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# The effect of Six Sigma on corporate performance in the manufacturing and service sectors

Luis F. Ojeda
*Purdue University*

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Dr. Edie Schmidt

Dr. Chad Laux

Dr. Regena Scott

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THE EFFECT OF SIX SIGMA ON CORPORATE PERFORMANCE IN THE MANUFACTURING AND SERVICE SECTORS

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To my wife, Aura – for her love and unconditional support.

To my children, Luis and Diego – for being my inspiration.

To my parents, Luis and Olga – for their love and for being my role models.

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# ABSTRACT

Ojeda, Luis F. M.S., Purdue University, December 2014. The Effect of Six Sigma on Corporate Performance in the Manufacturing and Service Sectors. Major Professor: Edie Schmidt.

As global competition becomes more intense, organizations try to implement strategies that allow them become more efficient, increase quality and productivity, and stay ahead of their competition. Over the years, there have been different programs or methodologies that companies have adopted with the purpose of achieving enhanced operational performance and bottom line impact. Six Sigma is one of the strategies that have gained more popularity during recent years, being adopted by companies in both manufacturing and service. There have been numerous claims by adopting companies about the financial benefits of implementing Six Sigma. However, the number of studies conducting empirical research to back those claims is limited.

The purpose of this study was to evaluate whether Six Sigma impacts corporate performance and the extent to which that impact is similar for manufacturing and service companies. The study was conducted by selecting a sample of 48 companies, within the manufacturing and service sectors, and assessing the effect of Six Sigma adoption by comparing their financial performance with the performance of control companies that did not implement Sig Sigma, during a period of 8 years after implementation.

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The statistical results provided evidence to conclude that Six Sigma has a positive effect on financial performance in the long term, showing significant results for years 7 and 8 after implementation, with the sample companies outperforming their corresponding control companies for these periods of time. The results were consistent in both manufacturing and service for year 8, validating that the impact of Six Sigma is similar for both sectors.

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# CHAPTER 1. INTRODUCTION

This chapter provides the background and introduction to this research, defines the problem statement, research question, scope, significance and establishes the research boundaries through the definition of the assumptions, limitations and delimitations. It also contains some key definitions.

## 1.1 Background

Over the years, the global economy has turned into a highly competitive playfield where organizations have to look for creative ways to get ahead of their competition and achieve sustainable growth in the long term. As companies try to gain competitive advantage, they strive for reaching higher productivity levels and exceeding customer expectations by providing high quality products and services that outperform those of their competition. In the hope of getting on the path of high levels of quality, customer satisfaction and profitability, many firms have embarked in different programs that require tremendous efforts as well as the commitment of considerable amounts of resources and the time of individuals at different levels of the organization.

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For many years, initiatives like ISO certifications, Total Quality Management (TQM), Just in Time, among others, have been adopted in different industries, obtaining results that vary from a company to another. More recently, initiatives like Six Sigma and Lean Manufacturing have become more popular, and there are plenty of reports from companies that claim to have achieved unprecedented savings associated with their implementation. In the case of Six Sigma particularly, after its inception in the mid-1980s by Motorola, an increasing number of organizations from diverse industries have adopted this methodology and have reported to achieve enhanced performance levels as a direct result of its implementation. There is much research regarding different aspects of Six Sigma, such as investigating the main factors that organizations consider to be critical for adoption of the program, and whether the size of an organization may have a significant effect on the results of implementation. However, there is a need to investigate whether the claims of financial benefits from organizations who have adopted the program can be substantiated, and how consistent those benefits are across different industries. This constitutes the basis of this research study.

## 1.2 Statement of Purpose

The adoption of Six Sigma methodology in organizations is a practice that has been significantly increasing in the US during recent years. Six Sigma is widely recognized as a customer oriented, statistical driven, problem solving methodology, and its implementation and deployment has been associated with the success of diverse organizations. Many companies have reported significant operational and financial benefits coming from the adoption of this methodology. High profile manufacturing

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companies such as Motorola and GE claim to have saved billions of dollars by implementing Six Sigma. Although there has been some research showing the positive impact that adopting Six Sigma has on corporate performance in general, it is not clear whether the magnitude of this impact is similar across organizations in different industries. Six Sigma was initially created in the manufacturing industry; however, over the years, it has extended to the service sector and claims indicate that the benefits can be equally achieved in both sectors. The purpose of this study was to evaluate whether Six Sigma impacts corporate performance and the extent to which that impact is similar for manufacturing and service companies.

## 1.3 Research Question

The primary question to this research is:

- Is there a difference in the impact of Six Sigma implementation on corporate performance among US organizations in the service sector and firms in the manufacturing sector?

## 1.4 Scope

There is no doubt that there are numerous benefits for organizations adopting structured methodologies such as Six Sigma to drive quality improvement. Many firms have made these programs an integral part of their operations and their culture, claiming remarkable positive results at an operational level and significant impact to their bottom lines.

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There is existing research that supports some of these claims. However, only a portion of this research has been conducted using a rigorous data driven approach, and in those cases, these results show the impact on organizations in general, with no consideration of the nature of the business. Shafer and Moeller (2012) conducted an empirical investigation to assess the impact of Six Sigma on firm performance, using sample comprised of companies from diverse industry groups. Following a similar approach, a study by Schroeder, Linderman, Liedtke and Choo (2008), selected companies from manufacturing and service to support an emergent theory that could potentially apply to both industries.

This study investigates whether the impact of the adoption of Six Sigma on corporate performance significantly differs between the US manufacturing and services sectors. The service companies subject of this study are in diverse areas such as healthcare, electrical services, financial services, insurance, retail, hotels and automobile rental. Manufacturing companies comprise a wide range of industry groups such as food manufacturing, computers, electronics, and automobiles, among others. A detailed list of the SIC codes that comprise the study is presented in table 4.1. The study utilizes commonly used financial measures to compare the corporate performance of sample companies that have implemented Six Sigma, before and after the adoption of the program, through the use of statistical testing. It shows a comparison between the sample companies selected control groups, and the results are contrasted between the two sets of companies (Barber &Lyon, 1996; Shafer & Moeller, 2012; Swink & Jacobs, 2012). In addition, the study evaluates the effect on performance in the short term, mid-term and a longer term periods.

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## 1.5 Significance

Six Sigma, like other quality programs such as TQM, has been widely applied in different industries and there is a large amount of unsubstantiated evidence intended to support the idea of numerous organizations benefiting from the use of these methodologies (Linderman et al., 2003). Most of the research in this field presents findings for the multitude of firms adopting the program, and the existing empirical evidence does not examine whether there is any difference on the degree to which Six Sigma impacts corporate performance in different industry sectors.

Research comparing the difference in performance between both sectors is limited. This study contributed to existing research in two ways: first, by showing data driven evidence about the extent to which organizations implementing Six Sigma have been able to reap the financial benefits of implementation, improving corporate performance, and second, by comparing the results between the manufacturing and service sectors and drawing conclusions. The period of study was expanded to 8 years after implementation, which provides a good basis to evaluate long term effect. The study presents as well a review of the Critical Success Factors and unique challenges for implementation facing the service sector, providing a succinct theoretical framework for practitioners to understand some of the factors that need to be considered for Six Sigma implementation in a service organization, compared to one in manufacturing.

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## 1.6 Assumptions

The assumptions associated with this study were: The data reported to Compustat ("Compustat from Standard and Poor's", n.d.) by the firms included in this study was accurate and reflected their actual financial performance.

1. The companies that comprised the sample, effectively implemented Six Sigma and continued with the program during the term selected for this study.
2. The industry performance matching method for establishing sample firm pre-adoption performance was appropriate for the purpose of isolating Six Sigma impact, according to previous research conducted by Barber and Lyon (1996).
3. The companies selected as industry performance benchmark (control groups) of the sample firms have not adopted a Six Sigma program.
4. The sample size was sufficient to conduct the statistical analysis required to test the hypotheses inherent to this research.
5. The research method chosen was appropriate to answer the research question subject of this study
6. The time period of study was sufficient to assess profitability in the short, mid and long terms.

## 1.7 Limitations

The limitations associated with this study were:

1. The study was conducted considering publicly traded firms that have made public their implementation of Six Sigma.

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2. Corporate performance was assessed by using Return on Assets (ROA) at the Operating Income level, a commonly used metric. No other financial metrics were used. Barber and Lyon (1996), state that ROA is the most common metric used in abnormal performance studies.
3. The time period of study was limited to eight years post implementation.
4. Sample firms control groups were selected by using SIC classification codes and considering a factor of 25 compared to the sample firms' total assets. This factor was suggested by Swink and Jacobs (2012) in a previous study.

## 1.8 Delimitations

The delimitations associated with this study were:

1. The study did not examine whether adoption of Six Sigma at sample firms was done in combination with any other program such as Lean, TQM or ISO certifications.
2. The study did not explore factors driving the success of Six Sigma implementation and their impact on corporate performance.
3. This research did not include an assessment of the sophistication of the quality system at the companies under study before the adoption date.
4. The study did not include an analysis about whether there is any effect of early versus most recent implementation on the performance of sample firms.
5. The sample did not include private companies for which financial data is not readily available and company size was not factored in during sample selection.

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6. The study does not include foreign companies that do not have operations in the US.
7. The extent to which Six Sigma was implemented throughout an entire organization or partially implemented was not controlled for on this study.

## 1.9 Definition of Key terms

Black Belt – a Six Sigma highly trained professional that leads six sigma teams. Typically dedicated to projects on a full time basis. Trains and coaches project teams (Breyfogle, 2003)

Critical Success Factor (CSF) – an element that is necessary for an organization or project to achieve its mission. It is a critical factor or activity required for ensuring the success of a company or an organization (Ahmad, 2013).

Compustat Annual Industrial File – a database of fundamental and market information on thousands of active and inactive publicly held global companies ("Compustat from Standard & Poor's", n.d.).

Green Belt – a Six Sigma trained professional that typically addresses projects confined to their functional area and is dedicated to improvement projects in a part-time role. (Breyfogle, 2003)

Mann Whitney Test – a non-parametric test used to test of the equality of two population medians. It is used for independent groups and non-normality assumptions are required. (Whitley & Ball, 2002)

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Manufacturing Sector – comprises entities dedicated to the transformation of materials, substances, or components into new products, through the use of mechanical, physical, or chemical methods ("About the Manufacturing sector", n.d.).

Operating Income (OI) – Gross income minus operating expenses, which includes depreciation and amortization. It shows the profit made from running the business (Berman, Knight, & Case, 2006).

Return on Assets (ROA) – the ratio of income to average total assets (Ross, Westerfield, & Jaffe, 1999).

Service Sector – comprises all industries except those that produce goods, agricultural, mining, construction and manufacturing. It includes companies in wholesale and retail, financial services, banks, insurance, transportation, logistics, among others. (Kutscher & Mark, 1986)

Sign Test – a non-parametric test used to compare the median of a population with a hypothesized value. It can be used with either a single sample or a paired sample. There are no requirements of normality or symmetry assumptions. (Whitley & Ball, 2002).

Six Sigma – an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates (Lindeman, Schroeder, Zaheer, & Choo, 2003).

Ticker Symbol – an arrangement of characters used to uniquely identify shares of a particular stock traded publicly. It may consist of letters, numbers or a combination of both ("Ticker Symbol", n.d.).

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Total Quality Management (TQM) – a continuously changing managing system, which is comprised of values, methodologies and tools, the aim of which is to increase external and internal customer satisfaction with a reduced amount of resources (Hellsten & Klefsjö, 2000).

Wilcoxon Sign Rank Test – a non-parametric test used to compare the median of a population with a hypothesized value. It can be used with either a single sample or a paired sample. Assumes symmetry of the data (Whitley & Ball, 2002).

## 1.10 Summary

This chapter provides an overview of the research study. The chapter includes background, significance, scope, statement of purpose, research question and key terms definitions. It also includes the specifics aspects that define the boundaries of the study: assumptions, limitations and delimitations. The next chapter provides an overview of Six Sigma, establishes a comparison between Six Sigma and TQM and describes the adoption of Six Sigma in the manufacturing and the service sectors, highlighting the unique challenges facing service organizations.

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# CHAPTER 2. LITERATURE REVIEW

This literature review presents an overview of Six Sigma, and shows a comparison of this methodology with Total Quality Management (TQM), with the purpose of explaining why Six Sigma has prevailed over TQM. The chapter contains a review of some of the research conducted on the Critical Success Factors (CSFs) for the implementation of Six Sigma and presents the challenges facing the service sector on the adoption of the methodology, and how organizations have been able to obtain substantial benefits from its implementation.

## 2.1 Introduction

For many years, organizations have sought different ways of becoming more competitive, efficient and hence, more profitable. There have been numerous programs used with this purpose, some more effective than others, but the goal is to embrace organizational excellence and outstanding customer satisfaction, with the aim to make firms sustainably competitive with long term growth and profitability.

One means of attaining high levels of customer satisfaction is to ensure that the requirements of the service or product are met, as a minimum, or exceeded. This entails a focus on achieving quality levels that allow the products or services to stand out from those of the competitors and, in turn, enable organizations to get a competitive advantage.

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Six Sigma has been around for more than 20 years, and it is known for its strength to dramatically improve quality and efficiency, which in turn brings along enhanced organization performance, both from an operations and a financial standpoint. As this methodology becomes more popular, further research helps scholars and practitioners learn more about whether the claims regarding the benefits it provides are realistic, and what are the critical factors for its effective implementation and sustainability.

## 2.2 Six Sigma Overview

Six Sigma methodology was created by Motorola in 1985 and, since then, it has been growing in popularity in the industry. There have been multiple definitions of Six Sigma since its inception. Although there is plenty of literature in books, magazines, case studies and websites that defines Six Sigma, it is not usual to find a common definition from practitioners or scholars (Hahn, Hill, Hoerl, & Zinkgraf, 1999). Six Sigma can be defined from two different points of view. First, from a technical standpoint, it means that variability of a process is operating at a Six Sigma level, in other words, "the name Six Sigma suggests a goal of 3.4 defects per million opportunities" (Linderman, Schroeder, Zaheer, & Choo, 2002, p. 193). Second, it can be defined from a process management point of view. The following definition contains some of its fundamental principles: "Six Sigma is an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates" (Linderman et al., 2003, p. 195).

