# Friends of My Enemies:

# A Longitudinal Investigation into Supply Base Management

by

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# ABSTRACT

In this dissertation research, I expand the definition of the supply network to include the buying firm's competitors. Just as one buyer-supplier relationship impacts all other relationships within the network, the presence of competitor-supplier relationships must also impact the focal buying firm. Therefore, the concept of a "competitive network" made up of a focal firm, its competitors and all of their combined suppliers is introduced. Utilizing a unique longitudinal dataset, this research explores how the organic structural changes within the new, many-to-many supply network impact firm performance. The investigation begins by studying the change in number of suppliers used by global auto manufacturers between 2004 and 2013. Following the Great Recession of 2008-09, firms have been growing the number of suppliers at more than twice the rate they had been reducing suppliers just a few years prior. The second phase of research explores the structural changes to the network resulting from this explosive growth in the number of suppliers. The final investigation explores a different flow – financial flow -- and evaluates its association with firm performance. Overall, this dissertation research demonstrates the value of aggregating individual supply networks into a macro-network defined as the competitive network. From this view, no one firm is able to control the structure of the network and the change in structure directly impacts firm performance. A new metric is introduced which addresses the subtle changes in buyer-supplier relationships and relates significantly to firm performance. The analyses expand the body of knowledge through the use of longitudinal datasets and uncovers otherwise overlooked dynamics existing within supply networks over the past decade.

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# INTRODUCTION

Traditionally, researchers investigated supply base management as a series of one-to-one dyadic relationships existing in isolation. More recent research has recognized that aggregating the individual buyer-supplier relationships creates a complex, inter-connected supply network. The supply chain management literature has now fully embraced the network perspective for investigating buyer-supplier relationships, and the volume of research being developed is staggering (Galaskiewicz, 2011). The configuration of the network is still assumed to be centrally coordinated by the buying firm and much of the research is cross-sectional, survey-based. Yet, there is emerging interest in understanding the dynamics present within the supply base system (Grewal et al., 2007; Kim, 2014; Murphy, 2008).

In this dissertation research, I expand the definition of the supply network to include the buying firm's competitors. Just as one buyer-supplier relationship impacts all other relationships within the network, the presence of competitor-supplier relationships must also impact the focal buying firm. Therefore, this research introduces the concept of a "competitive network" made up of a focal firm, its competitors and all of their combined suppliers. I create a unique longitudinal dataset for this research by combining multiple sources of firm relationships and finances. This allows exploration into the organic structural changes within the new, many-to-many supply network and the associated impact on firm performance over time.

My investigation begins by studying the change in the number of suppliers used by global auto manufacturers between 2004 and 2013. Grounded in Punctuated equilibrium theory, this investigation finds that the Great Recession of 2008-2009

represented a dramatic shift in supply base management philosophy. In the years leading up to 2008, practicing managers were utilizing a strategy of reducing the number of suppliers within the supply base. This was consistent with the research literature at the time which promoted the benefits of developing deeper relationships with fewer suppliers. However, after the Great Recession, my empirical analysis finds that the rate and direction of change in the number of suppliers has dramatically shifted. Buyers did not alter their "make vs buy" philosophy, but instead expanded their number of partnerships used to acquire the same amount of material. Firms are now growing the number of suppliers more than twice as fast as they were reducing suppliers just a few years prior.

The second phase of my research explores the structural changes to the network resulting from this explosive growth in the number of suppliers. Buying firms could partner with unique suppliers which would be new to the supply network, or the buying firms could partner with suppliers already used by their competitors. The extant literature on social networks provides two opposing views on whether the unique suppliers or shared suppliers approach would be more beneficial. I attempt to explore which philosophy is used by buying firms, whether that strategy also changed during the Great Recession and which strategy is associated with increasing firm performance. My research applies traditional network analysis concepts and introduces a new metric called "Structural Dependence" to better understand the dynamics present within the system. The analyses reveal that the Great Recession did represent a dramatic shift in strategy from increasingly dense networks before the recession to increasingly sparse networks in

the post-recession years. Interestingly, my new structural dependence metric shows that buying firms in dense networks are associated with increasing firm performance.

These first two investigations focused on material and information flow through the buyer-supplier network. My final investigation explores the third flow within a supply network – financial flow – and evaluates its association with firm performance. Previous research has shown suppliers to be sources of efficiency, quality, innovation and profitability (Autry and Griffis, 2008; Bellamy et al., 2014; Dyer and Hatch, 2004). I contribute to the emerging research stream of Supply Chain Finance by exploring the possibility that changing the financial relationships between buyers and suppliers can lead to increased performance. I develop a longitudinal dataset of firm metrics based on commercially available annual financial data. Using traditional financial metrics, I demonstrate that changing the cash flow between buyers and suppliers can lead to positive performance in the current as well as future periods. I offer a definition of Supply Chain Finance and promote the value of continued research on this emerging stream.

