales in Application Year			-0.030**	-2.39	-0.035***	-2.66	-0.037***	-2.71
Woman-owned			0.013	0.29	0.024	0.51	0.021	0.45
Minority-owned			-0.009	-0.25	-0.035	-0.79	-0.025	-0.45
Multiple State			-0.217***	-3.32	-0.210***	-3.44	-0.215***	-3.51
Number of Establishments			0.046***	3.42	0.039***	2.75	0.042***	3.06
Venture Capital Before SBIR					0.051	0.85	0.035	0.58
Paydex Index					0.000	0.17	0.000	0.29
Location Change					-0.052**	-2.21	-0.050**	-2.08
Industrial Classification Change					0.047**	1.96	0.046*	1.65
Northeast							-0.011	-0.29
South							-0.020	-0.53
West							0.037	0.99
Chemicals and Allied Products							0.023	0.39
Instruments & Related Products							-0.028	-0.51
Engineering & Management Services							-0.009	-0.23
Number of Observation	353		353		353		353	
F statistic	13.77		11.8		7.43		5.16	
Probability > F	0.0002		0		0		0	
R^2	0.0365		0.1275		0.1527		0.1658	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 13: Five Year Employment Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.044***	3.35	0.460***	3.69	0.494***	3.98	0.558***	4.01
Award (All Recipients)	0.085***	4.14	0.067***	3.32	0.066***	3.17	0.069***	3.39
Employment in Application Year			0.000	-1.39	0.000	-1.33	0.000	-1.37
Log of Sales in Application Year			-0.031***	-3.25	-0.032***	-3.37	-0.034***	-3.5
Woman-owned			-0.010	-0.32	-0.005	-0.14	-0.008	-0.23
Minority-owned			0.080	1.14	0.080	1.13	0.125*	1.76
Multiple State			-0.179***	-2.57	-0.173**	-2.44	-0.180***	-2.63
Number of Establishments			0.044***	3.79	0.041***	3.23	0.041***	3.39
Venture Capital Before SBIR					0.020	0.31	0.000	-0.01
Paydex Index					0.000	-0.42	0.000	-0.17
Location Change					-0.038*	-1.82	-0.033	-1.52
Industrial Classification Change					0.024	1.13	0.009	0.35
Northeast							-0.008	-0.22
South							-0.006	-0.15
West							0.034	0.95
Chemicals and Allied Products							0.007	0.16
Instruments & Related Products							-0.010	-0.2
Engineering & Management Services							-0.060*	-1.65
Number of Observation	329		329		329		329	
F statistic	17.11		.		.		.	
Probability > F	0		.		.		.	
R^2	0.0482		0.1697		0.1835		0.2088	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 14: Eight Year Employment Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.041***	4.15	0.347***	3.5	0.381***	3.88	0.439***	4
Award (All Recipients)	0.044***	2.71	0.031*	1.92	0.027*	1.68	0.028*	1.79
Employment in Application Year			0.000	-1.37	0.000	-1.27	0.000	-1.26
Log of Sales in Application Year			-0.023***	-3	-0.023***	-2.95	-0.026***	-3.24
Woman-owned			-0.010	-0.4	-0.006	-0.22	-0.003	-0.11
Minority-owned			-	-	-	-	-	-
Multiple State			-0.057	-1.16	-0.046	-0.96	-0.055	-1.19
Number of Establishments			0.032***	3.24	0.030***	2.89	0.029***	3.04
Venture Capital Before SBIR					0.033	0.73	0.007	0.17
Paydex Index					0.000	-0.44	0.000	-0.27
Location Change					-0.048***	-2.91	-0.044***	-2.66
Industrial Classification Change					-0.008	-0.46	-0.014	-0.64
Northeast							-0.007	-0.23
South							-0.019	-0.65
West							0.018	0.64
Chemicals and Allied Products							0.054	1.36
Instruments & Related Products							-0.004	-0.09
Engineering & Management Services							-0.036	-0.99
Number of Observation	287		287		287		287	
F statistic	7.33		4.86		4.77		3.84	
Probability > F	0.0072		0.0001		0		0	
R^2	0.023		0.1254		0.1558		0.2006	

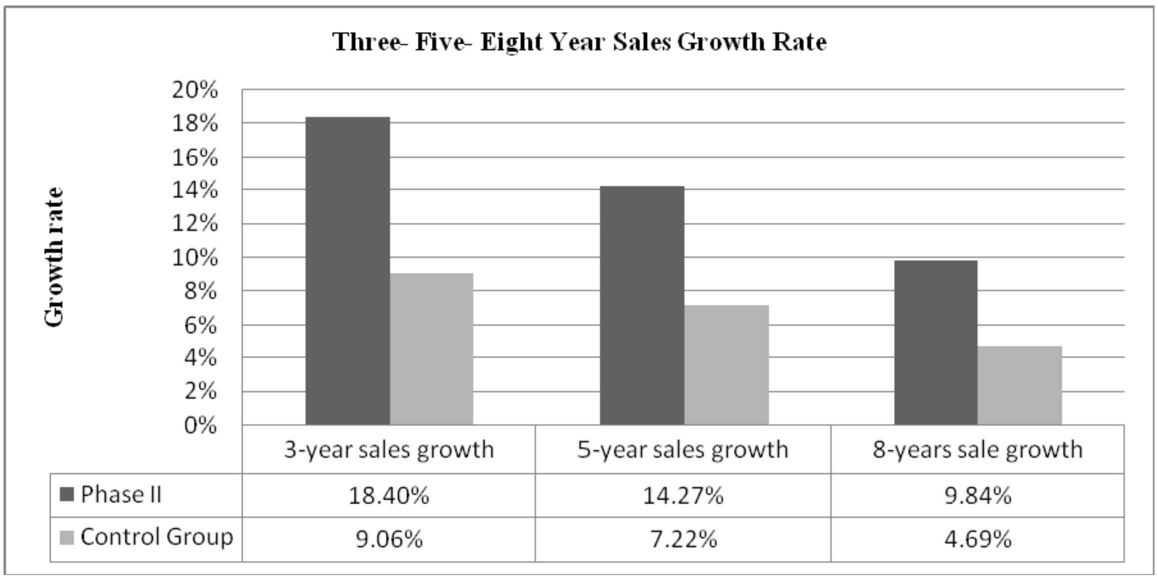
***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

4.2. Results: Phase II versus Control Group

4.2.1. Overall Effects of SBIR Awards: Mean Comparison

When I looked mean comparison among the Phase II recipients versus the control group, similar trends presented themselves. I began looking at the mean sales and employment growth rates among the Phase II recipient firms and non-recipients. Figures 6 and 7 below compare the average 3-year, 5-year and 8-year sales and employment growth rates of Phase II recipients, where the non-recipients serve as the control group.