A more comprehensive definition introduces the concept of understanding the needs of the customer (Pande, Neuman, & Cavanagh, 2000), which is one of the key foundations for the success of Six Sigma. However, some practitioners and scholars argue that a comprehensive definition must include the efficiency orientation of Six Sigma and the performance effect on the bottom line of organizations adopting it, instead of merely focusing on the aspect related to the application of quality tools for defect reduction and process improvement. This idea is summarized by defining Six Sigma as a methodology to achieve continuous improvement with focus on customer satisfaction, business process improvement and increased profitability (Breyfogle, 2003). Despite the numerous existing definitions, the underlying concept remains that Six Sigma is a well-structured, data-driven statistical based methodology that drives process improvements and enhances corporate financial performance.

Some argue that Six Sigma has nothing new to offer and that it is a repackaged program based on previously existed quality tools, being no more than a corporate fad (Clifford, 2001). However, Pande et al. (2000) maintain that Six Sigma is a flexible system that enhances business performance. Moreover, there are plenty of testimonials about the innumerable benefits brought by its application, and many leading firms known to have been high quality conscious, claim that adopting Six Sigma led to a transformation of their organizations (Schroeder, Linderman, Liedtke, &Choo, 2008).

Six Sigma was created by engineers at Motorola in the mid-1980s, with the purpose of improving quality and process performance. After establishing the methodology company wide, it permeated its entire culture, which led to a period of extraordinary growth and remarkable sales. According to Breyfogle (2003), a few years

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later the company obtained the Malcom Baldrige National Quality Award. Many other organizations have adopted Six Sigma since then. As pointed out by Eckes (2001), Allied Signal and Texas Instruments followed with implementation, reporting double digit growth in sales. General Electric stated that by adopting Six Sigma, the company had significantly increased its profit margin (Pande et al., 2000). Nowadays, the number of organizations using this methodology has grown notably and it seems to continue to gain popularity, as businesses rely more on quality, efficiency and productivity to compete in the global economy. Although not much scholarly research has been conducted, some proceedings, conference presentations and research papers have started to emerge (Schroeder, Linderman, & Zhang, 2009). Moreover, Schroeder et al. (2008) suggest that scholarly fact-based research, based on peer reviewed articles and books, is required to have a much better understanding of Six Sigma.

## 2.3 Total Quality Management and Six Sigma

In the search for superior quality and improved performance, organizations have sought quality tools and methodologies that contribute in a sustainable manner to a process of knowledge creation and continuous improvement. Programs such as ISO 9000, Lean Manufacturing, Just in Time and Total Quality Management (TQM) have been the subject of study and implementation in numerous organizations. One of the most popular and widely implemented programs in the 1990s was TQM, a management approach with a focus on customer satisfaction by promoting continuous process improvement throughout the organization. Hansson and Eriksson (2002) refer to different studies that show mixed results regarding the impact of TQM on financial performance. Despite its

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initial widespread popularity, there has been skepticism about effectiveness of TQM in terms of generating profit increase and impacting organizational performance (Hendricks & Shingal, 1997). Although in many organizations TQM evolved into other different quality efforts over time, including Six Sigma, some others still keep it as an integral part of their operations.

One of the lingering questions around the adoption of quality programs is whether the results are worth the effort and investment. Are organizations able to capitalize on the benefits associated with these programs and realize an impact to the bottom line? There has been some research attempting to answer this and other questions regarding the extent to which organizations get an effective payback from the commitment of time, money and effort to adoption of these programs (Swink & Jacobs, 2012; Kessler & Padula, 2002; Shafer & Moeller, 2012).

Taking quality award winning companies as a basis for sample selection, under the premise that a firm would be awarded such recognition after the implementation of TQM, some research studies show empirical evidence that answer these questions. As an example, a study performed by Hendricks and Shingal (1997), showed evidence that effective implementation of TQM has a positive impact on operational performance. Another study, conducted by Hansson and Ericksson (2002) on a group of Swedish quality award recipients, showed that these companies outperformed their control groups of competitors in most of the financial performance indicators established in the study. Despite this, and some additional evidence from other studies, the question arises about why TQM seems to have faded over the years. Although some companies still rely on

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their TQM programs for process improvement initiatives, the visibility of these efforts is much lower than it was in the 1990s (Pande et al., 2000)

There are diverse factors contributing to either the success or failure of TQM implementations. Taylor and Wright (2003) attributed the success of TQM to some critical factors such as the time since the program was first implemented, the alignment of the program with strategic planning, the commitment of senior management and the involvement of all employees in the implementation process. Despite these considerations, there seems to be a trend over the years to leave behind the TQM practices to switch to a more popular strategy like Six Sigma. For many companies, failing to apply or maintain the aforementioned critical elements of the program contributed to the failure of TQM as an integral part of their culture and operation for the long run.

However, there were other drawbacks that detracted from the original purpose of TQM. In comparing both methodologies, some scholars and practitioners agree that there are key differences that have made Six Sigma more powerful performance improvement methodology more widely applied in different industries. According to Antony (2009), despite the common characteristics between the two programs, there are some critical differences that make Six Sigma a more robust strategy. One major conclusion of his study points out that unlike TQM, Six Sigma provides the necessary leadership, infrastructure and structural approach that allow for successful implementation and deployment across the different business units.

An analysis presented by Pande et al. (2003) describes the key factors negatively impacting the long term preponderance of TQM and compares them with key

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characteristics of Six Sigma that make it more successful. This comparison is summarized as follows:

1. TQM is not integrated to the business strategy and performance goals of the organization, assigning this function to a particular functional group (i.e., quality department). Six Sigma, on the other hand, is part of the core process of operating managers, making it part of the daily activities.
2. In many firms, although there was management involvement in TQM programs, there was some skepticism in the program or the quality initiatives lacked the firm support of the company's leadership. Six Sigma companies show, not only top management commitment, but a drive to transform the business to be able to continue to achieve success.
3. The TQM concept was not clearly defined and seemed vague to many people. Discussing quality philosophy created a lot of confusion. Although Six Sigma is also a concept that may create a similar situation, organizations have made an effort to consistently convey to their people the clear message that it is a customer focused improvement effort with a basis on data analysis and statistical methods.
4. The absence of a clear goal across the organization and metrics to measure the progress toward that goal was a clear pitfall for TQM. Concepts like "meeting or exceeding customer expectations" or goals like "zero defects" were somewhat unrealistic and did not set a clear direction. Even though Six Sigma goals are really ambitious: 3.4 defects per million opportunities, they are still

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realistic, the progress towards its achievement can be tracked and, more importantly, can be associated with impact to the bottom line.

5. Even though TQM has an emphasis on the use of quality tools, there was a tendency to make people indistinctively use those tools, with little flexibility to discern whether they were appropriate to tackle different problems. A major drawback was the use of inappropriate tools to analyze quality problems, sometimes more complex and sophisticated than required. Also, many of those tools were used by people that did not have the expertise or adequate training, which created frustration and deviation from the expected results. Due to the fact that Six Sigma is integrated in the core of the business, it requires not only technical expertise but a different set of skills to be able to tie the program to business strategy and performance. Problems are solved by adopting the appropriate tools, without having to abide to strict rules set by the program.
6. The "total quality" concept of TQM was intended to transform the organization into an entity driven by continuous improvement as a whole. However, in reality there was a lot of departmental work done in isolation. This tends to cause duplication of efforts and loss of focus in terms of the ultimate goal: improve the performance of the organization. Although Six Sigma may be prone to suffer from the same issue, there has been a big effort shown by successful Six Sigma to eliminate silos and emphasize business process management, as opposed to individual departmental efforts.

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7. Reliance mostly on small improvements to drive change in the organization without much attention to radical changes made some corporate leaders impatient about the benefits being attained by TQM adoption. Six Sigma recognizes that small and large changes are important, but the fact that it is considered an instrument to achieve transformation of the organization implies recognition of how critical it is for firms to be open to significant changes.
8. If not a general trend, many companies failed to appropriately train their employees, focusing more on teaching them only tools and techniques. Because the focus was put on improvement efforts not necessarily in their work area, little emphasis was made on how to identify and tackle problems and achieve improvements within their own work area, which is an example of the program's lack of integration. A commonly used metric to measure success of the program was the number of people trained. Although training is instrumental in the adoption of any quality based performance improvement methodology, focusing the effort to achieve the most benefits is equally important. The organizational structure of Six Sigma, based on Champions, master black belts, black belts and green belts, guarantees that the improvement efforts are managed by highly trained specialists. And, although additional personnel receive training, they are all under the direction of these experts.
9. Despite the intention of a focus on "total" quality within organizations, most of the focus of TQM was on manufacturing processes, usually neglecting

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> other critical service areas such as sales, logistics and marketing. Besides manufacturing, the area where Six Sigma originated, it has been shown to work in service areas, so its application clearly has a more complete approach in terms of the total organization, compared with TQM.

The following statement supports the preceding analysis: "Six Sigma is not the same as other quality initiatives such as TQM due to various misconceptions among many quality practitioners of these two philosophies" (Antony, 2006, p. 234). The findings of this study corroborate some of the differences described above, and provide evidence that Six Sigma is an overall more effective program than TQM. The following statement summarizes the key difference between both initiatives regarding corporate performance focus: "contrary to TQM, the primary drivers leading to Six Sigma adoption are the financial results that have already adopted, as opposed to the original intent of TQM, that aimed at creating a Quality Management System, team involvement, cost reduction, customer satisfaction, safety and moral benefits, which, put together could eventually result in financial improvements" (Kessler & Padula, 2002, p. 12).

The factors described above, particularly regarding successful Six Sigma implementation, have been subject of research by various authors, arriving at the conclusion that many of them are key to success. Antony and Banuelas (2002) conducted a research study where different Six Sigma organizations ranked some of the critical success factors (CSFs) for a fruitful adoption of the program, with the following aspects resulting the top four priorities in terms of importance and contribution to success: a) The commitment of top management and different levels of leadership of the organization to the program, b) A clear understanding of the methodology, the statistical tools associated,

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and how to apply them in different situations, along with and a clear understanding of the metrics in place to determine whether the performance objectives are being met,
c) Linking Six Sigma to the business strategy, so performance improvement is achieved, instead of individual improvements through isolated projects and d) Linking Six Sigma to customers, which is the basis for converting the Voice of the Customer (VOC) into Critical to Quality (CTQ) factors, and establishing priorities. The factors that ranked least important in the study were training and linking the program to human resources.

Although these factors are in line with the ones discussed on the literature from Pande et al. (2003), other studies have resulted in different priorities regarding the importance of success factors. A study by Sharma and Chetiya (2012), where a survey was applied to a sample of manufacturing companies in India, found that utilizing the right tools, managing innovation and establishing a system of mutual collaboration with the suppliers were considered top factors for success, considering management commitment and resource availability much less important.

Despite different results from some studies, the framework defining the CFSs for Six Sigma is robust, and companies already embarked into Six Sigma or considering its adoption have a guideline to consider in order to increase their chances of being successful and achieving the ultimate goal: creating value by enhancing the corporate performance of the firm.

## 2.4 Six Sigma in the Manufacturing and Service Sectors

Although Six Sigma was initially designed and adopted in the manufacturing sector, over the years, many service organizations have reported numerous benefits,

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including financial gains. Besides reports from manufacturers like Motorola, General Electric, Allied Signal, Eastman Kodak, Texas Instruments, ABB and many others (Breyfogle, 2003), companies in the service sectors like Bank of America, JP Morgan, American Express, City Bank, Zurich Financial Services, etc. (Antony, 2006) have adopted Six Sigma as an integral business performance strategy, claiming to have obtained major benefits as well.

Many of the principles and CFS's identified for manufacturing apply to service companies. However, researchers agree that there are challenges that are unique to the service sector. By understanding the differences between both sectors regarding Six Sigma applications, it is easier to realize what those challenges are. As pointed out by Antony (2004), there are key factors that influence the effectiveness of Six Sigma adoption in the manufacturing versus service sectors. Some of the main factors being: in manufacturing there are usually a set of numeric indicators that allow to track quality and process performance, whereas in service industry measurement is not a strong area. In manufacturing some quality tools were already available before Six Sigma implementation, such tools are not very common in services. There are more uncontrollable factors in service processes than in manufacturing. Soft factors such as human behavior seem to have a higher impact in service processes, which tends to have an impact on customer service.

A recent study by Chiarini (2013) points out some key findings in regards to remarkable differences in the application of Six Sigma in service organizations, compared those in the manufacturing sector. First, indicators in service firms are different, timeliness and lead time are key. Also, some soft indicators associated with human

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behavior, like empathy and courtesy, which are more significant in services, would be worth measuring, although it is not an easy task. Second, it is difficult to create databases because of the nature of some services that are not repeated on a frequent basis. Also, the lack of personnel with engineering or technical background makes it difficult to use sophisticated statistical tools, and limits the use of more simple tools such as cause and effect and Pareto diagrams. Third, traditional diagrams like Value Stream Map (VSM) are more suitable to manufacturing processes. Therefore practitioners need to develop tools for analyzing data and identifying problems that are more applicable to services. Another finding was that it is a common belief that Black and Green Belt training needs to be adapted to the needs of the service sector.

Most of these findings are in line with the ones highlighted by Antony (2004) and complement the idea that the adoption of Six Sigma in the service sector faces unique challenges. Nevertheless, there is a growing trend to incorporate Six Sigma as part of the business strategy of these companies. It seems like, no matter how challenging the implementation, the benefits are worth the effort, especially when the transformation of the companies leads them to unprecedented levels of performance, according to the evidence reported by adopting companies.

Shafer and Moeller (2012) indicate that there is plenty of anecdotal evidence associated with the benefits of Six Sigma, but little rigorous research about it. Their study consisted of comparing financial performance of companies that have adopted Six Sigma, before and after implementation. The research was conducted using the event study methodology, which assesses whether organizations have abnormal financial performance following a specific event (Peterson, 1989). The companies were compared

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to control groups comprised of firms within their industry, selected within the same SIC code. For this study, the samples were selected in an aggregate manner, with no differentiation in terms of company size. The results indicated that for the companies that had adopted Six Sigma, there was a positive effect on corporate performance.

Based on what has been exposed, the following question arises: are companies in the service sector achieving levels of improvement on corporate performance comparable with those in the manufacturing sector, despite the unique challenges they face? This question is addressed in this research study, using data driven empirical evidence to find an answer and draw conclusions that contribute to existing research.

## 2.5 Summary

The increasing need of for improving business performance, has led organizations to pursue different ways of attaining a competitive advantage to get ahead of the competition or, as a minimum, be able to remain competitive. For many years, adopting quality improvement tools and methodologies has been the focus of many companies. In the 1990s, TQM became a popular program, being implemented by many companies with the aim to achieved excellence in process management and continuous improvement.