Overall, my research demonstrates the value of aggregating individual supply networks into a macro-network I call the competitive network. From this view, no one firm is able to control the structure of the network and the change in structure directly impacts firm performance. I introduce a new network metric which addresses the subtle changes in buyer-supplier relationships and relates significantly to firm performance. This research expands the body of knowledge through the use of longitudinal datasets

and uncovers otherwise overlooked dynamics existing within supply networks over the past decade.

# SUPPLY BASE RATIONALIZATION: STRATEGY CHANGES AFTER THE GREAT RECESSION

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Abstract

From the beginning of 2008 through the middle of 2009, the world experienced the most devastating global economic crisis since the Great Depression. This "Great Recession," acted as a disruptive event in which world trade fell by 25%-30% and altered the global economic system (Grusky et al., 2011). It is reasonable to assume that buyer-supplier relationships and the flow of products may also have been impacted by such a punishing environmental shock. This research uses a unique, longitudinal dataset to investigate changes in supply base sizes with the automotive industry between 2004 and 2013. Although supply base reduction has dominated the academic literature, we find evidence of this strategy only prior to the Great Recession. In the post-recession era, firms have been expanding their supply bases. The dramatic change in supply base management strategy is contrary to the common understanding and appears to be unacknowledged in the extant literature. In fact, researchers are continuing to investigate and promote supply base reduction as a critical success indicator for measuring the efficiency of supply base management strategies (Ab Talib and Abdul Hamid, 2014; Roh et al., 2014; Rotaru et al., 2014; Song et al., 2014). Our research demonstrates that the Great Recession represented a severe, disruptive event which has created a new equilibrium strategy of supply base expansion.

*Key words:* The Great Recession, supply base management, punctuated equilibrium theory, longitudinal data analysis, interrupted time series analysis

## Introduction

From the beginning of 2008 through the middle of 2009, the world experienced the most devastating global economic crisis since the Great Depression (Grusky et al., 2011). During this period (known as the "Great Recession"), the combined wealth of worldwide businesses, real estate and financial assets was reduced over $11 trillion USD (Roberts, 2009). The shocking fallout changed labor markets, wealth distributions, consumption patterns – even mortality and marriage rates (Grusky et al., 2011). The Great Recession, as a disruptive event, saw world trade fall by 25%-30% and forever changed the entire economic landscape worldwide (Grusky et al., 2011). It is reasonable to assume that buyer-supplier relationships and the flow of products were also impacted by such a punishing shock to the economy. By examining the world automotive industry through the theoretical lens of Punctuated equilibrium theory (PET) and utilizing a unique longitudinal dataset of buyer-supplier relationships, we seek to gain insights into the disruptive effect that the Great Recession had on supplier management strategy.

No firm can exist without its suppliers, and the extreme drop-off in trade due to the Great Recession magnifies the importance of those buyer-supplier relationships. Suppliers can be sources of efficiency, quality, innovation and profitability (Autry and Griffis, 2008; Bellamy et al., 2014; Dyer and Hatch, 2004). Therefore, how well a firm manages its supply base relationships is critical to the firm's competitive advantage (Bellamy et al., 2014; Chen et al., 2004; Chopra and Sodhi, 2004; Koufteros et al., 2012). A firm's supply base (SB) is defined as the collection of suppliers that provide goods or services and are actively managed by the buying company (Choi and Krause, 2006). The term supply base management (SBM) has emerged to describe various strategies used by

firms to maximize their performance through their relationships with suppliers (Anderson et al., 2000; Choi and Hong, 2002; Hahn et al., 1990; Johnson and Mena, 2008; Ogden and Carter, 2008). Figure 1 below was generated from the FactSet/Revere Supply Chain Relationships™ database (FactSet/Revere, 2014) and shows the annual supply base sizes for the five largest auto manufacturers in the world (Toyota, Volkswagen, Nissan, Ford and Daimler). This graph shows that the number of suppliers decreased or remained constant in years 2004 to 2007. However, the number of suppliers surprisingly saw a dramatic increase after the Great Recession (2010-2013).