Figure 6: Average Sales Growth Rate Comparison



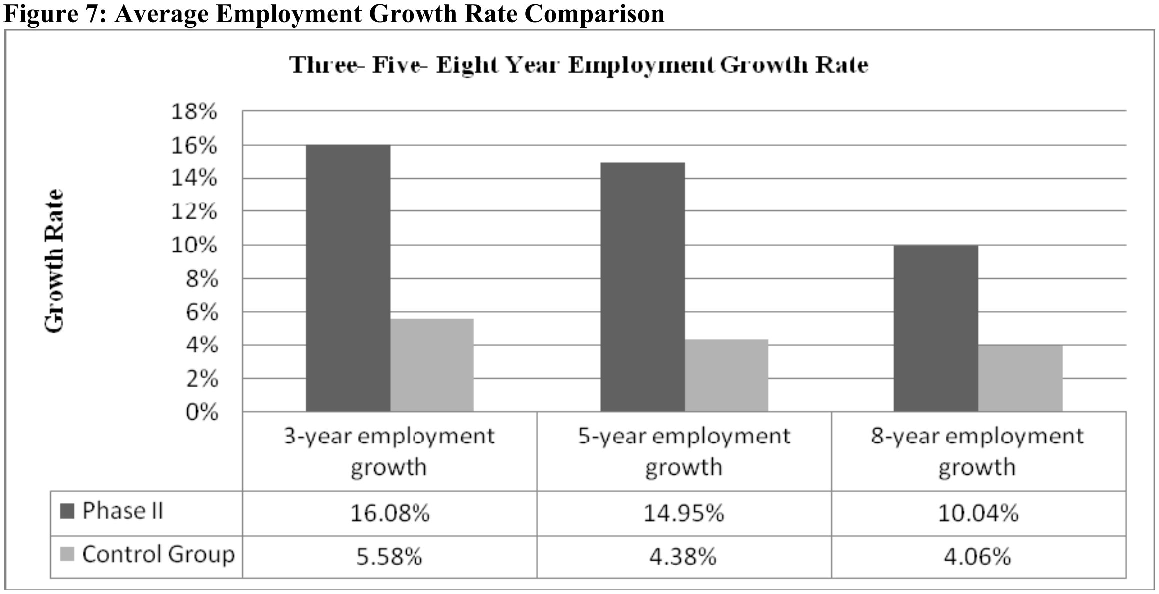
Source : Author

As evident in Figure 6 above, Phase II recipients had a higher average sales growth rate in all time ranges. To test this average growth rate among groups, I used a t-test among the means in the groups. The t-values show that the mean differences are statistically significant between the groups for three- and five-year sales growth rate. The t-test results for the 3-year sales growth rate was significant at 2.62 with a 1%

confidence level. The 5-year t-value was significant at 2.65 with a 1% confidence level. The t-value for 8-year sales growth rate was significant at 2.28 with a 5% level.

I took a similar approach to compare the mean employment growth rate. As shown in Figure 7 below, just as with the sales growth rate, the 3-year, 5-year and 8-year employment growth rates are higher for Phase II recipients than non-recipients. Phase II recipients grew by 16% on average, while non-recipient firms grew by 5% on average over 3 years. The mean growth rates over 5 years are 15% for Phase II recipients versus 4% for non-recipients. Similar to the results for sales growth, when I look at the 8-year growth rate, the numbers shrink on both sides, but not to the point that they lack statistical significance. The t-test results for the 3-year, 5-year and 8-year employment growth rate are 4.11, 4.98, and 3.48, respectively. Contrary to sales growth, all of the differences between the Phase II recipient group and the control group are statistically significant at %1 confidence level.

Figure 7: Average Employment Growth Rate Comparison



Source : Author

4.2.2. General Description of OLS Model for Sales and Employment

To calculate the average treatment effect on the treated, I ran OLS models regressing the 3-year, 5-year and 8-year sales and employment growths rate on the set of covariates in the same four groups as described in section 4.1.2. Model A regresses 3-year, 5-year and 8-year sales and employment growth on award only. Model B adds explanatory variables about firm characteristics to Model A. In Model C, I added the following additional covariates: venture capital before SBIR, paydex index, location change, and industrial classification change. The fourth specification, Model D, adds dummy variables for the firm's location and industry classification. I tested, but could not reject the null hypothesis that the Region and Industrial Classification dummies jointly equal zero, though I added them to the regression equation for Model D to be able to use them in equation (12). I ran the regressions according to equation (11) for Model A, Model B, Model C and Model D. I then ran the regressions according to equation (12), adding interaction terms, for Model A, Model B, Model C and Model D.

My tables show results according to the four different covariate groups described above, but my discussion of interesting covariates in the following sections uses the results from Model D, to account for the greatest number of explanatory variables.

4.2.3. Effects of SBIR Awards on Sales Growth (OLS)

Table 15, Model D, presents the regression results using equation (11) with the firms' 3-year sales growth rate as a dependent variable. The treated group "Phase II Recipients" shows a 6.1% higher 3-year sales growth than what they would have experienced if they had not received the grants, all other factors held constant. It is significant at a 10% level.

Among the control variables, there are three explanatory variables that hold constant any effects due to firm size in the initial year of application to the SBIR program. As described in Chapter 3, *employment* measures the total number of employees at the firm in the first year of application, *sales* measures the initial volume of sales in the year of application, and *number of establishments* is the total number of active locations for the firm in the first year of application.

Firms with more employees in the year of application have higher expected growth in sales, all else constant. It is significant at a 1% level. Firms with a higher initial volume of sales and locations in multiple states have lower expected sales growth, all else constant. They are significant at 1% and %10 levels, respectively. Firms with a greater number of establishments have higher expected sales growth rate, all else constant. It is significant at a 5% level. Firms that had venture capital before first applying to SBIR are expected to show a 16.7% increase in sales growth over three years, all else held constant. It is significant at a 10% level. Increased sales growth is expected from firms that had a better initial credit rating or a better initial financial situation, all else constant. It is significant at a 1% level. The sales growth rate is expected to fall over three years if there is a change in the location of one or more of a firm's establishments, all else constant. It is significant at a 1% level. Adding the interaction terms does not produce any large changes to the covariate estimates compared to Table 15. Table A.7 in the

Appendix shows 3-year sales growth rate as a dependent variable using equation (12), which includes interaction terms.

Table 16, Model D, presents the regression results using equation (11) with the firms' 5-year sales growth rate as a dependent variable. The treated group shows a 4.3% higher 5-year sales growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 10% level. Firms with initial larger sales are expected to show a decreased sales growth rate, all else constant. It is significant at a 1% level. Being minority-owned leads to a 34.9% expected increase in the sales growth rate over 5 years compared to non-minority owned firms, all else constant. It is significant at a 1% level. Firms with a greater number of establishments and with a better credit rating or initial financial health have a higher expected sales growth rate, all else constant. Both variables are significant at a 1% level.

Adding the interaction terms according to equation (12) made the award variable statistically insignificant. Regional differences also appeared when interaction terms were part of the equation. Sales in firms that were headquartered in the Northeast are expected to grow 10.8% more over five years than firms located in the benchmark region, Midwest. Firms located in the South are expected to grow 11.9% more than firms in the benchmark region, all else constant. These variables are significant at a 10% level. Similarly, firms in the West are expected to grow 13.7% more than firms in the benchmark region, all else constant. It is significant at a 5% level. Table A.8, found in the Appendix, presents these regression results using equation (12) with the firms' 5-year sales growth rate as a dependent variable and interaction terms.