However, some shortcomings of TQM led management of many organizations to either cut resources or drop the program completely, leaving the way to the adoption of Six Sigma, which is a more strategy based, data driven program that has proven to provide significant benefits. Six Sigma has gained popularity since its creation in the mid-1980s and nowadays many companies in both the manufacturing and the service sectors have made it an integral part of their operations.

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Due to differences in the nature of the service industry, compared with manufacturing, research shows that there are unique challenges that may lead to think that the opportunities of reaping the benefits are more limited for this sector. However, there are many service companies reporting significant financial benefits and the number of organizations using Six Sigma has increased notably. The next chapter provides an overview of the methodology used for the study, sample and data collection, hypotheses and associated statistical tests used.

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# CHAPTER 3. FRAMEWORK AND METHODOLOGY

This chapter outlines the methodology for this study, and explains the framework on which the research is based. The sample selection, data collection procedures, hypotheses, and the associated data analysis are described.

## 3.1 Research Framework

The purpose of this study was to determine the impact of Six Sigma on corporate performance and whether it is different in the manufacturing sector compared to the service sector for firms operating in the US. The research was based on the event study methodology, which is concerned with the effect that a specific event has on the financial performance of organizations.

The event study methodology consists of the following steps (Woon, n.d.):

1. Identify the event subject of the study and collect data for the sample organizations and the event date for each organization.
2. Establish a window of time for the study, clearly identifying the year of the event, and a pre and post event periods.
3. Select a portfolio of firms that was used as control group for each sample firm.
4. Identify the metrics to measure abnormal performance for the firms under study and calculate the change over the time period of study.

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5. Create the hypotheses and perform statistical analysis to test them.

This research followed the model recommended by Barber and Lyon (1996) to isolate the impact of Six Sigma adoption on the financial performance of the sample firms from temporary effects created by diverse factors, such as economic conditions, accounting practices or temporary shifts in demand. These factors create what is known as the mean reversion effect, by which the performance indicators of companies with abnormal temporary performance tend to reverse towards the population mean. For example if an organization has a good performance before Six Sigma adoption, the tendency to reverse to the mean might lead to the conclusion that the firm is performing poorly after adoption (Barber &Lyon, 1996).

There are some other factors that impact the performance of organizations. Company specific circumstances like strategic decisions, investment opportunities and managerial capabilities may create high or low financial returns. Based on their model, which consists of matching the sample firms under study to corresponding control groups in the same industry with similar pre-event performance, researchers were able to control for factors that would confound the effect of Six Sigma adoption. According to Barber and Lyon (1996) "By matching on performance, a researcher can control for various factors, unrelated to an event, that affect the operating performance of assets" (p. 366). One of the main conclusions of their study was that matching sample organizations with those that had a similar pre-event performance ensures that test statistics are well specified and robust, and that this is significantly more important that matching firms on other factors, like firm size for example.

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## 3.2 Methodology

The purpose of this study was to assess the impact of Six Sigma adoption on corporate performance and determine whether it is different in the manufacturing versus service sectors, so there were two considerations that needed to be evaluated. First, whether there was convincing evidence of an impact of adopting the program and, second, whether a difference exists on the level of this impact or both sectors are impacted similarly. In order to test these considerations, the following hypotheses were created:

Hypothesis 1:

Ho: Adopting Six Sigma has no effect on firm profitability

Ha: Adopting Six Sigma has a positive effect on firm profitability

Hypothesis 2:

Ho: The positive effect of adopting Six Sigma is the same for firms in the manufacturing sector compared to firms in the service sector.

Ha: The effect of adopting Six Sigma is different for firms in the manufacturing sector compared to firms in the service sector.

The procedure and appropriate statistical tools selected to test these hypotheses are described in the sections below.

The data to evaluate corporate performance for the sample firms and their respective control groups was gathered from the Compustat Annual Industrial File, which contains financial data for thousands of US and global companies. By using publically available audited financial data, the study allowed to overcome the limitations of using a survey methodology, such as: usually low response rates, biased or incomplete company

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reported financial data, lack of knowledge of survey respondents and questions misinterpretation.

## 3.3 Sample Selection

A series of web searches and other sources were used to compile a preliminary list of about 325 companies that were identified as adopters of Six Sigma. Although this list was not comprehensive, it included companies from different industries, sizes and with different years of adoption. This list was a starting point for defining the sample of Six Sigma firms. The next step in selecting the sample consisted in determining from the list, which companies actually implemented Six Sigma and their year of implementation. This was accomplished through systematic searches over the internet, trade publications, companies' websites, annual reports, and databases like Edgar SEC system, among other sources. A total of 52 publicly traded companies were identified to have public available information about adoption year, of which 48 had sufficient data available in Compustat, 32 in the manufacturing sector and 16 in the service sector. The sample firms were then classified by industry, by using SIC codes, which allowed to match each firm with their corresponding portfolio of similar performance firms, defined as control groups.

## 3.4 Time Period of Study

In order to assess the impact of adoption of Six Sigma on corporate performance, a period of 10 years was selected for the study. For each company, the year in which Six Sigma was adopted was designated as the event year or year 0, the remaining 9 years were be divided into two segments: one pre-event year, or years -1, , and eight post-event

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years, or years +1 through +8. Figure 3.1 illustrates the period of study for any given company.

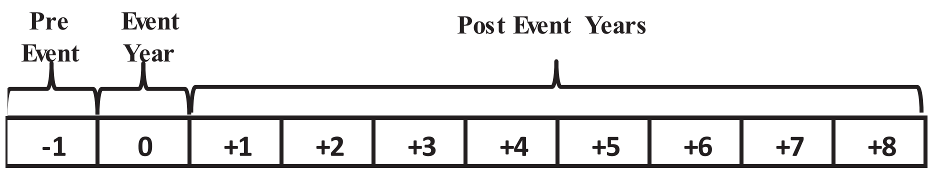


Figure 3.1. Time Period of Study

The purpose of looking into a pre-event year was to establish a firm performance baseline for comparison, before Six Sigma was implemented, by using data on year -1. The post-event years were used to compare the performance level to evaluate the impact as follows:

The change from year -1 to year +1, from year -1 to year +2, successively through year -1 to +8. This way the change in performance was assessed in the short, mid and long terms.

## 3.5 Measuring Corporate Performance

For the purpose of measuring financial performance, the Return on Assets (ROA) financial ratio was used. ROA is a widely used metric, and is calculated as Operating Income (OI) divided by total assets (TA). The reason for using operating income is that it is considered a better measure of firm performance compared to Net Income, as it is not impacted by debt interest and tax related decisions (Shafer & Moeller, 2012)

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The application of the model based on pre-event performance matching between sample firms and benchmark groups eliminates the impact of the market conditions and other factors, and allows to isolate the effect of Six Sigma on adopting firms by calculating abnormal performance. Barber and Lyon (1996) defined abnormal performance for a sample firm in any given year as follows:

Abnormal performance = Actual performance – Expected performance, where Actual performance was determined by calculating the firm's ROA. Expected performance is defined as the industry matched performance, determined by selecting all firms within the same 4, 3, 2 or 1-digit SIC code as the sample firm for which the ROA for years -1 was within +/- 10% of the sample firm's ROA and the total assets where within a 25 factor of the sample firm. The 90-110% range to determine benchmark ROA seems to be an adequate close match, and provides well-specified yield statistics (Barber & Lyon, 1996). The 25 factor was used in a previous study by Swink and Jacobs (2012) and serves as a means to limit the number of extreme outliers regarding control group firms size compared with the sample firms. However, it is important to note that, due to the nature of accounting data, the presence of extreme outliers is not completely eliminated.

### 3.6 Financial Data Collection

The financial data was collected from the Compustat Annual Industrial File, conducting a series of searches, using the SIC codes of the sample companies to match control companies with an ROA within a +/- 10% range from the sample company's ROA, starting with a 4-digit query, if at least one matching company was identified, the

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search was finalized, if no matches were found, new searches were conducted using a 3-digit, a 2-digit, and a 1-digit SIC codes until at least one matching company was found.

The queries were conducted within the Fundamentals Annual section of the North America database of Compustat. The following steps were followed to perform the searches:

1. Conducted a search using the sample company name to identify the corresponding SIC code.
2. Conducted a search using the SIC code found on step 1 to identify the ticker symbols of sample and control group companies.
3. Selected the 10 year period from years -1 to +8 corresponding to the sample company, using the fiscal year option.
4. Conducted a search of financial data for the sample company and the control groups using the ticker symbols found on step 2. The following fields were selecting for this search: company name, ticker symbol, SIC code, total assets and operating income.
5. The files resulting from the query were downloaded into an Excel file and the companies with a matching ROA on year prior to implementation were selected as part of the control group.
6. The median ROA was identified for the control group of each sample company.

   Summary tables containing the ROA for sample companies and the median ROA for their corresponding control groups were created. This information is presented in Appendix B.

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The ROA information contained on these tables was the basis for calculating Abnormal Performance Change for the different time periods under study.

## 3.7 Data Analysis

This research study entailed an empirical analysis of readily available financial data. The data for both the sample firms and their performance matched control groups were obtained from the Compustat database. The quantitative analysis was based on statistical tools using the following set of variables:

For the total sample:

T1: Abnormal performance for sample firms

For manufacturing firms:

M1: Abnormal performance for sample manufacturing firms

For service firms:

S1: Abnormal performance for sample service firms

In order to test the hypotheses defined on section 3.2, the following procedure was followed:

Hypothesis 1: Adopting Six Sigma has a positive effect on profitability.

There is dependence in the data for the different years in the study. Therefore, this hypothesis was tested by using a paired test for the change of the Abnormal Performance median for each of the defined periods, at a 5% and 10% significance levels. The results were aimed to establish whether there was significant evidence to conclude that the implementation of Six Sigma has a positive impact on corporate performance.

Hypothesis 2: The positive effect on profitability is the same for firms in the manufacturing sector as for firms in the service sector

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Variables M1 and S1 are independent from each other.

A statistical test for assessing group differences for independent variables was applied to test hypothesis 2.

This hypothesis was tested by using the same periods of time used to test Hypothesis 1. The results were aimed to establish whether there was significant evidence to conclude that the impact on financial performance is the same in the manufacturing and service sectors for organizations operating in the US.

## 3.8 Statistical Tools

Accounting data usually does not follow a normal distribution, so the analysis was conducted using a test statistic for non-parametric data instead of a Student's T test statistic. Barber and Lyon (1996) concluded that the most appropriate test statistic for this type of data is the Wilcoxon signed-rank test, which they found to be more powerful than T-tests used for data not following a normal distribution. However, the Wilcoxon signed-rank test assumes that the population is symmetric and, after creating a histogram for the abnormal performance change data, it was found that the data is not symmetric. Therefore, the Sign test was used, a similar test for non-parametric data that does not require the symmetry assumption. The Sign test was used by Shafer and Moeller (2012) in a previous study. These tests work well when the data are winsorized, so they are not affected by extreme outliers. This test is used for paired differences, so it was used to test Hypothesis 1.

For Hypothesis 2, the Mann–Whitney test statistic was used, because it is suited for comparing 2 independent groups.

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## 3.9 Summary

This chapter establishes the framework and methodology of the research. It starts by describing the model recommended by existing research, which allows to isolate the impact of Six Sigma adoption on firm performance. The methodology is described, the research hypotheses established and the sample selection method is explained. Next, the time period of study, the method to assess corporate performance and the data analysis method to be used and the associated statistical tools are described. The next chapter contains the data collected and the statistical analysis to test the hypotheses inherent to this study.

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# CHAPTER 4. RESULTS

The purpose of this study was to evaluate the impact of Six Sigma adoption on corporate performance in both manufacturing and service sectors and identify if the impact is different between the sectors. The hypotheses tested were:

Hypothesis 1: Adopting Six Sigma has a positive effect on firm profitability

Hypothesis 2: The positive effect on profitability is the same for firms in the manufacturing sector as for firms in the service sector.

This chapter presents the data collection, hypothesis testing and associated findings.

## 4.1 Sample Description

An initial list of approximately 400 organizations was reduced to 325 by eliminating, foreign companies with no operations in the US, private companies and other firms that did not have available financial information. The sample was selected by conducting searches over the Internet, trade articles and annual reports. A total of 52 publicly traded companies were identified to have public available information about adoption year. Only 48 out of the 52 companies had sufficient financial data available on Compustat and were selected as the sample group, composed of 32 firms in manufacturing and 16 in service. The list of sample firms is presented in Appendix A.

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### 4.1.1 SIC Classification

An SIC code was then associated with each sample firm according to its control group. Control groups were selected based on a ROA match prior to adoption and on Total Assets within a pre-established range, as explained below.

The matching control group for each sample firm was selecting a procedure similar to the one proposed by Barber and Lyon (1996), following these steps:

1. Identified firms within the same 4-digit SIC code as the sample company for which their ROA in year -1 (year prior to adoption) was within +/-10% of the sample firm ROA.
2. If no companies that matched the ROA within the specified ranges were found, then a search was performed within the 3-digit SIC code.
3. If no firms were identified on step 3, then the 2-digit SIC code was used.
4. Finally, a 1-digit SIC code was conducted for firms that did not have a match in the 3 steps above.

Only companies with Total Assets (TA) within a factor of 25 of the corresponding sample firm's Total Assets were selected as part of the control groups, using the criteria outlined above. Figure 4.1 shows the number of sample firms by SIC code type, with the majority (77%) being classified using a 2-digit code.