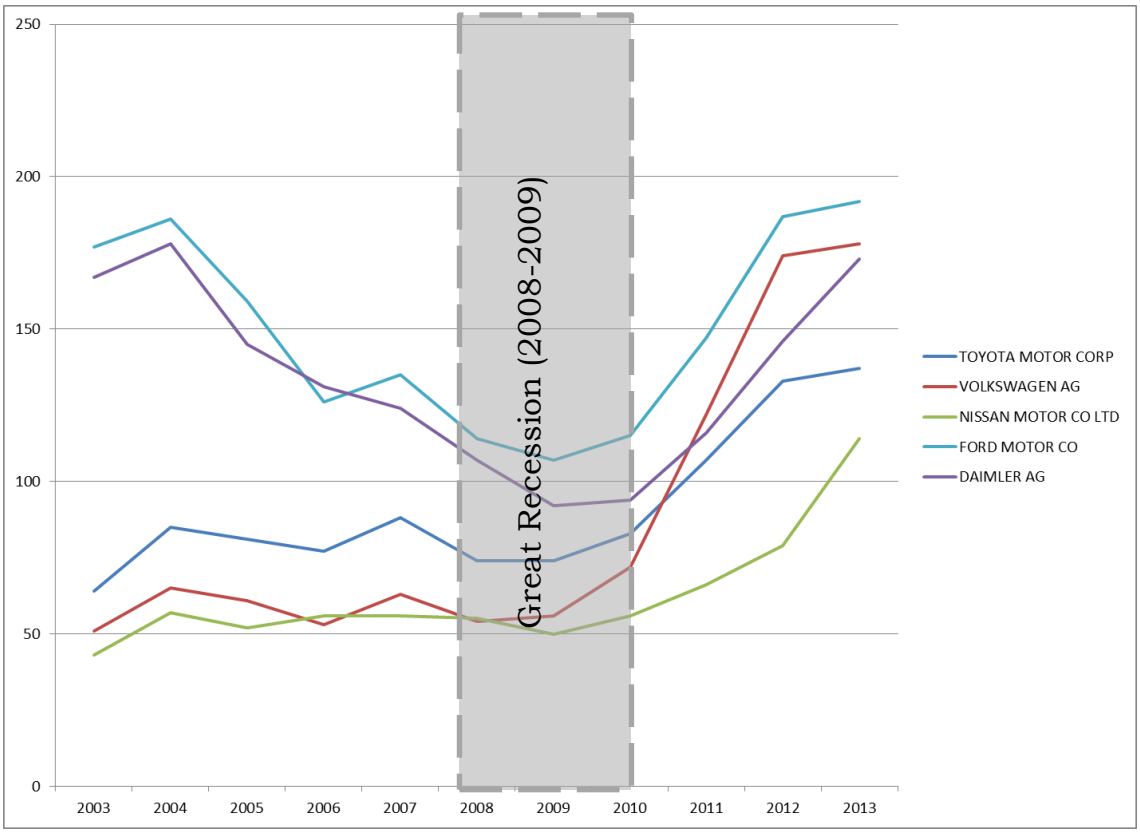


Figure 1. Number of Suppliers Utilized by Top-5 Auto Manufacturers (2004-2013).

Based on this evidence, we propose that there was a dramatic shift in SBM strategy which is contrary to the predictions of the SBM literature. Although research has examined buyer-supplier relationship management during the Great Recession (Krause and Ellram, 2014), firms' post-recession strategies appear to be unacknowledged in the extant literature (Ab Talib and Abdul Hamid, 2014; Roh et al., 2014; Rotaru et al., 2014; Song et al., 2014).

## Literature Review

Insights gained from the existing SBM research provide the foundation of our study. The extant literature frames supply base rationalization as a synonym for supply base reduction. Yet, a growing body of literature recognizes the Great Recession as a catastrophic event which had tremendous impact on nearly all aspects of our lives. Our goal is to extend the supply base management literature by investigating the consequences of this disruptive event on supplier management practices.

### *Supply Base Reduction*

Researchers have examined the changing role of buyer-supplier relationships as buying firms became more dependent on their suppliers (Burt and Doyle, 1993; Choi and Hartley, 1996; Park and Hartley, 2002). The strategy widely promoted in the supply chain literature is to develop long-term, heavily inter-twined relationships between buying firms and a decreasing number of suppliers (Hartley and Choi, 1996; Ogden and Carter, 2008; Trent and Monczka, 1998). The research stream on supply base reduction

(SBR) has increased over the past two decades, yet most of the published research focuses either on why companies should rationalize their supply base (Choi and Krause, 2006; Cousins, 1999), how to manage their relationships after reducing their supply base (Handfield and Nichols, 2004; Ogden and Carter, 2008), or quantitatively trying to determine the optimal supply base size (Agarwal et al., 2011; Agrawal and Nahmias, 1997; Cruz, 1996; Nam et al., 2011). Cousins (1999) surveyed 174 firms in the UK from ten different industries which were currently involved in or about to begin an SBR effort. He finds that 79% of the companies pursuing supply base reduction considered this a pure cost-saving measure without regard to the future buyer-supplier relationship. Interestingly, most of the firms in the study were "considering increasing their supply base after two years, due to cost increases" (Cousins, 1999; page 153). More recent research trends appear to consider the establishment of strategic supplier selection as a competitive advantage for the focal firm (Bellamy et al., 2014; Koufteros et al., 2012). The majority of these investigative streams assume that supply base reduction was a prerequisite activity and conducted their analyses by comparing firms which had reduced their supply bases to those that had not.