Table 17, Model D, presents the regression results using equation (11) with the firms' 8-year sales growth rate as a dependent variable. The t-value for the award variable becomes statistically insignificant for 8-year sales growth rate. Increased sales growth over 8 years is expected from firms that had a better initial credit rating or a better initial financial situation, all else constant. It is significant at a 1% level. Firms that are part of the Instruments and Related Products industrial classification group are expected to show an 11.4% higher 8-year sales growth rate than the benchmark group, all else constant. It is significant at a 5% level. As shown in Table A.9 in the Appendix, adding the interaction terms according to equation (12) did not produce any important changes in the results that came from equation (11).

Table 15: Three Year Sales Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.091***	4.6	1.449***	4.98	1.697***	5.35	1.627***	5.09
Award (Phase II)	0.093**	2.56	0.068***	2	0.057*	1.71	0.061*	1.86
Employment in Application Year			0.001***	3	0.001***	3.6	0.002***	3.59
Log of Sales in Application Year			-0.105***	-4.74	-0.126***	-4.99	-0.127***	-4.96
Woman-owned			-0.023	-0.45	0.019	0.36	0.015	0.28
Minority-owned			0.019	0.26	0.004	0.05	0.014	0.13
Multiple State			-0.191*	-1.75	-0.190	-1.6	-0.203*	-1.65
Number of Establishments			0.061***	3.26	0.046**	2.46	0.047**	2.35
Venture Capital Before SBIR					0.174*	1.79	0.167*	1.74
Paydex Index					0.002***	2.57	0.002***	2.75
Location Change					-0.078**	-2.47	-0.083***	-2.59
Industrial Classification Change					0.023	0.65	0.028	0.72
Northeast							0.014	0.3
South							0.058	1.1
West							0.082*	1.72
Chemicals and Allied Products							0.034	0.37
Instruments & Related Products							0.044	0.44
Engineering & Management Services							0.041	0.62
Number of Observation	309		309		309		309	
F statistic	6.56		5.66		4.63		3.31	
Probability > F	0.0109		0		0		0	
R^2	0.0219		0.1789		0.2483		0.2597	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 16: Five Year Sales Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.072***	4.11	1.044***	5.49	1.220***	5.86	1.205***	5.57
Award (Phase II)	0.070***	2.64	0.041	1.63	0.039	1.53	0.043*	1.72
Employment in Application Year			0.000	1.2	0.000	1.29	0.001	1.36
Log of Sales in Application Year			-0.075***	-5.15	-0.090***	-5.54	-0.093***	-5.58
Woman-owned			-0.047	-1.36	-0.021	-0.6	-0.027	-0.77
Minority-owned			0.328***	2.73	0.310***	2.68	0.349***	2.8
Multiple State			-0.176	-1.5	-0.180	-1.5	-0.190	-1.58
Number of Establishments			0.065***	4.18	0.055***	3.44	0.054***	3.25
Venture Capital Before SBIR					0.108	1.23	0.095	1.09
Paydex Index					0.001***	3.12	0.001***	3.27
Location Change					-0.037	-1.51	-0.039	-1.6
Industrial Classification Change					0.015	0.54	0.005	0.15
Northeast							0.028	0.61
South							0.043	0.93
West							0.072	1.58
Chemicals and Allied Products							0.010	0.16
Instruments & Related Products							0.090	1.56
Engineering & Management Services							-0.003	-0.07
Number of Observation	288		288		288		288	
F statistic	6.96		.		.		.	
Probability > F	0.0088		.		.		.	
R^2	0.024		0.2141		0.274		0.2911	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 17: Eight Year Sales Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.047***	3.36	0.960***	6.86	1.098***	8.05	1.133***	7.52
Award (Phase II)	0.052**	2.28	0.028	1.38	0.024	1.25	0.027	1.4
Employment in Application Year			0.001**	2.17	0.001**	2.24	0.001**	2.33
Log of Sales in Application Year			-0.070***	-6.6	-0.083***	-7.85	-0.086***	-7.72
Woman-owned			-0.032	-0.99	-0.015	-0.49	-0.017	-0.57
Minority-owned			-	-	-	-	-	-
Multiple State			-0.078	-0.93	-0.083	-1	-0.093	-1.14
Number of Establishments			0.053***	4.33	0.046***	3.62	0.044***	3.46
Venture Capital Before SBIR					0.101	1.58	0.083	1.33
Paydex Index					0.001***	3.77	0.001***	3.71
Location Change					-0.018	-0.9	-0.020	-0.98
Industrial Classification Change					0.008	0.34	-0.001	-0.03
Northeast							-0.016	-0.54
South							-0.020	-0.62
West							0.016	0.53
Chemicals and Allied Products							0.029	0.57
Instruments & Related Products							0.114**	2.31
Engineering & Management Services							-0.005	-0.11
Number of Observation	251		251		251		251	
F statistic	5.2		9.19		8.13		5.85	
Probability > F	0.0234		0		0		0	
R^2	0.0206		0.2473		0.313		0.3374	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

4.2.4. Effects of SBIR Awards on Employment Growth (OLS)

Table 18, Model D, presents the regression results using equation (11) with the firms' 3-year employment growth rate as a dependent variable. The treated group shows a 7.9% higher 3-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 1% level. Firms with a higher initial volume of sales and locations in multiple states have lower expected employment growth, all else constant. Variables are significant at 1% and 5% levels, respectively. Firms with a greater number of establishments have a higher expected employment growth, all else constant. It is significant at a 1% level. The employment growth rate is expected to fall over three years if there is a change in the location of one or more of a firm's establishments, all else constant. It is significant at a 5% level.

As reported in Table A.10 in the Appendix, when interaction terms were included, Phase II Recipients showed a 6.6% greater 3-year employment growth rate compared to the control group, all other factors held constant. This is significant at a 5% level. Firms that had venture capital before first applying to SBIR are expected to show a 14.2% increase in employment growth over three years, all else constant. It is significant at a 1% level.

Table 19, Model D, presents the regression results using equation (11) with the firms' 5-year employment growth rate as a dependent variable. The treated group shows a 8.2% higher 5-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 1% level.

Firms with a higher initial volume of sales and locations in multiple states have lower expected employment growth, all else constant. These variables are significant at 1% and 5% levels, respectively. Firms with a greater number of establishments have a higher expected employment growth rate over 5 years, all else constant. It is significant at a 1% level.

Table A.11, found in the Appendix, presents the regression results using equation (12) with the firms' 5-year employment growth rate as a dependent variable and interaction terms. The treated group shows a 6.9% higher 5-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 1% level. Regional differences also appeared when interaction terms were part of the equation. Employment in firms that were headquartered in the Northeast is expected to grow 9.9% more over five years and significant at a 10% level; firms in the South are expected to grow 10.8% more and firms in the West are expected to grow at a 9.9% higher rate than the benchmark region, Midwest. They are significant at a 5% level.

Table 20, Model D, presents the regression results using equation (11) with the firms' 8-year employment growth rate as a dependent variable. The treated group shows a 4% higher 8-year employment growth rate than what they would have experienced if they had not received the grant, all other factors held constant. It is significant at a 5% level.

Firms with a higher initial volume of sales have lower expected employment growth, all else constant. Firms with a greater number of establishments have a higher expected employment growth rate over 8 years, all else constant. The employment growth rate is expected to fall over eight years if there is a change in the location of one or more of a firm's establishments. All of these variables are significant at a 1% level.