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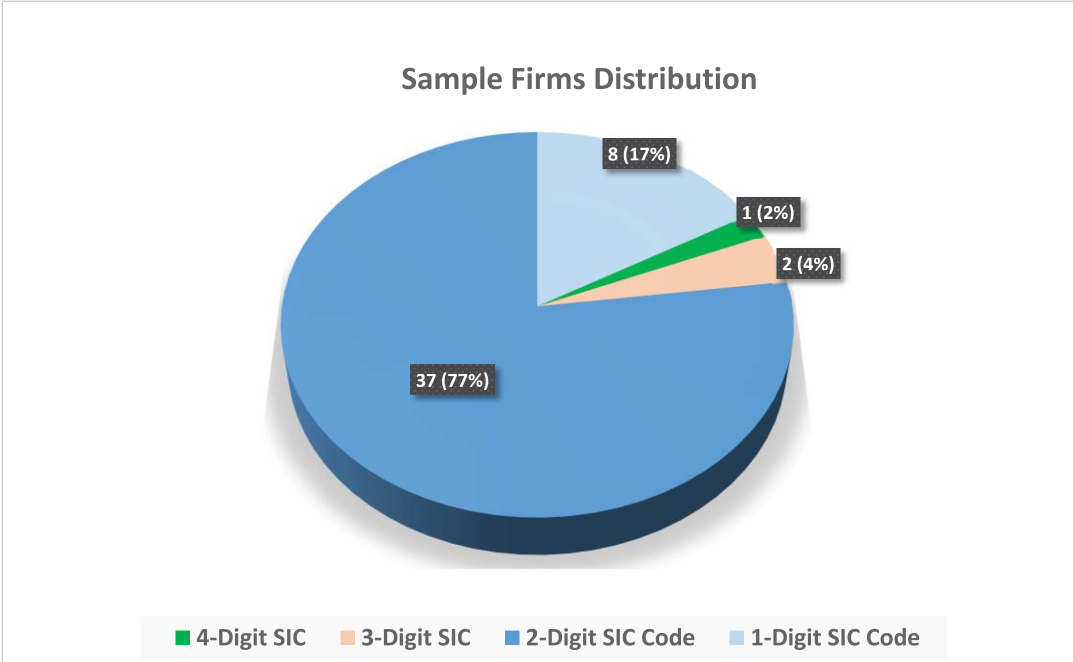


Figure 4.1. Sample Firms Distribution by SIC Code

The detail of sample firms distribution by SIC code is shown in Table 4.1 below, indicating the category within each industry sector and their respective number of companies for 77% of the firms. As shown in the table, the top SIC groups containing a higher number of firms are: industrial machinery and equipment, transportation equipment, and chemicals for manufacturing; as well as general services, and finance, insurance & real estate in the service sector. The remaining 20% were associated with a SIC code each, scattered throughout diverse industry groups. The size of the control groups varied across the sample firms, with as few as one matching company and as many as 18.

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Table 4.1. Sample Firms Most Frequent SIC Codes

| 4-Digit SIC | Frequency | 3-Digit SIC | Frequency |
|---|---|---|---|
| 4911 - Electric Svcs. | 1 (2.1%) | 602 - Commercial Banks | 1 (2.1%) |
| | | 737 - Comp. & Data Proc. | 1 (2.1%) |
| **2-Digit SIC Code** | **Frequency** | **1-Digit SIC Code** | **Frequency** |
| 35 - Ind. mach. and equip. | 8 (16.7%) | 6 - Finance, insurance & Real Est. | 2 (4.2%) |
| 37 - Transportation equip. | 7 (14.6%) | 7 - Services, general | 3 (6.3%) |
| 28 - Chemicals and allied prod. | 5 (10.4%) | | |
| 38 - Instruments and related prod. | 3 (6.3%) | | |
| 26 - Paper and allied products | 2 (4.2%) | | |
| 36 - Electronic & electric equip. | 2 (4.2%) | | |
| 60 - Depository institutions | 2 (4.2%) | | |

### 4.1.2 Financial Data

Financial data was collected from the Compustat database for each of the 48 sample companies, using a time period of study of 10 years, designating year 0 as the year of Six Sigma adoption, -1 the pre-adoption year and continuing with years +1 through +8 after the adoption year. Adoption years for the sample companies go from 1985 through 2007. Approximately 75% of the companies adopted Six Sigma between with 1997 and 2002, with 1999 and 2001 accounting for about 38% of the total. Figure 4.2 shows the distribution of the sample by adoption year.

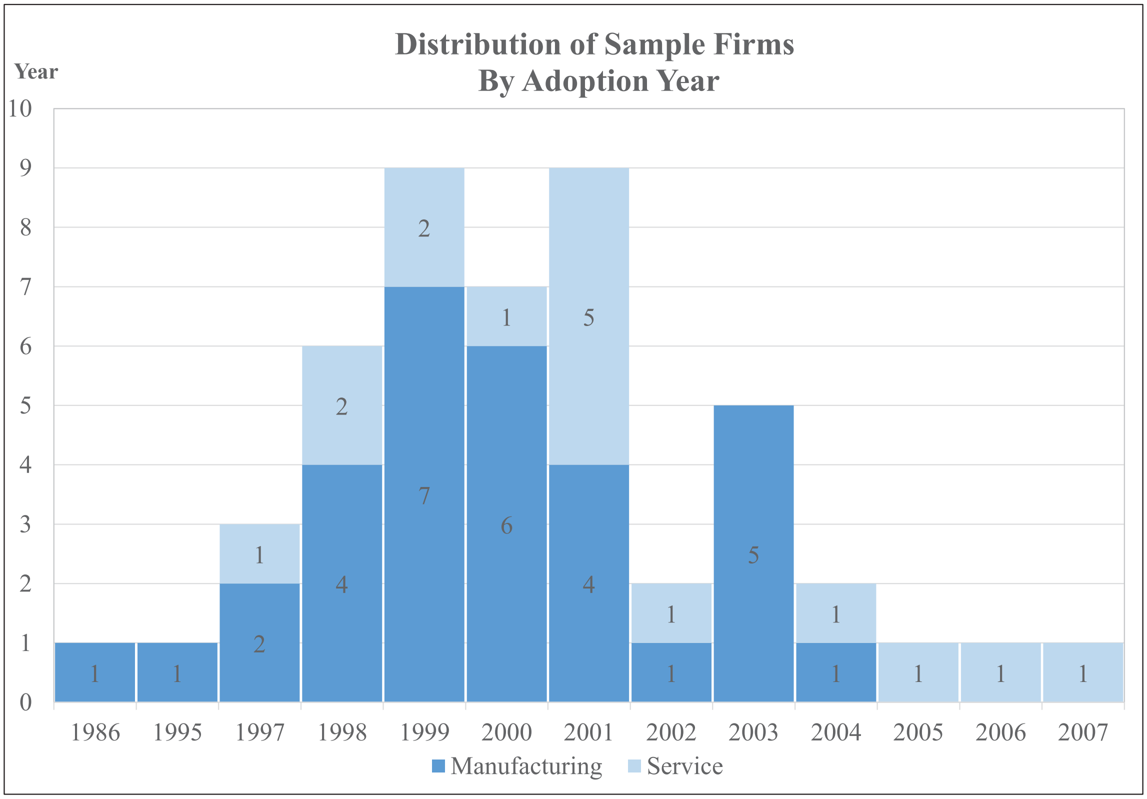


Figure 4.2. Distribution of Sample Firms by Adoption Year

The following financial data was collected for each sample firm and for the firms comprising its control group for the 10 year period: Average Total Assets (TA) and Operating Income (OI), these figures were used to calculate performance, defined as Return on Assets (ROA), and calculated as Operating Income / Average Total Assets. Appendix B shows the sample and control group companies ROA.

A set of descriptive statistics was calculated for the sample and the companies in the control groups in the year prior to adoption, for both manufacturing and service. Table 4.2 shows the descriptive statistics. As it can be noted, the standard deviation is significantly large for both the sample and the control firms. The data for the different groups also showed the presence of extreme outliers, which have an impact on the

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measures of central tendency, especially the mean, making it extremely large compared to the median.

Table 4.2. Financial Data for Sample and Control Companies in Year -1

| | | Total | |
|---|---|---|---|
| Sample Companies | ROA | TA ($MM) | OI ($MM) |
| Mean | 0.0909 | 52,115 | 2,880 |
| Median | 0.0876 | 13,529 | 1,494 |
| Stdev | 0.0654 | 110,559 | 4,094 |
| Max | 0.2651 | 637,383 | 18,592 |
| Min | -0.1610 | 648 | -104 |
| Control Groups | | | |
| Mean | 0.0928 | 10,837 | 651 |
| Median | 0.0934 | 2,345 | 216 |
| Stdev | 0.0465 | 23,870 | 1,160 |
| Max | 0.2724 | 175,725 | 9,833 |
| Min | -0.1556 | 99 | -15 |

| | | Manufacturing | | | Service | |
|---|---|---|---|---|---|---|
| Sample Companies | ROA | TA ($MM) | OI ($MM) | ROA | TA ($MM) | OI ($MM) |
| Mean | 0.1084 | 29,528 | 2,750 | 0.0560 | 97,290 | 3,139 |
| Median | 0.0942 | 13,528 | 1,513 | 0.0525 | 21,310 | 1,421 |
| Stdev | 0.0530 | 53,427 | 4,105 | 0.0751 | 170,690 | 4,193 |
| Max | 0.2651 | 256,887 | 18,592 | 0.1781 | 637,383 | 16,495 |
| Min | 0.0277 | 2,583 | 121 | -0.1610 | 648 | -104 |
| Control Groups | | | | | | |
| Mean | 0.1046 | 5,576 | 527 | 0.0686 | 21,548 | 909 |
| Median | 0.1020 | 1,882 | 188 | 0.0566 | 6,321 | 307 |
| Stdev | 0.0394 | 13,653 | 1,008 | 0.0500 | 34,271 | 1,391 |
| Max | 0.2724 | 144,521 | 9,833 | 0.1962 | 175,725 | 9,764 |
| Min | 0.0278 | 157 | 10 | -0.1556 | 99 | -15 |

Given the descriptive statistics shown above, a probability plot to test for normality was performed with the sample companies using ROA data.

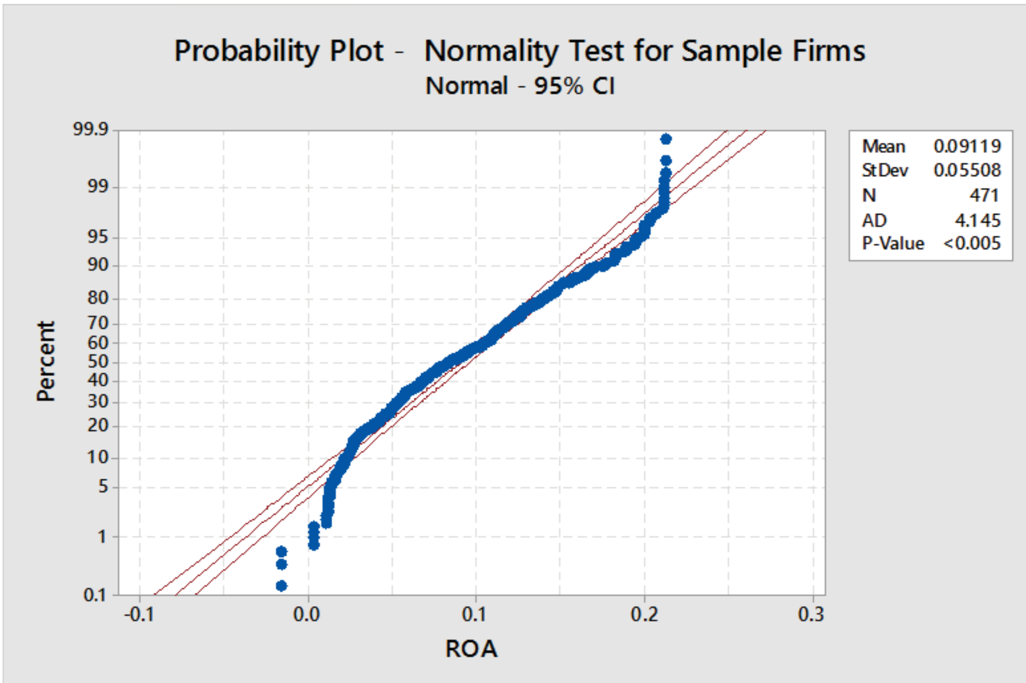


Figure 4.3. Probability Plot for Normality Test

As it can be seen in Figure 4.3, the plot shows non-normality as a significant portion of the plotted points do not fall close to the fitted distribution line, the p-value is smaller than the chosen alpha of 0.05 and the Anderson-Darling (AD) statistic is large (4.145). Therefore, the median was selected over the mean to conduct the statistical analysis.

In addition to the probability plot to test for normality, a Boxplot was the performed to determine if there was any trend in the data that might have an impact on the results. Figure 4.4 presents the results of the Boxplot. There is no evidence of a trend

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in the Boxplot chart, as the medians are approximately aligned. Also, it can be noted that there is a significant presence of outliers and the data is spread for each of the periods plotted.

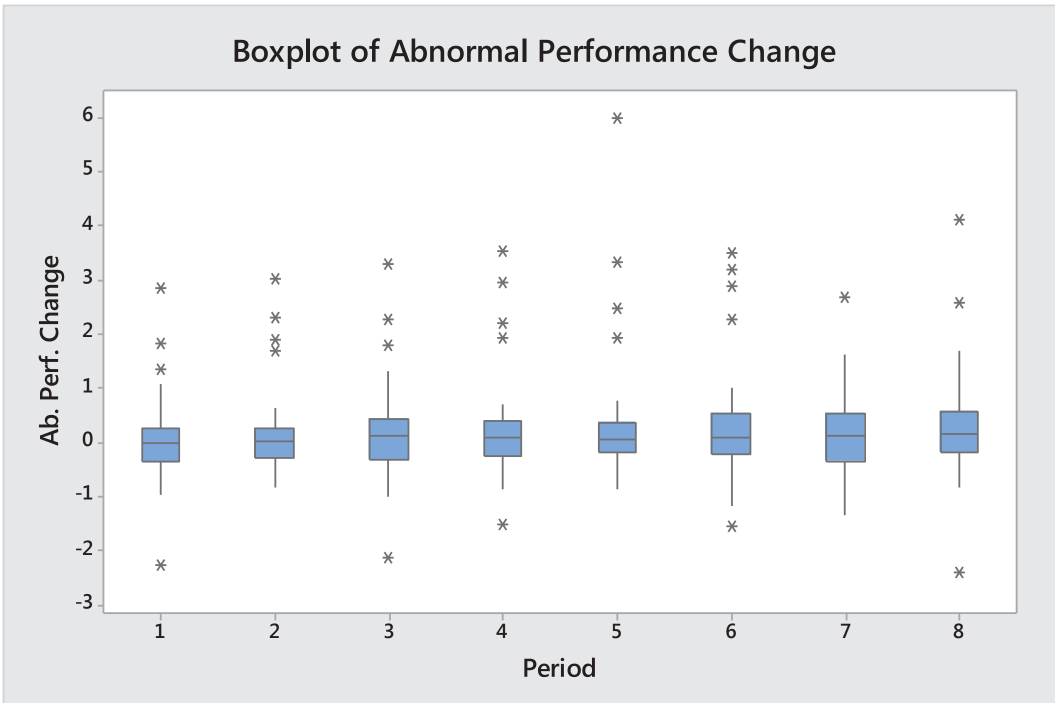


Figure 4.4. Boxplot for Abnormal Change

### 4.1.3 Statistical Tests

The performance of a given company is measured using ROA. The objective of the study was to compare the change of performance of the sample companies with that of their corresponding control groups to assess the impact of Six Sigma implementation, under the premise that if a company had not adopted Six Sigma, its performance should mirror the one of the companies in the control group defined within the same SIC code.