Despite the growing amount of supply chain research promoting the advantages of a smaller supply base, others did not share in the universal reduction solution. Birou et al (1997) reported that in a survey of purchasing executives, reducing their number of suppliers (i.e., supply base reduction) ranked 25$^{th}$ out of the 43 most important purchasing/sourcing strategies for their firms. The survey showed that competitive bidding and cost reduction ranked as the two most important issues for future firm strategy development. Risk analysis research concluded that reducing the number of

suppliers may not be the correct strategy for firms at all (Agarwal et al., 2011; Agrawal and Nahmias, 1997; Fang et al., 2016; Meena and Sarmah, 2016). Agarwal and Nahmias (1997) developed a model for determining and evaluating the optimal number of suppliers for a firm when the yield of suppliers' products is uncertain. Their research demonstrates that increasing the size of the supply base can reduce risks for the buying firm, where single-sourcing operations represent the most significant risk. Ha and Krishnan (2008) propose a "hybrid" model of qualitative and quantitative elements for conducting supplier selection which accounts for the cost benefits of single-sourcing and the risk mitigation component of multi-sourcing. The volume of cross-disciplinary research focused on the construction of supply base management strategy demonstrates the nuanced nature of the topic.

Just after the recession of the mid-1990's, Maloni and Benton (1997) called for a shift in the extant literature on supply base relationships, saying, "[a]s industry continues to implement supply chain partnerships, a wealth of research opportunities concerning the design, implementation and control of the supply chain are created." Given the magnified impacts across all aspects of the global economy from the Great Recession, we believe the call to action from Maloni and Benton should also be magnified. Our research utilizes a unique dataset to investigate the implementation of supply base management strategies before the Great Recession as well as alternative strategies implemented in the post-Recession recovery. Our desire is to expand the supply base management literature by recognizing the dynamic nature of supplier management decisions as well as lay the groundwork for future studies on the potential drivers and consequences of strategy changes.

*Punctuated Equilibrium Theory*

We use punctuated equilibrium theory (PET) as the overarching lens for this research. The defining characteristic of PET is that, as opposed to the view of gradual evolution, PET views systems as existing in equilibrium until "punctuated" by a short period of "revolutionary upheaval" (Gersick, 1991; Romanelli and Tushman, 1994). Then, the system establishes a new, different equilibrium which will eventually be shocked into upheaval again in the future. PET suggests that short bursts of radical change are not "flukes", but rather are an integral component of the environment under study. In other words, periods of stability and change are not conflicting processes, but instead, they may be considered inevitable consequences of each other (Princen, 2013). Although PET is relatively unused within the supply chain management literature (Ketchen and Hult, 2007), it has been used effectively to research technology diffusion (Loch and Huberman, 1999), political science (Princen, 2013), group development (Gersick, 1991) and organizational evolution (Romanelli and Tushman, 1994; Tushman and Romanelli, 1985). We believe that PET describes supply networks operating in the dynamic environment of a global economy.

Many segments of SCM research may be characterized as PET investigations though they are not classified as such. For example, innovation research generally classifies new product introductions as contributing incremental or radical change. The literature defines radical innovation as a completely new product which represents a clear departure from the company's existing products -- such as a new, breakthrough technology (Amara and Traoré, 2008; Dahlin and Behrens, 2005; Damanpour, 1991;

Garcia and Calantone, 2002; McCarthy et al., 2006; Tatikonda, 1999). Radical innovations provide the opportunity for firms to "create new markets and completely change the balance of power within existing markets" (Herrmann et al., 2007; page 93). On the other hand, incremental innovations offer small modifications to existing products and only create the opportunity for gradual growth through refinement and cost savings (Garcia and Calantone, 2002; Oke et al., 2007; Rothwell and Gardiner, 1989). Thus, we could consider the series of incremental changes to represent periods of stability in a PET model while radical changes would denote the upheaval period.