When the interaction terms are added in equation (12), Phase II Recipients showed a 3.4%, 8-year employment growth rate as compared to the control group, all others factors are held constant. This is significant at a 5% level. No other significant changes came from adding the interaction terms for 8-year employment growth rate. Table A.12, found in the Appendix, presents the regression results using equation (12) with the firms' 8-year employment growth rate as a dependent variable and interaction terms.

Table 18: Three Year Employment Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.056***	3.78	0.444**	2.41	0.534***	2.79	0.546***	2.68
Award (Phase II)	0.105***	4.03	0.083***	3.27	0.079***	3.09	0.079***	3.08
Employment in Application Year			0.000	-0.88	0.000	-0.78	0.000	-0.71
Log of Sales in Application Year			-0.030**	-2.07	-0.035**	-2.3	-0.037**	-2.34
Woman-owned			0.016	0.35	0.029	0.62	0.026	0.57
Minority-owned			-0.030	-0.86	-0.049	-1.11	-0.041	-0.71
Multiple State			-0.191***	-3.03	-0.187***	-2.98	-0.195***	-3.02
Number of Establishments			0.048***	3.26	0.042***	2.7	0.044***	2.89
Venture Capital Before SBIR					0.041	0.65	0.027	0.42
Paydex Index					0.000	0.47	0.000	0.51
Location Change					-0.059**	-2.33	-0.058**	-2.21
Industrial Classification Change					0.035	1.35	0.033	1.06
Northeast							0.002	0.06
South							-0.005	-0.13
West							0.040	0.98
Chemicals and Allied Products							0.023	0.35
Instruments & Related Products							-0.012	-0.21
Engineering & Management Services							-0.010	-0.23
Number of Observation	309		309		309		309	
F statistic	16.28		13.76		7.14		4.66	
Probability > F	0.0001		0		0		0	
R^2	0.0523		0.133		0.1586		0.1679	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 19: Five Year Employment Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.044***	3.35	0.437***	3.17	0.496***	3.45	0.544***	3.45
Award (Phase II)	0.106***	4.92	0.082***	3.83	0.081***	3.84	0.082***	3.95
Employment in Application Year			0.000	-1.12	0.000	-1.04	0.000	-1.06
Log of Sales in Application Year			-0.030***	-2.79	-0.033***	-2.94	-0.035***	-3.06
Woman-owned			-0.010	-0.3	-0.002	-0.06	-0.004	-0.12
Minority-owned			0.091	1.17	0.094	1.17	0.130	1.6
Multiple State			-0.195**	-2.56	-0.193**	-2.41	-0.196**	-2.52
Number of Establishments			0.047***	3.73	0.044***	3.25	0.044***	3.35
Venture Capital Before SBIR					0.001	0.02	-0.015	-0.25
Paydex Index					0.000	0.12	0.000	0.3
Location Change					-0.048**	-2.31	-0.046**	-2.14
Industrial Classification Change					0.026	1.25	0.012	0.48
Northeast							0.009	0.23
South							0.015	0.39
West							0.041	1.11
Chemicals and Allied Products							0.009	0.19
Instruments & Related Products							-0.017	-0.33
Engineering & Management Services							-0.052	-1.46
Number of Observation	288		288		288		288	
F statistic	24.23		.		.		.	
Probability > F	0		.		.		.	
R^2	0.0801		0.2027		0.2243		0.2464	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table 20: Eight Year Employment Growth Rate

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.041***	4.15	0.362***	3.41	0.414***	3.76	0.468***	3.9
Award (Phase II)	0.060***	3.47	0.042**	2.51	0.040**	2.42	0.040**	2.48
Employment in Application Year			0.000	-0.84	0.000	-0.65	0.000	-0.64
Log of Sales in Application Year			-0.024***	-2.98	-0.026***	-3.04	-0.029***	-3.25
Woman-owned			-0.011	-0.39	-0.005	-0.17	-0.002	-0.07
Minority-owned			-	-	-	-	-	-
Multiple State			-0.071	-1.33	-0.063	-1.19	-0.068	-1.31
Number of Establishments			0.035***	3.28	0.032***	2.99	0.031***	3.13
Venture Capital Before SBIR					0.021	0.45	0.000	0
Paydex Index					0.000	0.02	0.000	0.1
Location Change					-0.052***	-3.16	-0.050***	-3.04
Industrial Classification Change					-0.001	-0.03	-0.004	-0.2
Northeast							-0.013	-0.47
South							-0.019	-0.63
West							0.009	0.35
Chemicals and Allied Products							0.048	1.15
Instruments & Related Products							-0.009	-0.2
Engineering & Management Services							-0.028	-0.73
Number of Observation	251		251		251		251	
F statistic	12.04		5.11		4.53		3.61	
Probability > F	0.0006		0.0001		0		0	
R^2	0.0465		0.1501		0.186		0.2201	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

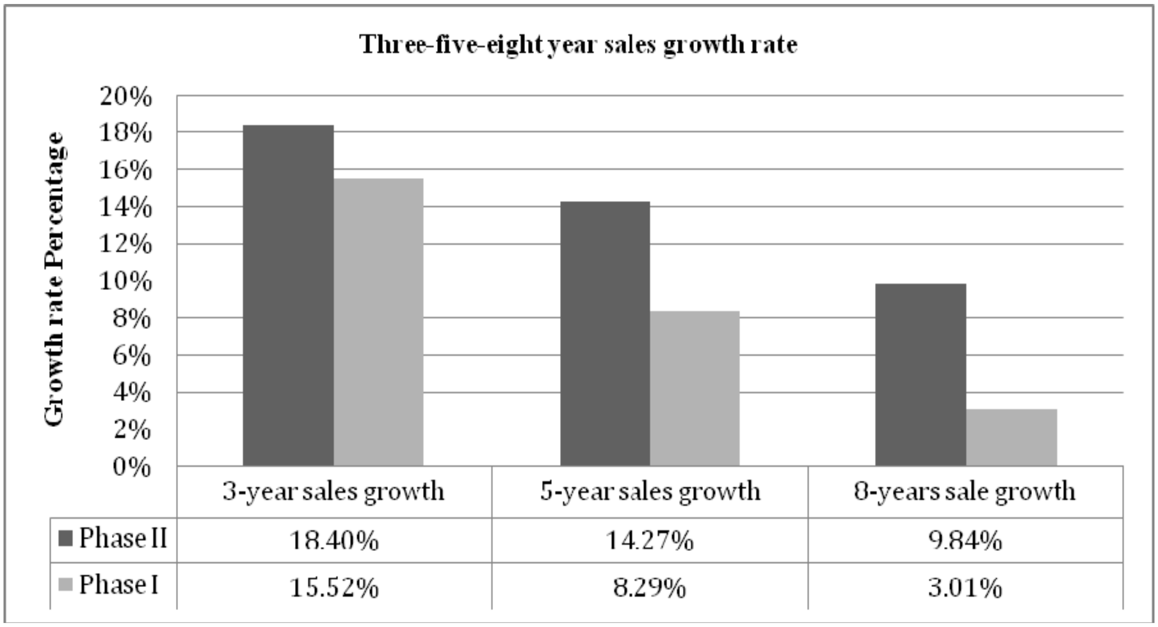
4.3. Results: Phase II versus Phase I as Control Group

4.3.1. Overall Effects of SBIR Awards: Mean Comparison

Lastly, I looked at the difference in average sales and employment growth between Phase II recipient firms and Phase I recipient firms. Because Phase II recipient firms actually finish developing a new product as the result of receiving an SBIR grant, one would expect those firms to show better performance in sales and performance growth. Figures 8 and 9 below compare the average 3-year, 5-year and 8-year sales and employment growth rates for Phase II recipients, where the Phase I recipients serve as the control group.