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Abnormal performance change for any given sample firm was calculated by subtracting the percentage change of performance of its control group from the sample firm's percentage change of performance during a given period of time. A positive difference was considered as the sample company outperforming its control group.

The sample companies Abnormal Performance Change data for the different periods under study is presented on Appendix C.

A histogram was constructed to test the abnormal performance data for Symmetry.

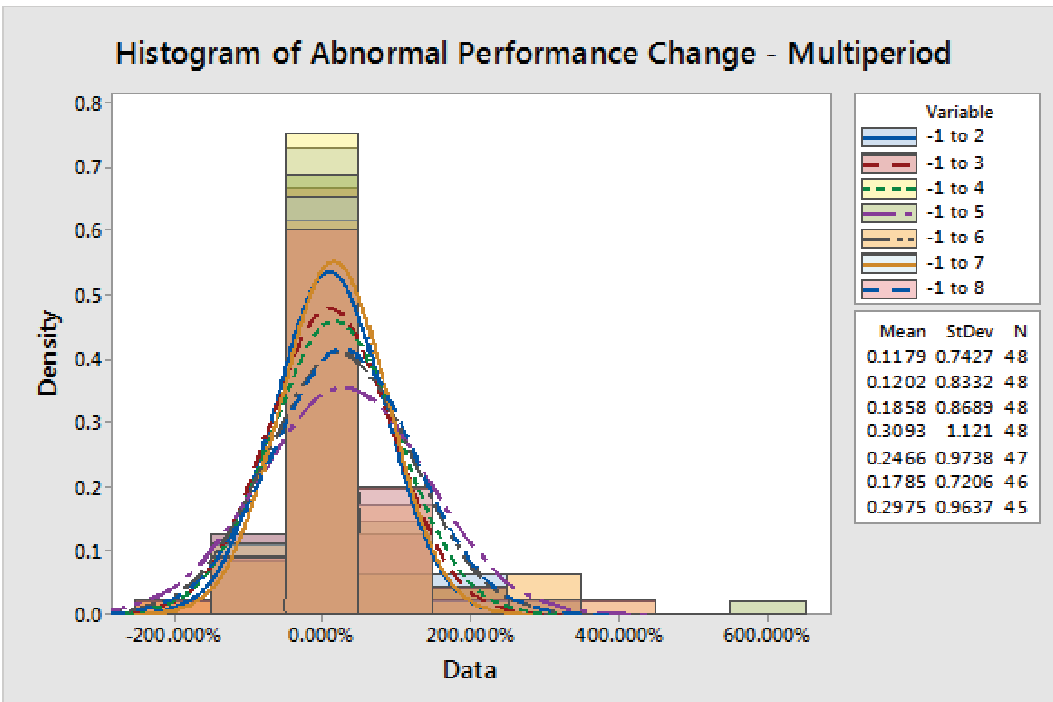


Figure 4.5. Histogram for Abnormal Performance Change

Figure 4.5 shows that the data are not symmetric, thus the assumption for the use of the Wilcoxon Signed Rank test is not met. Therefore, the Sign test was selected.

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The analysis to test the two formulated hypotheses was performed using the following procedure:

1. The one tailed non-parametric Sign test statistic was conducted for the difference of the medians using data for the 48 sample companies and their control groups, as the purpose was to test whether there was a positive effect on Abnormal Performance of sample companies versus control groups.
2. The same test was applied for both manufacturing and service samples individually to verify if there is any impact on each industry sector.
3. The Mann-Whitney non-parametric test for median comparison for independent samples was conducted for the manufacturing and service data sets.

The non-parametric Sign test was conducted for two different for multi-year time periods, calculating the abnormal performance change from year -1 to each post-adoption year: year -1 to + 2, -1 to +3, through period -1 to +8. This was used as a way to check if there was a lag in the impact of Six Sigma implementation due to factors such as: learning curve, deployment of resources, training, etc. The Mann Whitney test was conducted for the multi-period changes. The Minitab output for the tests is presented in Appendix D.

All tests were conducting using significance levels of 5% and 0.10% and data were winsorized at a 2.5% and a 97.5% to reduce the impact of outliers. The tests were conducted for the total sample of companies without distinction of sector, as well as separate for the sample companies comprising each sector.

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The results for multi-year abnormal change are presented in Table 4.3. As it can be noted, the changes in performance are consistently positive throughout the different periods for all three sample groups, except for the period -1 to +1 in general and for period -1 to +5 in manufacturing. However the results are only significant as follows: for the total sample, for the periods -1 to +7 at the 10% level and -1 to +8 at the 5% level. The manufacturing sample shows significance at the 5% level for the period -1 to +7 and at the 10% level for -1 to +8%, and the service sample shows significance for period -1 to +8 only, at a significance level of 10%. These results show consistency in both sectors for the period ending in year 8, showing that sample companies outperformed their respective control groups in both manufacturing and services in the period -1 to +8. For period -1 to +7 the manufacturing sector shows consistency with the total sample regarding significance, whereas service does not show significance for that period.

Table 4.3. Abnormal Performance Changes on a Multi-Year Basis

| | Total Sample | | | Manufacturing | | | Service | | |
|---|---|---|---|---|---|---|---|---|---|
| Period | N | Median | P-Value | N | Median | P-Value | N | Median | P-Value |
| -1 to +1 | 48 | -0.031% | 0.7646 | 32 | -0.0080% | 0.5700 | 16 | -0.0087% | 0.8949 |
| -1 to +2 | 48 | 0.017% | 0.4427 | 32 | 0.0089% | 0.5700 | 16 | 0.0171% | 0.4018 |
| -1 to +3 | 48 | 0.098% | 0.2354 | 32 | 0.0451% | 0.4300 | 16 | 0.1760% | 0.2272 |
| -1 to +4 | 48 | 0.075% | 0.1562 | 32 | 0.0391% | 0.1885 | 16 | 0.0897% | 0.4018 |
| -1 to +5 | 48 | 0.034% | 0.3327 | 32 | -0.1186% | 0.7017 | 16 | 0.1752% | 0.1051 |
| -1 to +6 | 47 | 0.067% | 0.1908 | 31 | 0.0634% | 0.2366 | 16 | 0.1019% | 0.4018 |
| -1 to +7 | 46 | 0.110% | 0.0519 ** | 31 | 0.0864% | 0.0354 * | 15 | 0.3406% | 0.5000 |
| -1 to +8 | 45 | 0.157% | 0.0178 * | 31 | 0.1428% | 0.0748 ** | 14 | 0.1714% | 0.0898 ** |

* Significant at 5%, Sign Test, one tailed
** Significant at 10%, Sign Test, one tailed

Once the test to evaluate the effect of Six Sigma implementation on corporate performance, a test to determine whether the impact differs between both sectors. A

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Mann-Whitney non-parametric test for median differences between independent groups was used to assess whether the impact of Six Sigma adoption is different between the manufacturing and service sectors. Table 4.4 shows a summary of the test results for the different multi-year periods. The test results were non-significant for all periods at the 5% and 10% significance level. Appendix E shows the test Minitab output for the different periods under study.

Table 4. 4. Mann-Whitney Test for Median Differences

| Period | N1, N2 | Point Est. | P-Value |
|---|---|---|---|
| -1 to +2 | 32, 16 | 0.013% | 0.939 |
| -1 to +3 | 32, 16 | -0.098% | 0.670 |
| -1 to +4 | 32, 16 | -0.086% | 0.638 |
| -1 to +5 | 32, 16 | -0.254% | 0.152 |
| -1 to +6 | 31, 16 | -0.106% | 0.508 |
| -1 to +7 | 31, 15 | -0.172% | 0.439 |
| -1 to +8 | 31, 14 | -0.173% | 0.371 |

* Significant at 5%, Mann Whitney test, two tailed
** Significant at 10%, Mann Whitney test, two tailed

### 4.1.4 Hypothesis Testing

The results discussed above are used to evaluate the Hypotheses formulated for this study:

Hypothesis 1:

Ho: Adopting Six Sigma has no effect on firm profitability

Ha: Adopting Six Sigma has a positive effect on firm profitability

The purpose of this hypothesis was to determine whether there is a difference in corporate performance between the sample companies and their corresponding

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benchmark or control groups. The results show significance for the abnormal performance change for some time periods, noting that these differences did not occur in the short to mid-term,  but later, at the 10% significance level on period -1 to +7 and at the 5% significance level on period -1 to +8

These results are significant on both manufacturing and service sectors, where they show significance for longer time periods, especially for the -1 to +8 period at a 5% level for total and service and 10% for manufacturing.

Based on the results of the test statistics, as illustrated on Table 4.3, there is enough evidence to reject the null hypothesis, which means that there is an impact of Six Sigma implementation on corporate performance.

Hypothesis 2:

Ho: The positive effect on profitability is the same for firms in the manufacturing sector as for firms in the service sector.

Ha: The positive effect on profitability is different in manufacturing versus service.

The purpose of this hypothesis was to determine whether there is a difference in the impact of Six Sigma implementation between the firms in the manufacturing sector versus firms in the service sector. According to the results of the Mann Whitney test shown on table 4.5 there is not enough evidence to reject the null hypothesis. Therefore, the results indicate that there is no difference in the impact of Six Sigma Implementation on corporate performance between both sectors.

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## 4.2 Summary

This chapter presents the data and the results of the statistical analysis. It describes the sample companies and the associated control groups, presenting the composition of the sample companies in terms of industry per SIC codes and their descriptive statistics. It follows by showing the results of the tests applied to the data and a discussion regarding the hypotheses subject of the study. The next chapter presents a discussion about the results, conclusions and recommendations for future research.

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# CHAPTER 5. DISCUSSION, CONCLUSION AND RECOMENDATIONS

This chapter presents a discussion on the data presented on chapter four and the results of the statistical tests, followed by conclusions and recommendations for future research on this topic

## 5.1 Discussion

Six Sigma on and its effect on corporate performance has been a subject of study for a long time. According to Antony (2010), the methodology delivers solutions that impact the firms' bottom line by using a data driven approach to implement solutions. Although many companies have made public claims that the adoption of this strategy has led them to achieve enhanced financial performance, there are few studies that evaluate those claims using empirical evidence and most of the evidenced is not supported with data (Linderman et al., 2003).

The main focus of this study was to assess whether implementing Six Sigma has an impact of company profitability and the whether the impact differs from manufacturing and service. The test results provided evidence that led to reject null hypothesis 1 and accept the alternative hypothesis, that Six Sigma has a positive effect on profitability. They also led to fail to reject null hypothesis 2, that the positive impact of Six Sigma is the same for manufacturing and services. The results obtained were

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consistent across the sample companies selected within both the manufacturing and service sectors in the US. The results of the statistical tests applied to the Abnormal Performance Change data throughout the different time periods showed that companies benefit from Six Sigma implementation in a long term, showing significance for the periods of time ending in years 7 and 8 after the adoption year, defined as year zero. The next section presents a discussion on the characteristics of the data and the implication for the study, and an explanation of the results obtained on the different tests.

### 5.1.1 Financial Data

This study used financial data to measure corporate performance, focusing on Return on Assets (ROA), which is one of the most widely used metrics for this purpose (Barber & Lyon, 1996). ROA was used as the basis for calculating abnormal performance change, by comparing the change of performance of the sample companies to that of their corresponding control groups. Accounting based contains extreme outliers which have a significant impact on sample mean. Therefore median comparison versus mean is preferred (Swink & Jacobs, 2012).

With the purpose of verifying the non-normality condition, a probability plot was constructed for the Abnormal Performance Change data. The results showed that the data was not normal and, therefore not suitable for application of the T-Test, which assumes normality. Instead, non-parametric tests were used to evaluate the two hypotheses defined in the study.

The presence of extreme outliers was verified by constructing a Boxplot for the Abnormal Performance Change data. The Boxplot also showed that the median was

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approximately centered within throughout the period of study, with no apparent trends. In addition, a histogram was created, showing that the data are skewed to the right. This led to the decision of selecting the Sign test, a more appropriate test that does not require a symmetry assumption, as Wilcoxon Signed Rank test does.

### 5.1.2 Tests Results

The Sign test was applied to the total sample and to the manufacturing and service samples individually. The purpose of the test was to evaluate whether there was a positive effect on corporate performance for the different periods of time considered. The results showed that, except for the period -1 to +1 in general, the median abnormal performance was consistently positive for most periods, indicating that sample companies outperformed their respective control groups. However, the results are significant for the periods years -1 to +7 and years -1 to +8. Showing that the impact is predominantly in the long term after Six Sigma adoption. The results were significant at the 5% level for the total sample in period -1 to +8 and at the 10% level in period -1 to +7. For manufacturing, the results were significant at the 5% level for period -1 to +7 and at the 10% level for period -1 to +8, whereas for service, the results were significant at the 10% level for period -1 to +8. Regarding hypothesis 1, these results led to the rejection of the null hypothesis, Ho: Adopting Six Sigma has no effect on profitability.

The aforementioned results, presented on Table 4.3, show that the significant positive effects in the long term are consistent across both sectors. The data seem to suggest that the positive effect is driven by manufacturing, as service shows significance for the period -1 to +8 only. However, a possible explanation could be the size of the

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service sample, which only has 16 data points and, given the small size of the Abnormal Changes, the test may not be able to detect it on period -1 to +7. The results for the short and mid-terms are also consistent with the ones obtained by a previous study by Shafer and Moeller (2012) that showed no significant effect on ROA Abnormal Performance for most of the multi-year periods of their study, which considered up to 6 years after the adoption year and instead, the main effect was related to employee productivity.

The lag of the results for the short and mid-term may be related to contextual factors of different nature. One possible explanation could be the time that it takes organizations to deploy Six Sigma across different divisions and the extent to which it is implemented across different sites, either locally or globally. Also, many companies may have reached a certain maturity level on their quality program; therefore Six Sigma may have been implemented as a newer quality improvement strategy, preceded by programs like ISO-9000, TQM and Just in Time, which may have already helped attain quick wins. Therefore, achieving operational performance and remarkable bottom line results may take longer (Swink & Jacobs, 2012).

Another factor that may contribute to a less than desired performance effect may have to do with external factors that impact the economy. Although the methodology used indicates that establishing a performance match based on ROA in the year prior to Six Sigma implementation helps to account for the regression to the mean effect and other external factors, there are events that impact the economy and have a detrimental effect on firms' profitability. As an example, the economic downturn that started in 2008 and impacted global economies for several years may have played a role in profit reduction for the sample companies, and even though this type of events would have

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impacted both sample and control group companies, it hinders the ability for organizations to perform at their best. Economic crisis consequences such as reduced sales, higher raw materials prices, higher market risks, etc. can take a toll on firms' financial health and may explain in part why the desired effect did not take place sooner.

Furthermore, organizations are less willing to take risks, many tend to reduce head count, which in turn increases the workload of employees on their core functions, limiting their time to dedicate to other projects. Approximately 46% of the sample firms on this study had a time period beyond 2008, the year the most recent global recession started, so their performance during the recession period may have reduced the ROA improvement compared to their control groups.

The other statistical test performed was intended to evaluate the hypothesis that the impact of Six Sigma implementation is no different between the manufacturing and the service sectors. The non-parametric Mann Whitney test is used to evaluate median differences between independent groups. It was applied to test the medians of the Abnormal Performance Change between both sectors. The results came out non-significant for each of the periods of study -1 to +1 through -1 to +8, thus leading to failing to reject Ho for hypothesis 2: The positive effect on profitability is the same for firms in the manufacturing sector as for firms in the service sector.

These results suggest that the extent to what Six Sigma produces effects on performance is not dependent on the type of industry. Despite having started in the manufacturing sector, Six Sigma has progressively expanded into the service industry and adopting companies have been able to reap the benefits of its implementation (Antony, 2006; Ozcelik, 2010). Swink and Jacobs (2012) suggest that Six Sigma's positive ROA

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effects are most related to cultural factors and program structure than to the difference in applicability of some statistical tools in manufacturing versus service. This provides some explanation to the increasing use of Six Sigma by service organizations.

### 5.2 Conclusion

This study provided evidence that the implementation of Six Sigma has a positive effect on firm profitability. The effect was observed on time periods considered long term on this study, specifically on periods where a positive effect on ROA was observed, from year prior to adoption, year -1, to years +7 and +8 post adoption. This evidence supports the claims of many Six Sigma adopters about getting benefits that not only boost operating performance but that actually have a bottom line impact.

These results are not only significant from a statistical standpoint but are also meaningful. The average change in Abnormal Performance for the total sample firms due to Six Sigma effect during the 9 year period was 0.297 percentage points (Appendix C), or an average of 0.033 percentage points per year. When the 0.297 increase is applied to the median ROA of 8.76% for the sample firms in year -1, it represents an improvement of 3.4% compared to the control group companies.

For a company with median Total Assets of $13.53 billion on year -1, the 8.76% ROA represents an Operating Income of $1.18 billion per year, for a total of $10.7 billion over the 9 year period. Those would be the expected results for a company without Six Sigma adoption, holding everything else constant.

On the other hand, the total Operating Income for a Six Sigma adopting company over the same period of time would be $10.9 billion, for a favorable difference of

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approximately $200 million ($22 million per year), due to the 3.4% improvement mentioned above. These figures are an estimate for a company with the median Total Assets. However, the financial benefits will widely vary for companies implementing Six Sigma. A detailed calculation of these estimated financial benefits is presented on Appendix F.

As discussed before, the study also provided evidence that this financial effect is similar for manufacturing and service organizations. Most likely, companies from both sectors will continue to seek ways to enhance operating performance, adopting strategies like Six Sigma to attain enhanced quality levels and achieve competitive advantage. Despite the evidence of financial benefits presented, this study does not propose a predictive model. The decision for a company to commit to Six Sigma implementation is particular to each organization and must be thoroughly evaluated by management within its contextual framework. The study shows that it takes time for companies to see the financial benefits. Therefore, careful consideration must be given to the associated risks, expected rate of return compared to other projects, expected initial investment, commitment of additional employee time and other resources, cultural impact, etc. putting emphasis on a detailed evaluation of the Critical Success Factors (CFSs). In summary, whether adopting Six Sigma, or a different program such as Lean Manufacturing, or a combination, the main decision criteria must be based on the company's readiness and the chances of success, given its particular contextual situation, rather than based on expectation of attaining potential benefits that might not be realistic for a particular organization.

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## 5.3 Recommendations for Future Research

Similar studies with a larger sample size should be conducted to validate the findings. Given the difficulties of finding publicly available data on implementation dates, the data collection process should be conducted during a period of time long enough to collect a large sample size. A calculation of the required sample size should be conducted considering a non-parametric methodology. In addition to the data collecting method used in this study, it would be recommended to use alternative methods, such as try collecting data from diverse Six Sigma training companies, industry organizations or quality associations such as isixsigma and the American Society of Quality (ASQ). It would be recommended to conduct similar research, expanding the time period of study to evaluate whether the effect of Six Sigma extends beyond the periods of time considered on this study.

Additional studies should be conducted, considering company size and comparing the impact of Six Sigma across different sub-sectors within each particular industry, for example, electronics versus automotive and others. This type of studies could provide with interesting information on whether there are particular groups of companies that get higher improved performance compared to others and what the influencing factors might be.

Studies for Six Sigma implementation in small and medium size companies (SMEs) and their ability to achieve corporate performance, compared to larger companies should be conducted. This research would provide industry practitioners a better understanding on the challenges facing SMEs and the realistic opportunities of implementation success, compared to larger companies.

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There are numerous areas of research related to Six Sigma that can help practitioners and scholars have a better idea of the magnitude of the Six Sigma effect on performance and the drivers behind it. The studies recommended above are intended to build upon the research presented on this study and are expected to add to the empirical research conducted so far on this topic.

## 5.4 Summary

This chapter contains a discussion of the results of the statistical analysis and an explanation of why those results may have occurred. The conclusions state that, based on the results of the statistical tests, it can be concluded that Six Sigma has a positive effect on profitability on the long term, or 7 to 8 years as defined on this study. Also, the statistical tests led to conclude that the effect is not different between the manufacturing and service sectors. It contains an explanation of how the results are not only significant but also meaningful, by estimating the amount of profit resulting from Six Sigma implementation based on the financial figures for a median company. Finally, it presents some recommendations for future research that would build upon this study.

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APPENDICES

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# Appendix A

## Sample Six Sigma Companies

| Sector | Company | SIC Code |
|---|---|---|
| Manufacturing | 3M | 2670 |
| | ALCAN | 3350 |
| | Avery Dennison | 2670 |
| | Becton Dickinson & Co | 3841 |
| | Black & Decker | 3540 |
| | Boeing | 3721 |
| | Caterpillar | 3531 |
| | Chevron Corp. | 2911 |
| | Cintas Uniforms | 2320 |
| | Cummins | 3510 |
| | Deere & Company | 3523 |
| | Dell | 3571 |
| | Dow Chemical | 2821 |
| | DuPont | 2820 |
| | Eastman Kodak | 3861 |
| | Eli Lilly | 2834 |
| | Ford Motor Company | 3711 |
| | General Electric | 9997 |
| | Heinz Co. | 2030 |
| | Honeywell International | 3728 |
| | Lockheed Martin | 3760 |
| | McKesson Corporation | 5122 |
| | Motorola | 3663 |
| | PACCAR | 3711 |
| | Pfizer Inc | 2834 |
| | Pitney Bowes | 3579 |
| | Raytheon | 3812 |
| | Sun Microsystems | 3571 |
| | Textron | 3721 |
| | Visteon Corporation | 3714 |
| | Whirlpool Corporation | 3630 |
| | Xerox Corporation | 7374 |

Sample Six Sigma Companies (Continued)

| Sector | Company | SIC Code |
|---|---|---|
| Service | Amazon | 5961 |
| | American Express | 6199 |
| | Avis Budget Group. | 7510 |
| | Bank of America | 6020 |
| | Baxter Healthcare | 2836 |
| | Capital One | 6141 |
| | CIGNA | 6324 |
| | Citigroup | 6199 |
| | Dominion Resources | 4911 |
| | JP Morgan Chase | 6020 |
| | Quest Diagnostics | 8071 |
| | Seagate Technology | 3572 |
| | Staples Inc. | 5940 |
| | Starwood Hotels & Resorts | 7011 |
| | Target Corporation | 5331 |
| | The Hertz Corporation | 7510 |

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# Appendix B

## Sample Companies ROA (Page 1 of 2)

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Company | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| HEINZ (H J) CO | 0.14756 | 0.14386 | 0.13578 | 0.13289 | 0.14635 | 0.15234 | 0.14767 | 0.16028 | 0.14879 | 0.13839 |
| CINTAS CORP | 0.16406 | 0.17017 | 0.16849 | 0.16865 | 0.16507 | 0.15651 | 0.13165 | 0.10700 | 0.10583 | 0.12678 |
| AVERY DENNISON | 0.16755 | 0.17727 | 0.18198 | 0.18176 | 0.14849 | 0.13616 | 0.10908 | 0.10985 | 0.11405 | 0.12175 |
| 3M | 0.21216 | 0.19013 | 0.18198 | 0.18944 | 0.20379 | 0.20007 | 0.21174 | 0.21335 | 0.19542 | 0.18378 |
| DOW CHEMICAL | 0.11065 | 0.09329 | 0.08721 | 0.08080 | 0.03604 | 0.02930 | 0.04957 | 0.07815 | 0.11671 | 0.10317 |
| DUPONT | 0.11314 | 0.10878 | 0.11261 | 0.05771 | 0.06664 | 0.05054 | 0.07211 | 0.09349 | 0.10482 | 0.12329 |
| PFIZER | 0.21216 | 0.15992 | 0.14213 | 0.12714 | 0.12842 | 0.12667 | 0.14871 | 0.09871 | 0.08857 | 0.10323 |
| LILLY (ELI) & CO | 0.16154 | 0.15721 | 0.14757 | 0.17730 | 0.19672 | 0.19969 | 0.21174 | 0.21335 | 0.19542 | 0.14580 |
| CHEVRON CORP | 0.07333 | 0.20000 | 0.15100 | 0.08943 | 0.14601 | 0.19077 | 0.19372 | 0.21335 | 0.18391 | 0.18378 |
| ALCAN INC | 0.05368 | 0.05863 | 0.06031 | 0.04158 | 0.04576 | 0.04942 | 0.10483 | | | |
| CUMMINS INC | 0.08026 | 0.04915 | 0.01653 | 0.02355 | 0.01867 | 0.07432 | 0.11378 | 0.13812 | 0.11890 | 0.12648 |
| BLACK & DECKER CORP | 0.12709 | 0.13637 | 0.12892 | 0.08579 | 0.10333 | 0.11021 | 0.12902 | 0.14405 | 0.13384 | 0.12276 |
| DEERE & CO | 0.10671 | 0.04464 | 0.06331 | 0.04002 | 0.04817 | 0.05483 | 0.08513 | 0.07664 | 0.08388 | 0.08795 |
| CATERPILLAR INC | 0.08520 | 0.07175 | 0.05795 | 0.06227 | 0.08178 | 0.10233 | 0.12317 | 0.11313 | 0.09707 | 0.05378 |
| DELL INC | 0.21216 | 0.20000 | 0.16841 | 0.18944 | 0.20379 | 0.20007 | 0.20676 | 0.13007 | 0.14080 | 0.12667 |
| SUN MICROSYSTEMS INC | 0.19506 | 0.20000 | 0.11412 | 0.01272 | -0.01518 | 0.01276 | 0.01962 | 0.00336 | 0.02626 | 0.04268 |
| PITNEY BOWES INC | 0.11587 | 0.11378 | 0.11175 | 0.11378 | 0.12146 | 0.12936 | 0.12358 | 0.10953 | 0.10874 | 0.10678 |
| GENERAL ELECTRIC CO | 0.06678 | 0.07798 | 0.07330 | 0.06879 | 0.06924 | 0.06610 | 0.07031 | 0.06626 | 0.05311 | 0.04911 |
| MOTOROLA SOLUTIONS INC | 0.02769 | 0.07755 | 0.09897 | 0.11803 | 0.10781 | 0.09727 | 0.08191 | 0.09568 | 0.13810 | 0.16620 |
| WHIRLPOOL CORP | 0.04230 | 0.04348 | 0.08491 | 0.11856 | 0.11757 | 0.11724 | 0.12811 | 0.12293 | 0.10037 | 0.10408 |
| PACCAR INC | 0.08258 | 0.11161 | 0.13030 | 0.14601 | 0.11411 | 0.06077 | 0.09559 | 0.10904 | 0.14789 | 0.16665 |
| HONEYWELL INTERNATIONAL | 0.12016 | 0.13408 | 0.16737 | 0.14903 | 0.11125 | 0.09686 | 0.07711 | 0.07767 | 0.08990 | 0.11209 |
| BOEING CO | 0.04273 | 0.08457 | 0.09243 | 0.10439 | 0.07846 | 0.03318 | 0.04198 | 0.04496 | 0.07184 | 0.10001 |
| TEXTRON INC | 0.07784 | 0.08381 | 0.09645 | 0.05842 | 0.06015 | 0.05373 | 0.05929 | 0.07080 | 0.08300 | 0.08940 |
| LOCKHEED MARTIN CORP | 0.08993 | 0.05668 | 0.05348 | 0.05320 | 0.07946 | 0.07610 | 0.08305 | 0.09633 | 0.12270 | 0.14565 |
| VISTEON CORP | 0.09551 | 0.05561 | 0.01149 | 0.01272 | -0.01518 | 0.01276 | 0.01962 | 0.00336 | 0.01660 | 0.01379 |
| FORD MOTOR CO | 0.06731 | 0.07011 | 0.01196 | 0.03189 | 0.02733 | 0.03577 | 0.02443 | 0.00336 | 0.02879 | 0.01379 |
| RAYTHEON CO | 0.09299 | 0.07304 | 0.05921 | 0.02973 | 0.06904 | 0.05528 | 0.05805 | 0.07042 | 0.07599 | 0.09546 |
| BECTON DICKINSON & CO | 0.13106 | 0.13879 | 0.14308 | 0.14791 | 0.16465 | 0.17576 | 0.17837 | 0.18727 | 0.19542 | 0.18378 |
| EASTMAN KODAK CO | 0.09228 | 0.10220 | 0.07223 | 0.05650 | 0.04006 | 0.03858 | 0.02402 | 0.00377 | 0.01660 | 0.05327 |
| MCKESSON CORP | 0.06775 | 0.03241 | 0.01316 | 0.01804 | 0.05769 | 0.06645 | 0.05630 | 0.05221 | 0.05144 | 0.05317 |
| XEROX CORP | 0.07228 | 0.07197 | 0.06985 | 0.07293 | 0.08165 | 0.08844 | 0.07510 | 0.05366 | 0.07358 | 0.06733 |
| AMERICAN EXPRESS CO | 0.02629 | 0.02220 | 0.02511 | 0.02627 | 0.02769 | 0.03040 | 0.04502 | 0.04176 | 0.02676 | 0.02084 |
| SEAGATE TECHNOLOGY | 0.15170 | 0.01433 | 0.06259 | 0.01419 | -0.01518 | 0.09263 | 0.21174 | 0.13487 | 0.15720 | 0.12456 |
| DOMINION RESOURCES INC | 0.05210 | 0.05603 | 0.07983 | 0.06717 | 0.06089 | 0.04972 | 0.06563 | 0.07521 | 0.09037 | 0.07047 |
| TARGET CORP | 0.11151 | 0.11309 | 0.12769 | 0.13936 | 0.12873 | 0.09929 | 0.10544 | 0.11904 | 0.11783 | 0.10992 |
| STAPLES INC | 0.17108 | 0.18339 | 0.18198 | 0.14023 | 0.11290 | 0.11808 | 0.11911 | 0.12263 | 0.10587 | |
| AMAZON.COM INC | 0.02197 | 0.01433 | 0.01149 | 0.01272 | 0.05827 | 0.13040 | 0.15946 | 0.13392 | 0.10150 | 0.12076 |
| JPMORGAN CHASE & CO | 0.02197 | 0.02345 | 0.02721 | 0.02468 | 0.01374 | 0.01276 | 0.01962 | 0.02088 | 0.02222 | 0.02436 |
| BANK OF AMERICA CORP | 0.02460 | 0.02597 | 0.02767 | 0.03061 | 0.03200 | 0.02710 | 0.03013 | 0.02010 | 0.01660 | 0.01379 |
| CAPITAL ONE FINANCIAL CORP | 0.05853 | 0.04318 | 0.03272 | 0.03855 | 0.01658 | 0.01373 | 0.02893 | 0.02749 | 0.01869 | 0.02411 |
| CIGNA CORP | 0.02197 | 0.01433 | 0.01149 | 0.02636 | 0.02471 | 0.04378 | 0.04252 | 0.01709 | 0.04906 | 0.04789 |
| HERTZ GLOBAL HOLDINGS INC | 0.09376 | 0.03921 | 0.05475 | 0.04931 | 0.06542 | 0.06376 | 0.06040 | 0.07010 | 0.04923 | 0.03719 |
| AVIS BUDGET GROUP INC | 0.03489 | 0.04661 | 0.03396 | 0.03839 | 0.05877 | 0.04874 | 0.06500 | 0.05555 | | |
| QUEST DIAGNOSTICS INC | 0.05282 | 0.11068 | 0.14198 | 0.18944 | 0.20379 | 0.20007 | 0.20827 | 0.21071 | 0.15534 | 0.14653 |
| STARWOOD HOTELS&RESORTS | 0.08120 | 0.05224 | 0.04527 | 0.03514 | 0.05009 | 0.06705 | 0.09256 | 0.09468 | 0.07833 | 0.04623 |
| CITIGROUP INC | 0.03912 | 0.06433 | 0.04912 | 0.04295 | 0.05578 | 0.04434 | 0.03040 | 0.03104 | 0.02725 | 0.03575 |
| BAXTER INTERNATIONAL INC | 0.11096 | 0.11909 | 0.11658 | 0.13800 | 0.15653 | 0.15153 | 0.12309 | 0.11015 | 0.12696 | 0.14117 |