As evident in Figure 8 below, Phase II recipients had a slightly higher average sales growth rate in all time ranges. To find out whether these differences were statistically significant, I used a t-test between the means of the groups. The t-values show that the mean differences are not statistically significant for three- and five-year sales growth. The t-value for the 3-year sales growth rate was 0.46, and was 1.29 for the five-year sales growth rate. For eight-year sales growth, the t-value was 1.81 and was statistically significant at a 10% level. The statistically insignificant results for 3- and 5-year sales growth may be the result of a small sample problem in the control group in this comparison, Phase I recipients.

Figure 8: Average Sales Growth Rate Comparison

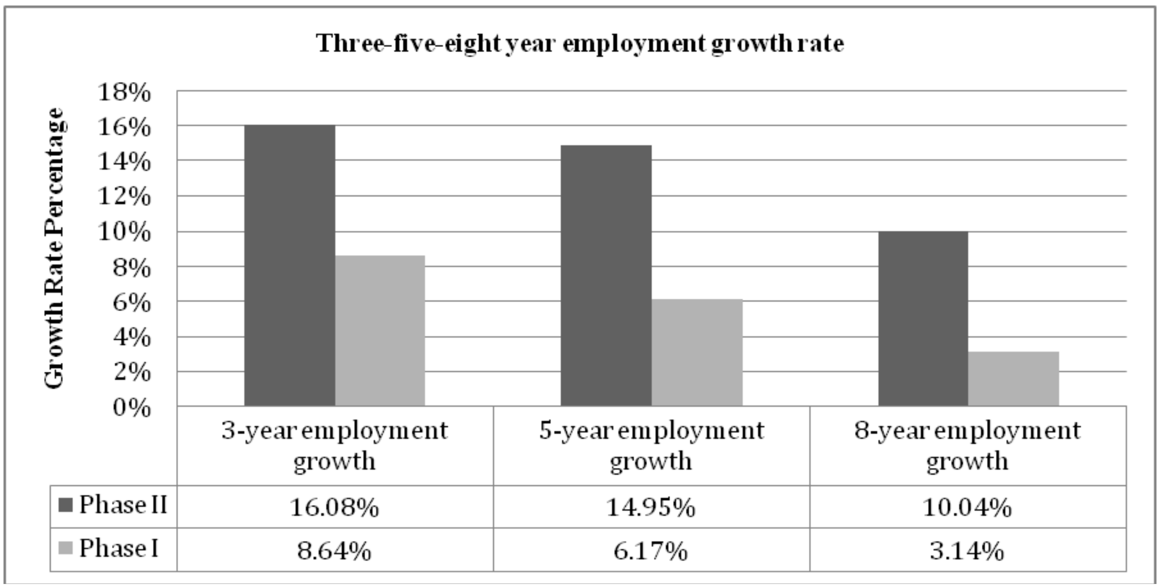


Source : Author

I took a similar approach to compare the mean employment growth rates. In contrast to the sales growth compairson above, employment growth rates are more than 50% higher for Phase II recipients than Phase I recipients in all time ranges. As shown in Figure 9 below, Phase II recipient firms grew by 16 % on average, while Phase I recipients grew by 8% on average over 3 years. The mean growth rates over 5 years are nearly 15% for recipients versus 6% for Phase I recipients. After 8 years, the mean employment growth rates are 10% for Phase II recipients versus 3% for Phase I recipients. The t-test results for the 3-year, 5-year and 8-year employment growth rates are 1.71, 2.36, 2.22, respectively, and are statistically significant at a 10% level for the 3-year growth rate, and 5% for the 5- and 8-year growth rates. We can see clearly from these results that the most pronounced employment growth effect comes from a firm receiving a Phase II award.

I would have liked to continue with a regression analysis similar to sections 4.1 and 4.2, but because of the small sample size of the Phase I recipients control group (57 firms) compared to the Phase II recipients treatment group (191 firms), the overlap assumption fails. So, I was unable to present regression results for Phase II recipients as the treated group versus Phase I recipients as the control group.

Figure 9: Average Employment Growth Rate Comparison



Source : Author

CHAPTER 5: CONCLUSION

This thesis analyzed the impact of Small Business Innovation Research (SBIR) grants awarded by the US National Institutes of Health (NIH) by examining sales and employment growth in firms that received SBIR awards from NIH. In the current economic environment, NIH administrators are interested in the relationship between the research funding they supply and health, economic growth and global competitiveness. Evaluations of programs like SBIR give policy makers the information they need to maintain the competitive edge of the United States, and make amendments when necessary.

The main strength of this study is that it evaluated the effect of SBIR subsidies on firm performance indicators while controlling for selection into the program. My data set included firm-level observations for all firms (both recipient and rejected) that applied to the SBIR program administered by the NIH from 1994-2005. Because I had access to data on rejected firms, I was able to construct my main control group out of firms that applied, but were rejected. Previous papers on this topic included eligible firms that did not apply for SBIR grants as part of their control groups because the rejected firms' data was not available. Lerner's control group was constructed of 294 Phase I recipients, plus 600 matched firms similar to his Phase II recipient firms. Even though Wallsten's study dealt with all SBIR awards from eleven participating agencies during 1990-1992, his control group of 90 firms came from only two federal agencies, NASA and DoD, leaving the rejected firms from the nine other participating agencies unrepresented.

In contrast, my main control group of firms that applied to SBIR at NIH, but were rejected, controls for unobservable characteristics shared by both the recipients and the control group. The "cohort" design of my research further helps to account for unobserved reasons that led firms to apply to the program for the first time in the same year. The firms in my primary control group are more similar to the firms in my treatment groups than the control groups of previous researchers were to their treatment groups. Additionally, my All Recipients treated group contains 208 firms, and my primary "applied but rejected" control group contains 195 firms. Wallsten had 367 firms in his treated group, but only 112 firms in his control group, which made for a less favorable ratio.

This study finds that SBIR awards have positive effects on both sales and employment growth in recipient firms. Firms that received any kind of award grow at a greater rate than non-recipients. In my OLS results, both of my treated groups, All Recipients and Phase II Recipients, experienced higher sales growth rates than they would have if they had not received an SBIR grant. This positive affect was shown to only last for a short time; the eight year sales growth rate for both treated groups was statistically insignificant. Unlike sales growth, employment growth for both treatment groups remained statistically significant throughout the time range of my data. The Phase II Recipient group steadily showed more employment growth than the All Recipients group. Phase II awards are greater in amount than Phase I, and it is reasonable to expect that Phase II recipient firms may decide to hire new employees after receiving the SBIR award.

When I used Phase I recipients as a control group and compared them to Phase II recipients as the treatment group, the mean comparison showed that Phase II recipients experience higher sales and employment growth than Phase I recipients. This is very pronounced in employment growth; Phase II recipients have a 50% greater employment growth rate than Phase I recipients in all time ranges. I would have liked to continue with regression analysis between these two groups, but the sample size of Phase I recipients was not large enough.