Control Groups Median ROA Corresponding to Each Sample Company (Page 2 of 2)

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Company | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| HEINZ (H J) CO | 0.14901 | 0.14810 | 0.14128 | 0.11251 | 0.12725 | 0.12251 | 0.11120 | 0.13506 | 0.12518 | 0.10867 |
| CINTAS CORP | 0.16791 | 0.15790 | 0.15884 | 0.16278 | 0.15534 | 0.07962 | 0.08074 | 0.07978 | 0.09680 | 0.07881 |
| AVERY DENNISON | 0.16606 | 0.16026 | 0.15188 | 0.13827 | 0.12049 | 0.12390 | 0.08578 | 0.09840 | 0.10216 | 0.11424 |
| 3M | 0.21384 | 0.11889 | 0.11528 | 0.06702 | 0.05284 | 0.05430 | 0.06171 | 0.04928 | 0.01683 | 0.02386 |
| DOW CHEMICAL | 0.10750 | 0.11256 | 0.09675 | 0.11022 | 0.07502 | 0.07968 | 0.07471 | 0.08872 | 0.08344 | 0.08338 |
| DUPONT | 0.10993 | 0.11311 | 0.11448 | 0.09883 | 0.09724 | 0.09056 | 0.09123 | 0.08344 | 0.08338 | 0.08888 |
| PFIZER | 0.21419 | 0.22228 | 0.16841 | 0.19610 | 0.20379 | 0.20003 | 0.20676 | 0.17428 | 0.16793 | 0.15012 |
| LILLY (ELI) & CO | 0.15589 | 0.16279 | 0.16544 | 0.15477 | 0.15029 | 0.16109 | 0.14559 | 0.16193 | 0.16793 | 0.17046 |
| CHEVRON CORP | 0.07397 | 0.17189 | 0.13543 | 0.08327 | 0.08596 | 0.15305 | 0.20676 | 0.17428 | 0.15440 | 0.17046 |
| ALCAN INC | 0.05269 | 0.06361 | 0.03769 | 0.02709 | 0.15718 | 0.12844 | 0.12609 | | | |
| CUMMINS INC | 0.08084 | 0.08818 | 0.08626 | 0.06983 | 0.06514 | 0.06348 | 0.09675 | 0.13740 | 0.15970 | 0.15419 |
| BLACK & DECKER CORP | 0.12498 | 0.11685 | 0.13252 | 0.08961 | 0.06039 | 0.07180 | 0.10026 | 0.10674 | 0.10267 | 0.10287 |
| DEERE & CO | 0.10598 | 0.08689 | 0.07966 | 0.04040 | 0.06376 | 0.05918 | 0.05197 | 0.09547 | 0.08051 | 0.04485 |
| CATERPILLAR INC | 0.08404 | 0.09131 | 0.07560 | 0.08476 | 0.08929 | 0.10624 | 0.13265 | 0.15817 | 0.14340 | 0.10083 |
| DELL INC | 0.21419 | 0.22228 | 0.16841 | 0.19610 | 0.20379 | 0.20003 | 0.20676 | 0.13007 | 0.14080 | 0.12667 |
| SUN MICROSYSTEMS INC | 0.21419 | 0.22228 | 0.16841 | 0.19610 | 0.20379 | 0.20003 | 0.20676 | 0.13007 | 0.14080 | 0.12667 |
| PITNEY BOWES INC | 0.11048 | 0.12455 | 0.15134 | 0.14372 | 0.16443 | 0.17111 | 0.13739 | 0.06439 | 0.15593 | 0.15739 |
| GENERAL ELECTRIC CO | 0.06910 | 0.06586 | 0.04235 | 0.04145 | 0.04189 | 0.02806 | 0.02401 | 0.01619 | 0.01404 | 0.01034 |
| MOTOROLA SOLUTIONS INC | 0.02781 | 0.02298 | 0.02393 | 0.03514 | 0.01672 | 0.04418 | 0.02937 | 0.01619 | 0.10554 | 0.14862 |
| WHIRLPOOL CORP | 0.04300 | 0.06073 | 0.03105 | 0.02237 | 0.02188 | 0.02540 | 0.02401 | 0.02804 | 0.03924 | 0.04142 |
| PACCAR INC | 0.07828 | 0.09044 | 0.09260 | 0.09687 | 0.08222 | 0.05727 | 0.04912 | 0.02437 | 0.04513 | 0.02577 |
| HONEYWELL INTERNATIONAL | 0.11931 | 0.12574 | 0.16677 | 0.14493 | 0.13492 | 0.13877 | 0.10511 | 0.11388 | 0.08066 | 0.09879 |
| BOEING CO | 0.04407 | 0.03876 | 0.03180 | 0.02421 | 0.02378 | 0.02540 | 0.04791 | 0.05512 | 0.06347 | 0.06079 |
| TEXTRON INC | 0.07462 | 0.09660 | 0.08213 | 0.05281 | 0.06249 | 0.06867 | 0.06776 | 0.06046 | 0.05226 | 0.05177 |
| LOCKHEED MARTIN CORP | 0.08679 | 0.10092 | 0.08739 | 0.05975 | 0.06677 | 0.05829 | 0.07594 | 0.06626 | 0.07071 | 0.06599 |
| VISTEON CORP | 0.09461 | 0.08213 | 0.05842 | 0.05425 | 0.05787 | 0.07054 | 0.07034 | 0.06767 | 0.05473 | 0.01605 |
| FORD MOTOR CO | 0.06512 | 0.04395 | 0.02393 | 0.02237 | 0.01672 | 0.02834 | 0.03353 | 0.10462 | 0.11563 | 0.17046 |
| RAYTHEON CO | 0.09847 | 0.10297 | 0.09834 | 0.06582 | 0.09145 | 0.07614 | 0.08263 | 0.07654 | 0.07196 | 0.09051 |
| BECTON DICKINSON & CO | 0.13235 | 0.12656 | 0.09919 | 0.06769 | 0.09308 | 0.12303 | 0.09416 | 0.10286 | 0.11255 | 0.05801 |
| EASTMAN KODAK CO | 0.09406 | 0.11278 | 0.12131 | 0.11669 | 0.10116 | 0.09742 | 0.10298 | 0.11623 | 0.11573 | 0.11957 |
| MCKESSON CORP | 0.06605 | 0.10312 | 0.06731 | 0.05195 | 0.04730 | 0.06401 | 0.09268 | 0.09174 | 0.09931 | 0.10787 |
| XEROX CORP | 0.07132 | 0.08260 | 0.08440 | 0.08516 | 0.09179 | 0.06745 | 0.08555 | 0.07457 | 0.07627 | 0.07796 |
| AMERICAN EXPRESS CO | 0.02650 | 0.02610 | 0.02652 | 0.02613 | 0.02651 | 0.02668 | 0.02531 | 0.02308 | 0.01404 | 0.01034 |
| SEAGATE TECHNOLOGY | 0.14635 | 0.10918 | 0.13250 | 0.13763 | 0.11767 | 0.11906 | 0.10242 | 0.08700 | 0.09198 | 0.09370 |
| DOMINION RESOURCES INC | 0.05332 | 0.05365 | 0.04944 | 0.05042 | 0.04980 | 0.04183 | 0.05108 | 0.04285 | 0.04968 | 0.04325 |
| TARGET CORP | 0.12706 | 0.13771 | 0.13975 | 0.10159 | 0.07062 | 0.05224 | 0.03309 | 0.06904 | 0.09098 | 0.10554 |
| STAPLES INC | 0.16416 | 0.17061 | 0.16841 | 0.16232 | 0.14949 | 0.15762 | 0.17562 | 0.17428 | 0.16793 | |
| AMAZON.COM INC | 0.02337 | 0.08715 | 0.07789 | 0.02237 | 0.06762 | 0.05661 | 0.02970 | 0.06110 | 0.08802 | 0.03255 |
| JPMORGAN CHASE & CO | 0.02337 | 0.02595 | 0.02393 | 0.02723 | 0.02670 | 0.02540 | 0.02401 | 0.02485 | 0.02648 | 0.02483 |
| BANK OF AMERICA CORP | 0.02657 | 0.02809 | 0.02605 | 0.02510 | 0.02687 | 0.02707 | 0.02721 | 0.02640 | 0.02742 | 0.01983 |
| CAPITAL ONE FINANCIAL CORP | 0.05787 | 0.07027 | 0.06733 | 0.06506 | 0.03558 | 0.02718 | 0.04352 | 0.05564 | 0.04674 | 0.04054 |
| CIGNA CORP | 0.02337 | 0.02298 | 0.03149 | 0.03501 | 0.01672 | 0.04998 | 0.04475 | 0.01619 | 0.01424 | 0.01284 |
| HERTZ GLOBAL HOLDINGS INC | 0.09919 | 0.07567 | 0.06536 | 0.04055 | 0.05758 | 0.07803 | 0.09137 | 0.09838 | 0.09738 | 0.07235 |
| AVIS BUDGET GROUP INC | 0.03532 | 0.02298 | 0.02801 | 0.03254 | 0.04609 | 0.04594 | 0.06832 | 0.06474 | | |
| QUEST DIAGNOSTICS INC | 0.05118 | 0.07202 | 0.09164 | 0.09744 | 0.10693 | 0.04387 | 0.03133 | 0.04198 | 0.01404 | 0.01034 |
| STARWOOD HOTELS&RESORTS W | 0.07985 | 0.07675 | 0.07052 | 0.07934 | 0.08499 | 0.08830 | 0.07908 | 0.08360 | 0.08558 | 0.05847 |
| CITIGROUP INC | 0.03824 | 0.04109 | 0.04027 | 0.04119 | 0.03600 | 0.02738 | 0.02449 | 0.03149 | 0.03501 | 0.02875 |
| BAXTER INTERNATIONAL INC | 0.10911 | 0.11625 | 0.11022 | 0.11658 | 0.09903 | 0.10018 | 0.09056 | 0.09123 | 0.08344 | 0.08338 |