In general, my results demonstrate a more positive relationship between SBIR awards and firm performance than Wallsten and Lerner's results. For instance, my OLS analysis of Phase II recipients versus the main control group of firms that applied but were rejected showed that recipient firms experienced 6.13% greater sales growth and 7.86% greater employment growth over three years compared to their control counterparts. Wallsten's OLS results showed that one Phase II award is expected to increase employment by 2% in the recipient firm. Because this coefficient estimate was small, he did not consider this to be a significant employment growth increase, and concluded in general that SBIR awards did not any effect on employment levels in recipient firms, contrary to my results. In Lerner's OLS results, the award variable was statistically insignificant, but when he used interaction terms between his venture capital variable and award variable, the result became statistically significant. So for Lerner, SBIR awards were correlated with increased employment and sales growth only in geographic regions where there had already been significant venture capital activity. In Lerner's study, the expected sales growth increased 2.41% and the expected employment growth increased 5.11% for an SBIR recipient firm in a high venture capital activity area.

Like Lerner's focus on venture capital activity in a geographic region, my study showed some interesting results that came from looking at the covariates. Firms with a higher initial sales volume have lower expected sales and employment growth rates. This holds true when Phase II recipients were compared to Non-Recipient firms. It is not surprising that a higher initial sales volume lowers the growth rate in general.

For both "treated groups," firms with more employees at the time of application to SBIR have a higher expected sales growth than smaller firms. This growth may come from larger firms having an active and effective sales force compared to smaller firms. While initial firm size affected sales growth rate positively, on the contrary, I did not find that it had any effect on the employment growth rate.

Contrary to my expectations, firms in both treatment groups that have multiple state locations at the time of application to SBIR have lower expected sales and employment growth rates. This may be the result of irregularities in management or operations. As our sample consists of small businesses, we can conclude that there are difficulties in managing locations in multiple states. Similarly, if a firm changes the location of one or more of its establishments, sales and employment growth are expected to decrease.

For both treated groups, a firm's initial financial health or credit ratings affects the sales growth rate positively, but has not effect on the employment growth rate.

As shown in Table 21 below, the likelihood of receiving an SBIR award was roughly 50% for firms that first applied to the SBIR program at NIH in the years 1994-

1997. Firms with 1-5 employees at the time of application are the most active applicant group; firms with up to 10 employees account for over half of the total applications in this time period. As initial firm size grows, application interest in SBIR decreases. Perhaps the 500-employee limit for SBIR is too high. Firms with 200-500 employees, for instance, have completely different characteristics in terms of management structure, culture and innumerable other factors than firms with 1-10 employees. Perhaps the SBIR program could be amended to target firms with 50 or fewer employees.

Table 21: Breakdown of Applications According to Firm Size

No. of Employees		Applications	Phase I	Phase II	Total	Rejected
1-5	Employees	190	26	68	94	96
6-10	Employees	83	6	39	45	38
11-50	Employees	83	12	34	46	37
51-100	Employees	28	8	6	14	14
101-500	Employees	19	5	4	9	10

Among the applications shown above, 38 applications came from woman-owned small businesses, and 16 of these applications resulted in an SBIR award. Even though this number of applications is sadly small, when I examined the type of grants they received, the results were interesting. Of those 16 awards, 15 are Phase II awards, which means that only one project from a woman-owned firm did not reach the second phase of the SBIR program.

The SBIR program at NIH works according to its stated goals. Companies that received SBIR grants sold more, and hired more. Companies owned by women also recorded successes.

One shortcoming of this study is that only 427 of the 3595 firms that applied to SBIR at NIH for the first time between 1994 and 1997 were able to be matched to their sales and employment figures in the NETS database. This leaves 3168 firms which I could have included and observed if I had had sales and employment figures, making a much larger sample.

Additionally, I would have liked to compare those firms that only received one or more Phase I award to firms that received one or more Phase II awards. I was not able to do this because the data did not contain enough observations for Phase I-only recipients.

APPENDIX

REGRESSION RESULTS EQUATION (12)