# Appendix C

## Sample Companies Abnormal Performance Change (Percentage Points)

| | Period | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Company | -1 to 1 | -1 to 2 | -1 to 3 | -1 to 4 | -1 to 5 | -1 to 6 | -1 to 7 | -1 to 8 |
| HEINZ (H J) CO | -0.028 | 0.146 | 0.138 | 0.210 | 0.254 | 0.180 | 0.168 | 0.209 |
| CINTAS CORP | 0.081 | 0.058 | 0.081 | 0.480 | 0.322 | 0.177 | 0.069 | 0.303 |
| AVERY DENNISON | 0.171 | 0.252 | 0.161 | 0.067 | 0.134 | 0.063 | 0.065 | 0.039 |
| 3M | 0.319 | 0.579 | 0.713 | 0.689 | 0.709 | 0.775 | 0.842 | 0.755 |
| DOW CHEMICAL | -0.112 | -0.295 | -0.372 | -0.476 | -0.247 | -0.119 | 0.279 | 0.157 |
| DUPONT | -0.046 | -0.389 | -0.296 | -0.377 | -0.193 | 0.067 | 0.168 | 0.281 |
| PFIZER | 0.264 | -0.316 | -0.346 | -0.337 | -0.264 | -0.348 | -0.367 | -0.214 |
| LILLY (ELI) & CO | -0.391 | 0.105 | 0.254 | 0.203 | 0.377 | 0.282 | 0.133 | -0.191 |
| CHEVRON CORP | -0.917 | 0.094 | 0.829 | 0.533 | -0.153 | 0.553 | 0.421 | 0.202 |
| ALCAN INC | 1.344 | 0.261 | -2.130 | -1.517 | -0.440 | | | |
| CUMMINS INC | 0.057 | -0.570 | -0.573 | 0.141 | 0.221 | 0.021 | -0.494 | -0.331 |
| BLACK & DECKER CORP | -0.854 | -0.042 | 0.330 | 0.293 | 0.213 | 0.279 | 0.232 | 0.143 |
| DEERE & CO | 0.263 | -0.006 | -0.150 | -0.045 | 0.307 | -0.183 | 0.026 | 0.401 |
| CATERPILLAR INC | -0.306 | -0.278 | -0.103 | -0.063 | -0.133 | -0.554 | -0.567 | -0.568 |
| DELL INC | -0.106 | -0.023 | 0.009 | 0.009 | 0.009 | 0.006 | 0.006 | 0.006 |
| SUN MICROSYSTEMS INC | 0.008 | -0.850 | -1.029 | -0.868 | -0.865 | -0.590 | -0.523 | -0.373 |
| PITNEY BOWES INC | -0.785 | -0.319 | -0.440 | -0.432 | -0.177 | 0.363 | -0.473 | -0.503 |
| GENERAL ELECTRIC CO | 0.351 | 0.430 | 0.431 | 0.584 | 0.705 | 0.758 | 0.592 | 0.586 |
| MOTOROLA SOLUTIONS INC | 0.237 | 2.999 | 3.292 | 1.925 | 1.902 | 2.874 | 1.193 | 0.659 |
| WHIRLPOOL CORP | 2.852 | 2.283 | 2.271 | 2.181 | 2.471 | 2.254 | 1.461 | 1.497 |
| PACCAR INC | 0.825 | 0.531 | 0.331 | 0.004 | 0.530 | 1.009 | 1.214 | 1.689 |
| HONEYWELL INTERNATIONAL | 0.180 | 0.025 | -0.205 | -0.357 | -0.239 | -0.308 | 0.072 | 0.105 |
| BOEING CO | 0.671 | 1.894 | 1.297 | 0.200 | -0.104 | -0.199 | 0.241 | 0.961 |
| TEXTRON INC | 1.063 | 0.043 | -0.065 | -0.230 | -0.146 | 0.099 | 0.366 | 0.455 |
| LOCKHEED MARTIN CORP | 0.232 | -0.097 | 0.114 | 0.175 | 0.049 | 0.308 | 0.550 | 0.859 |
| VISTEON CORP | -0.023 | -0.440 | -0.771 | -0.612 | -0.538 | -0.680 | -0.405 | -0.025 |
| FORD MOTOR CO | -0.247 | 0.130 | 0.149 | 0.096 | -0.152 | -1.557 | -1.348 | -2.413 |
| RAYTHEON CO | -0.821 | -0.349 | -0.186 | -0.179 | -0.215 | -0.020 | 0.086 | 0.107 |
| BECTON DICKINSON & CO | -0.113 | 0.617 | 0.553 | 0.412 | 0.650 | 0.652 | 0.641 | 0.964 |
| EASTMAN KODAK CO | -0.198 | -0.628 | -0.641 | -0.618 | -0.834 | -1.195 | -1.051 | -0.694 |
| MCKESSON CORP | -0.236 | -0.520 | 0.135 | 0.012 | -0.572 | -0.618 | -0.744 | -0.849 |
| XEROX CORP | -0.989 | -0.185 | -0.157 | 0.278 | -0.160 | -0.303 | -0.051 | -0.162 |
| AMERICAN EXPRESS CO | -0.034 | 0.013 | 0.053 | 0.149 | 0.757 | 0.718 | 0.488 | 0.403 |
| SEAGATE TECHNOLOGY | 0.050 | -0.847 | -0.904 | -0.203 | 0.696 | 0.295 | 0.408 | 0.181 |
| DOMINION RESOURCES INC | -0.515 | 0.344 | 0.235 | 0.170 | 0.302 | 0.640 | 0.803 | 0.542 |
| TARGET CORP | 0.432 | 0.450 | 0.599 | 0.479 | 0.685 | 0.524 | 0.341 | 0.155 |
| STAPLES INC | 0.119 | -0.169 | -0.251 | -0.270 | -0.374 | -0.345 | -0.404 | |
| AMAZON.COM INC | -2.269 | -0.379 | -0.242 | 3.511 | 5.985 | 3.479 | 0.852 | 4.103 |
| JPMORGAN CHASE & CO | -0.501 | -0.042 | -0.517 | -0.506 | -0.134 | -0.114 | -0.122 | 0.046 |
| BANK OF AMERICA CORP | 0.258 | 0.299 | 0.289 | 0.083 | 0.201 | -0.176 | -0.357 | -0.186 |
| CAPITAL ONE FINANCIAL CORP | -0.039 | -0.466 | -0.332 | -0.235 | -0.258 | -0.492 | -0.488 | -0.289 |
| CIGNA CORP | -0.789 | -0.298 | 0.409 | -0.147 | 0.020 | 0.085 | 1.624 | 1.630 |
| HERTZ GLOBAL HOLDINGS INC | -0.136 | 0.117 | 0.117 | -0.107 | -0.277 | -0.244 | -0.457 | -0.333 |
| AVIS BUDGET GROUP INC | -0.209 | 0.179 | 0.379 | 0.096 | -0.071 | -0.241 | | |
| QUEST DIAGNOSTICS INC | -0.817 | 1.683 | 1.769 | 2.931 | 3.331 | 3.169 | 2.667 | 2.572 |
| STARWOOD HOTELS&RESORTS | 1.805 | -0.561 | -0.448 | -0.280 | 0.150 | 0.119 | -0.107 | -0.163 |
| CITIGROUP INC | -0.495 | 0.021 | 0.484 | 0.417 | 0.137 | -0.030 | -0.219 | 0.162 |
| BAXTER INTERNATIONAL INC | 0.245 | 0.175 | 0.503 | 0.448 | 0.279 | 0.157 | 0.380 | 0.508 |
| Mean | -0.003 | 0.118 | 0.120 | 0.186 | 0.309 | 0.247 | 0.178 | 0.297 |
| Median | -0.028 | 0.021 | 0.114 | 0.083 | 0.049 | 0.076 | 0.133 | 0.159 |

Appendix D

Minitab Sign Test Results

## Sign Test for Median: Total Sample:

Sign test of median = 0.00000 versus > 0.00000

| | N | N* | Below | Equal | Above | P | Median |
|---|---|---|---|---|---|---|---|
| Total -1 to +1 | 48 | 0 | 26 | 0 | 22 | 0.7646 | -0.03099 |
| Total -1 to +2 | 48 | 0 | 23 | 0 | 25 | 0.4427 | 0.01706 |
| Total -1 to +3 | 48 | 0 | 21 | 0 | 27 | 0.2354 | 0.09766 |
| Total -1 to +4 | 48 | 0 | 20 | 0 | 28 | 0.1562 | 0.07476 |
| Total -1 to +5 | 48 | 0 | 22 | 0 | 26 | 0.3327 | 0.03411 |
| Total -1 to +6 | 47 | 1 | 20 | 0 | 27 | 0.1908 | 0.06730 |
| Total -1 to +7 | 46 | 2 | 17 | 0 | 29 | 0.0519 | 0.10950 |
| Total -1 to +8 | 45 | 3 | 15 | 0 | 30 | 0.0178 | 0.15680 |

## Sign Test for Median: Manufacturing Sample

Sign test of median = 0.00000 versus > 0.00000

| | N | N* | Below | Equal | Above | P | Median |
|---|---|---|---|---|---|---|---|
| Manuf -1 to +1 | 32 | 0 | 16 | 0 | 16 | 0.5700 | -0.00767 |
| Manuf -1 to +2 | 32 | 0 | 16 | 0 | 16 | 0.5700 | 0.00964 |
| Manuf -1 to +3 | 32 | 0 | 15 | 0 | 17 | 0.4300 | 0.04507 |
| Manuf -1 to +4 | 32 | 0 | 13 | 0 | 19 | 0.1885 | 0.03910 |
| Manuf -1 to +5 | 32 | 0 | 17 | 0 | 15 | 0.7017 | -0.11860 |
| Manuf -1 to +6 | 31 | 1 | 13 | 0 | 18 | 0.2366 | 0.06304 |
| Manuf -1 to +7 | 31 | 1 | 10 | 0 | 21 | 0.0354 | 0.08644 |
| Manuf -1 to +8 | 31 | 1 | 11 | 0 | 20 | 0.0748 | 0.14280 |

## Sign Test for Median: Service Sample

Sign test of median = 0.00000 versus > 0.00000

| | N | N* | Below | Equal | Above | P | Median |
|---|---|---|---|---|---|---|---|
| Serv -1 to +1 | 16 | 0 | 10 | 0 | 6 | 0.8949 | -0.08727 |
| Serv -1 to +2 | 16 | 0 | 7 | 0 | 9 | 0.4018 | 0.01706 |
| Serv -1 to +3 | 16 | 0 | 6 | 0 | 10 | 0.2272 | 0.17600 |
| Serv -1 to +4 | 16 | 0 | 7 | 0 | 9 | 0.4018 | 0.08968 |
| Serv -1 to +5 | 16 | 0 | 5 | 0 | 11 | 0.1051 | 0.17520 |
| Serv -1 to +6 | 16 | 0 | 7 | 0 | 9 | 0.4018 | 0.10190 |
| Serv -1 to +7 | 15 | 1 | 7 | 0 | 8 | 0.5000 | 0.34060 |
| Serv -1 to +8 | 14 | 2 | 4 | 0 | 10 | 0.0898 | 0.17140 |

`

# Appendix E

## Minitab Mann Whitney Test Results (Page 1 of 2)

### Mann-Whitney Test and CI: Manuf -1 to +1, Serv -1 to +1

```
                  N   Median
Manuf -1 to +1   32  -0.0077
Serv -1 to +1    16  -0.0873

Point estimate for η1 - η2 is 0.1818
95.2 Percent CI for η1 - η2 is (-0.1641,0.5578)
W = 830.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.3197
```

### Mann-Whitney Test and CI: Manuf -1 to +2, Serv -1 to +2

```
                  N  Median
Manuf -1 to +2   32  0.0096
Serv -1 to +2    16  0.0171

Point estimate for η1 - η2 is 0.0127
95.2 Percent CI for η1 - η2 is (-0.2721,0.3148)
W = 788.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.9390
```

### Mann-Whitney Test and CI: Manuf -1 to +3, Serv -1 to +3

```
                  N  Median
Manuf -1 to +3   32  0.0451
Serv -1 to +3    16  0.1760

Point estimate for η1 - η2 is -0.0984
95.2 Percent CI for η1 - η2 is (-0.4252,0.3122)
W = 764.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.6698
```

### Mann-Whitney Test and CI: Manuf -1 to +4, Serv -1 to +4

```
                  N  Median
Manuf -1 to +4   32   0.039
Serv -1 to +4    16   0.090

Point estimate for η1 - η2 is -0.086
95.2 Percent CI for η1 - η2 is (-0.409,0.213)
W = 762.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.6382
```

Minitab Mann Whitney Test Results (Page 2 of 2)

## Mann-Whitney Test and CI: Manuf -1 to +5, Serv -1 to +5

```
                  N  Median
Manuf -1 to +5   32  -0.119
Serv -1 to +5    16   0.175

Point estimate for η1 - η2 is -0.254
95.2 Percent CI for η1 - η2 is (-0.541,0.075)
W = 718.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.1520
```

## Mann-Whitney Test and CI: Manuf -1 to +6, Serv -1 to +6

```
                  N  Median
Manuf -1 to +6   31   0.063
Serv -1 to +6    16   0.102

Point estimate for η1 - η2 is -0.106
95.1 Percent CI for η1 - η2 is (-0.504,0.223)
W = 714.0
```

## Mann-Whitney Test and CI: Manuf -1 to +7, Serv -1 to +7

```
                  N  Median
Manuf -1 to +7   31  0.0864
Serv -1 to +7    15  0.3406

Point estimate for η1 - η2 is -0.1724
95.1 Percent CI for η1 - η2 is (-0.6108,0.3059)
W = 695.0
Test of η1 = η2 vs η1 ≠ η2 is significant at 0.4394
```

## Mann-Whitney Test and CI: Manuf -1 to +8, Serv -1 to +8

```
                  N  Median
Manuf -1 to +8   31   0.143
Serv -1 to +8    14   0.171

Point estimate for η1 - η2 is -0.173
95.2 Percent CI for η1 - η2 is (-0.670,0.235)
```

`

# Appendix F

## Estimated Benefits of Six Sigma Adoption

Average change for periods -1 to +8: 0.297 percentage points, or 0.0033 per year for a median Six Sigma Company (million USD)

| | Without Six Sigma | | | With Six Sigma | | |
|---|---|---|---|---|---|---|
| Year | TA ($MM) | ROA | OI ($MM) | TA ($MM | ROA | OI ($MM) |
| -1 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0876 | 1,185 |
| 0 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0879 | 1,190 |
| 1 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0883 | 1,194 |
| 2 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0886 | 1,199 |
| 3 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0889 | 1,203 |
| 4 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0893 | 1,207 |
| 5 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0896 | 1,212 |
| 6 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0899 | 1,216 |
| 7 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0902 | 1,221 |
| 8 | 13,529 | 0.0876 | 1,185 | 13,529 | 0.0906 | 1,225 |
| Totals | | | 10,666 | | | 10,867 |
| Difference: | | | | | | 201 |

`