Table A.1: Three Year Sales Growth with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.091***	4.60	1.061***	3.64	1.276***	3.97	1.198***	3.74
Award (All Recipients)	0.087***	2.65	0.070***	2.28	0.065**	2.13	0.068**	2.24
Employment in Application Year			0.001*	1.68	0.001**	2.39	0.001**	2.48
Log of Sales in Application Year			-0.076***	-3.49	-0.096***	-3.77	-0.092***	-3.62
Woman-owned			-0.003	-0.05	0.031	0.50	0.034	0.56
Minority-owned			-0.050	-0.64	-0.085	-1.09	-0.070	-0.96
Multiple State			-0.053	-0.73	-0.060	-0.95	-0.075	-1.12
Number of Establishments			0.084***	3.27	0.070**	2.74	0.067**	2.50
Venture Capital Before SBIR					0.216	1.04	0.239	1.25
Paydex Index					0.001**	1.97	0.001**	2.07
Location Change					-0.065*	-1.73	-0.067*	-1.68
Industrial Classification Change					0.057	1.34	0.053	1.10
Northeast							0.046	0.79
South							0.063	0.89
West							0.091	1.61
Chemicals and Allied Products							-0.104	-1.11
Instruments & Related Products							-0.020	-0.20
Engineering & Management Services							-0.019	-0.24
Number of Observation	353		353		353		353	
F statistic	7.01		.		.		.	
Probability > F	0.0085		.		.		.	
R^2	0.0187		0.214		0.2652		0.2992	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.2: Five Year Sales Growth with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.072***	4.11	0.999***	4.11	1.176***	4.8	1.037***	4.21
Award (All Recipients)	0.056**	2.14	0.036	1.42	0.039	1.47	0.042	1.61
Employment in Application Year			0.000	0.88	0.000	1.16	0.000	1.29
Log of Sales in Application Year			-0.071***	-3.82	-0.090***	-4.77	-0.088***	-4.81
Woman-owned			-0.033	-0.8	-0.003	-0.08	-0.001	-0.03
Minority-owned			0.422	2.3	0.367**	2.15	0.386**	2.09
Multiple State			-0.271	-1.53	-0.295	-1.72	-0.320*	-1.82
Number of Establishments			0.068**	2.54	0.058**	1.99	0.051*	1.72
Venture Capital Before SBIR					0.043	0.22	0.076	0.44
Paydex Index					0.002***	3.37	0.002***	3.6
Location Change					-0.008	-0.25	-0.009	-0.29
Industrial Classification Change					0.067*	1.7	0.058	1.3
Northeast							0.108*	1.72
South							0.119*	1.8
West							0.137**	2.23
Chemicals and Allied Products							-0.034	-0.46
Instruments & Related Products							0.085	1.34
Engineering & Management Services							0.000	0
Number of Observation	329		329		329		329	
F statistic	4.59		.		.		.	
Probability > F	0.0328		.		.		.	
R^2	0.0136		0.1916		0.2502		0.2817	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.3: Eight Year Sales Growth with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.047***	3.36	0.790***	4.23	0.848***	4.65	0.820***	3.73
Award (All Recipients)	0.036*	1.71	0.020	1	0.020	1.05	0.023	1.19
Employment in Application Year			0.000*	1.73	0.000*	1.71	0.000	1.81
Log of Sales in Application Year			-0.057**	-4.04	-0.067***	-4.79	-0.066***	-4.31
Woman-owned			0.004	0.11	0.020	0.63	0.011	0.36
Minority-owned			-	-	-	-	-	-
Multiple State			-0.124	-1.26	-0.140	-1.59	-0.153*	-1.71
Number of Establishments			0.045***	2.65	0.035*	1.79	0.030	1.38
Venture Capital Before SBIR					0.098***	2.9	0.098**	2.08
Paydex Index					0.001***	3.49	0.001***	3.46
Location Change					0.023	0.93	0.024	0.97
Industrial Classification Change					0.045	1.62	0.036	1.24
Northeast							0.015	0.33
South							0.025	0.47
West							0.035	0.76
Chemicals and Allied Products							-0.025	-0.39
Instruments & Related Products							0.084	1.26
Engineering & Management Services							-0.009	-0.16
Number of Observation	287		287		287		287	
F statistic	2.94		5.28		6.95		4.15	
Probability > F	0.0877		0		0		0	
R^2	0.0097		0.2274		0.3044		0.3337	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.4: Three Year Employment Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.056***	3.78	0.382**	1.99	0.455**	2.15	0.429*	1.91
Award (All Recipients)	0.088***	3.71	0.071***	3.07	0.065***	2.84	0.063***	2.76
Employment in Application Year			0.000	-0.44	0.000	-0.25	0.000	-0.3
Log of Sales in Application Year			-0.025**	-1.76	-0.031*	-1.88	-0.029*	-1.73
Woman-owned			0.027	0.63	0.036	0.86	0.041	0.94
Minority-owned			-0.068	-0.76	-0.075	-0.8	-0.085	-0.87
Multiple State			-0.149**	-1.76	-0.147*	-1.7	-0.139	-1.53
Number of Establishments			0.039**	2.11	0.033*	1.72	0.033*	1.67
Venture Capital Before SBIR					0.135***	3.45	0.142***	3.31
Paydex Index					0.000	0.41	0.000	0.53
Location Change					-0.040	-1.26	-0.040	-1.19
Industrial Classification Change					0.031	1.08	0.028	0.86
Northeast							0.032	0.68
South							0.039	0.81
West							0.029	0.64
Chemicals and Allied Products							-0.006	-0.09
Instruments & Related Products							-0.073	-1.24
Engineering & Management Services							-0.023	-0.45
Number of Observation	353		353		353		353	
F statistic	13.77		.		.		.	
Probability > F	0.0002		.		.		.	
R^2	0.0365		0.1377		0.1655		0.1939	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.5: Five Year Employment Growth Rate Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.044***	3.35	0.368**	2.3	0.452**	2.49	0.351*	1.85
Award (All Recipients)	0.085***	4.14	0.067***	3.32	0.065***	3.1	0.064***	3.12
Employment in Application Year			0.000	-0.61	0.000	-0.37	0.000	-0.36
Log of Sales in Application Year			-0.025**	-2.02	-0.032**	-2.31	-0.031**	-2.21
Woman-owned			0.014	0.43	0.024	0.72	0.038	1.14
Minority-owned			0.110	1.03	0.099	0.94	0.090	0.79
Multiple State			-0.231**	-2.25	-0.239**	-2.29	-0.239**	-2.18
Number of Establishments			0.040**	2.31	0.037**	1.99	0.034*	1.78
Venture Capital Before SBIR					0.008	0.07	0.023	0.28
Paydex Index					0.000	1.1	0.001	1.43
Location Change					-0.022	-0.85	-0.023	-0.83
Industrial Classification Change					0.032	1.14	0.029	0.96
Northeast							0.099**	1.96
South							0.108**	2.12
West							0.099**	2.06
Chemicals and Allied Products							0.037	0.68
Instruments & Related Products							-0.035	-0.52
Engineering & Management Services							-0.015	-0.38
Number of Observation	329		329		329		329	
F statistic	17.11		.		.		.	
Probability > F	0		.		.		.	
R^2	0.0482		0.1951		0.2192		0.2633	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.6: Eight Year Employment Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.041***	4.15	0.310***	2.58	0.358***	2.83	0.283**	1.97
Award (All Recipients)	0.044***	2.71	0.032**	2.01	0.029*	1.81	0.031**	1.99
Employment in Application Year			0.000	0.18	0.000	0.45	0.000	0.29
Log of Sales in Application Year			-0.021**	-2.25	-0.025**	-2.49	-0.024**	-2.37
Woman-owned			0.020	0.78	0.026	1.04	0.034	1.36
Minority-owned			-	-	-	-	-	-
Multiple State			-0.058*	-1.65	-0.060	-1.51	-0.061	-1.32
Number of Establishments			0.023**	2.17	0.020*	1.76	0.022*	1.77
Venture Capital Before SBIR					0.040	0.5	0.017	0.23
Paydex Index					0.000	0.77	0.000	0.87
Location Change					-0.023	-1.15	-0.024	-1.24
Industrial Classification Change					0.015	0.69	0.024	1.09
Northeast							0.038	0.96
South							0.038	0.89
West							0.034	0.88
Chemicals and Allied Products							0.057	0.99
Instruments & Related Products							-0.040	-0.58
Engineering & Management Services							0.023	0.43
Number of Observation	287		287		287		287	
F statistic	7.33		3.98		3.3		3.21	
Probability > F	0.0072		0		0		0	
R^2	0.023		0.17		0.2248		0.2878	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.7: Three Year Sales Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.091***	4.6	1.061***	3.63	1.276***	3.96	1.198***	3.71
Award (Phase II)	0.093**	2.56	0.071**	2.06	0.051	1.5	0.055	1.62
Employment in Application Year			0.001*	1.68	0.001**	2.38	0.001**	2.46
Log of Sales in Application Year			-0.076***	-3.48	-0.096***	-3.75	-0.092***	-3.59
Woman-owned			-0.003	-0.05	0.031	0.5	0.034	0.55
Minority-owned			-0.050	-0.64	-0.085	-1.08	-0.070	-0.96
Multiple State			-0.053	-0.73	-0.060	-0.94	-0.075	-1.11
Number of Establishments			0.084***	3.26	0.070***	2.73	0.067**	2.48
Venture Capital Before SBIR					0.216	1.03	0.239	1.24
Paydex Index					0.001**	1.96	0.001**	2.06
Location Change					-0.065*	-1.72	-0.067	-1.67
Industrial Classification Change					0.057	1.33	0.053	1.09
Northeast							0.046	0.79
South							0.063	0.88
West							0.091	1.6
Chemicals and Allied Products							-0.104	-1.1
Instruments & Related Products							-0.020	-0.2
Engineering & Management Services							-0.019	-0.24
Number of Observation	309		309		309		309	
F statistic	6.56		.		.		.	
Probability > F	0.0109		.		.		.	
R^2	0.0219		0.2182		0.2927		0.3293	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.8: Five Year Sales Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.072***	4.11	0.999***	4.1	1.176***	4.78	1.037***	4.17
Award (Phase II)	0.070***	2.64	0.042	1.54	0.038	1.32	0.042	1.49
Employment in Application Year			0.000	0.88	0.000	1.15	0.000	1.28
Log of Sales in Application Year			-0.071***	-3.81	-0.090***	-4.75	-0.088***	-4.77
Woman-owned			-0.033	-0.79	-0.003	-0.07	-0.001	-0.03
Minority-owned			0.422**	2.29	0.367**	2.13	0.386**	2.08
Multiple State			-0.271	-1.53	-0.295*	-1.71	-0.320*	-1.8
Number of Establishments			0.068**	2.54	0.058**	1.98	0.051*	1.71
Venture Capital Before SBIR					0.043	0.21	0.076	0.44
Paydex Index					0.002***	3.35	0.002***	3.58
Location Change					-0.008	-0.25	-0.009	-0.29
Industrial Classification Change					0.067*	1.69	0.058	1.29
Northeast							0.108*	1.71
South							0.119*	1.79
West							0.137**	2.21
Chemicals and Allied Products							-0.034	-0.46
Instruments & Related Products							0.085	1.33
Engineering & Management Services							0.000	0
Number of Observation	288		288		288		288	
F statistic	6.96		.		.		.	
Probability > F	0.0088		.		.		.	
R^2	0.024		0.2221		0.3086		0.3382	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.9: Eight Year Sales Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.047***	3.36	0.790***	4.22	0.848***	4.63	0.820***	3.7
Award (Phase II)	0.052**	2.28	0.029	1.36	0.025	1.17	0.029	1.39
Employment in Application Year			0.000*	1.73	0.000*	1.7	0.000*	1.8
Log of Sales in Application Year			-0.057***	-4.02	-0.067***	-4.77	-0.066***	-4.27
Woman-owned			0.004	0.11	0.020	0.63	0.011	0.36
Minority-owned			-	-	-	-	-	-
Multiple State			-0.124	-1.26	-0.140	-1.58	-0.153*	-1.69
Number of Establishments			0.045***	2.64	0.035*	1.78	0.030	1.36
Venture Capital Before SBIR					0.098***	2.88	0.098**	2.06
Paydex Index					0.001***	3.47	0.001***	3.43
Location Change					0.023	0.93	0.024	0.96
Industrial Classification Change					0.045	1.61	0.036	1.23
Northeast							0.015	0.32
South							0.025	0.47
West							0.035	0.75
Chemicals and Allied Products							-0.025	-0.38
Instruments & Related Products							0.084	1.24
Engineering & Management Services							-0.009	-0.16
Number of Observation	251		251		251		251	
F statistic	5.2		5.7		7.57		4.81	
Probability > F	0.0234		0		0		0	
R^2	0.0206		0.2603		0.3542		0.3844	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively

Table A.10: Three Year Employment Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.105***	4.03	0.382**	1.98	0.455**	2.14	0.429*	1.89
Award (Phase II)	0.056***	3.78	0.079***	3.12	0.068**	2.51	0.066**	2.4
Employment in Application Year			0.000	-0.44	0.000	-0.25	0.000	-0.3
Log of Sales in Application Year			-0.025*	-1.75	-0.031*	-1.87	-0.029*	-1.71
Woman-owned			0.027	0.63	0.036	0.85	0.041	0.93
Minority-owned			-0.068	-0.76	-0.075	-0.8	-0.085	-0.86
Multiple State			-0.149*	-1.76	-0.147*	-1.69	-0.139	-1.51
Number of Establishments			0.039**	2.11	0.033*	1.71	0.033**	1.66
Venture Capital Before SBIR					0.135***	3.44	0.142***	3.29
Paydex Index					0.000	0.41	0.000	0.52
Location Change					-0.040	-1.25	-0.040	-1.18
Industrial Classification Change					0.031	1.07	0.028	0.85
Northeast							0.032	0.67
South							0.039	0.8
West							0.029	0.64
Chemicals and Allied Products							-0.006	-0.09
Instruments & Related Products							-0.073	-1.23
Engineering & Management Services							-0.023	-0.45
Number of Observation	309		309		309		309	
F statistic	16.28		.		.		.	
Probability > F	0.0001		.		.		.	
R^2	0.0523		0.1396		0.1712		0.1953	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.11: Five Year Employment Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.044***	3.35	0.368**	2.29	0.452**	2.48	0.351*	1.83
Award (Phase II)	0.106***	4.92	0.076***	3.41	0.070***	2.81	0.069***	2.82
Employment in Application Year			0.000	-0.6	0.000	-0.37	0.000	-0.36
Log of Sales in Application Year			-0.025**	-2.02	-0.032**	-2.3	-0.031**	-2.2
Woman-owned			0.014	0.43	0.024	0.71	0.038	1.13
Minority-owned			0.110	1.03	0.099	0.94	0.090	0.79
Multiple State			-0.231**	-2.25	-0.239**	-2.28	-0.239**	-2.16
Number of Establishments			0.040**	2.3	0.037**	1.98	0.034*	1.76
Venture Capital Before SBIR					0.008	0.07	0.023	0.28
Paydex Index					0.000	1.09	0.001	1.42
Location Change					-0.022	-0.85	-0.023	-0.83
Industrial Classification Change					0.032	1.13	0.029	0.96
Northeast							0.099*	1.94
South							0.108**	2.11
West							0.099**	2.04
Chemicals and Allied Products							0.037	0.68
Instruments & Related Products							-0.035	-0.51
Engineering & Management Services							-0.015	-0.37
Number of Observation	288		288		288		288	
F statistic	24.23		.		.		.	
Probability > F	0		.		.		.	
R^2	0.0801		0.2252		0.2602		0.2988	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

Table A.12: Eight Year Employment Growth Rate with Interaction Terms

	Model A		Model B		Model C		Model D	
Covariates	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic	Estimate	*t*-statistic
Constant	0.041***	4.15	0.310***	2.57	0.358***	2.82	0.283*	1.95
Award (Phase II)	0.060***	3.47	0.038**	2.26	0.032*	1.82	0.034**	1.98
Employment in Application Year			0.000	0.18	0.000	0.45	0.000	0.28
Log of Sales in Application Year			-0.021**	-2.25	-0.025**	-2.47	-0.024**	-2.35
Woman-owned			0.020	0.78	0.026	1.03	0.034	1.35
Minority-owned			-	-	-	-	-	-
Multiple State			-0.058*	-1.64	-0.060	-1.5	-0.061	-1.31
Number of Establishments			0.023**	2.16	0.020**	1.75	0.022*	1.76
Venture Capital Before SBIR					0.040	0.5	0.017	0.23
Paydex Index					0.000	0.76	0.000	0.86
Location Change					-0.023	-1.15	-0.024	-1.23
Industrial Classification Change					0.015	0.68	0.024	1.08
Northeast							0.038	0.95
South							0.038	0.88
West							0.034	0.87
Chemicals and Allied Products							0.057	0.98
Instruments & Related Products							-0.040	-0.57
Engineering & Management Services							0.023	0.43
Number of Observation	251		251		251		251	
F statistic	12.04		3.83		3.31		3.98	
Probability > F	0.0006		0		0		0	
R^2	0.0465		0.1839		0.2451		0.2985	

***, **, and * represent statistical significance at the 1%, 5%, 10% levels, respectively.

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