Another key component of a PET model is that the system being studied must portray a "deep structure," which is defined as "(1) the basic parts into which the units will be organized and (2) the basic activity patterns that will maintain its existence" (Gersick, 1991; page 14). Supply chain management research focuses on buyers and sellers as the basic units which are organized to create the supply network (Choi and Hong, 2002; Choi and Krause, 2006; Gulati et al., 2000; Gulati and Sytch, 2007). The basic activity patterns of material, monetary and information flows define the network of relationships of the deep structure. Thus, the punctuated equilibrium model provides a useful theoretical lens through which we examine supply base management strategy decisions.

The Great Recession provides a "transformative" event which caused major changes in almost every aspect of the world's economy (Grusky et al., 2011; Roberts, 2009). PET suggests that frequency and magnitude of future punctuations are unpredictable which makes their impacts potentially devastating (Wowak and Boone,

2015). Our research seeks to extend the body of knowledge on supply base management by utilizing both PET and a unique longitudinal dataset (described below) to provide unique insights otherwise undetected. Formally, we offer the following research proposition with regard to supply base management strategy:

> *Research Question: How did buying firms' SBM strategies change before and after the "Great Recession"?*

## Hypothesis Development

Empirical supply chain management research either explicitly or implicitly considers phenomena whose effects are seen over time. However, most investigations are done using cross-sectional data where associations between two or more variables are inferred to represent future performance (Ployhart and Vandenberg, 2010). Other disciplines such as medicine, engineering, finance and management utilize longitudinal examinations to provide keen insights which might otherwise go unacknowledged. However, there is very little, if any, SCM research which has explored the changes in supply bases sizes over time (Cousins, 1999). Building upon the foundation of punctuated equilibrium theory, this research analyzes the trend of supply base sizes for world automobile manufacturers in three distinct periods: (1) prior to 2008, (2) during the disruptive period 2008-2009 and (3) post-Recession years after 2009.

*Before the Great Recession*

Prior to 2008, "effective" SBM became an alternative way to state that firms needed to reduce their number of suppliers (Chen et al., 2004; Cousins, 1999; Ogden, 2006). There was vast conceptual and analytical research on the inverse relationship between the number of suppliers and firm performance of Japanese auto manufacturers (Choi and Hong, 2002; Dyer and Nobeoka, 2000; Park and Hartley, 2002). During this period, many researchers focused on methods to determine the "optimal" supply base size (Agrawal and Nahmias, 1997; Helper, 1991; Majumder and Srinivasan, 2008). Much of the prevailing SBM literature focused on metrics used to assess existing suppliers and the process for removing the lowest performers from the supply base (Kannan and Tan, 2002; Sarkar and Mohapatra, 2006). Thus, it is not surprising that we expect the size of supply bases to shrink over time prior to 2008.

> *H1: Prior to the Great Recession, the equilibrium state was supply base size reduction (i.e., a negative association with time).*

*After the Great Recession*

PET suggests that systems will find a new equilibrium state after experiencing a short period of dramatic, revolutionary change (Gersick, 1991). Prior to the Great Recession, the automotive industry was in a period of equilibrium as firms were gradually reducing supply base sizes over time (Choi and Krause, 2006; Cousins, 1999). The central idea was that the buying firm benefits from deeper relationships with fewer

suppliers (Choi and Hartley, 1996). However, this evolutionary change period was punctuated by the massive disruptive event known as the Great Recession (2008 – 2009). According to PET, the auto industry should emerge from the chaotic period in a distinctly new equilibrium state – different than the pre-Recession equilibrium. *A priori*, there is no way to predict the change in equilibrium, so we introduce our second hypothesis as two competing sub-hypotheses. One potential result would be that the Great Recession revealed the inherent risk associated with reducing supply base sizes too much, causing firms to change their post-recession strategy to supply base expansion (Cousins, 1999). The PET model would suggest that the new post-Recession equilibrium state was demonstrated through a reversal in direction of supply base size trends. Therefore, our formal hypothesis could be stated as:

> *H2a: After the Great Recession, the equilibrium state becomes supply base expansion (i.e., a positive association with time).*

An alternative result would be that the Great Recession demonstrated the importance of working very closely with a few selected supply partners whose future successes are intertwined with the focal firm (Chen et al., 2004; Choi and Hartley, 1996; Chopra and Sodhi, 2004). The buying firm would quickly slash the size of their supply base down to only the ultra-critical suppliers that directly benefit the buying firm's performance (Flynn et al., 2010; Grewal et al., 2007). The PET model would suggest that the direction of evolution is the same (reduction), but that the significantly higher rate of change represents the distinct, new system equilibrium.

*H2b: After the Great Recession, the equilibrium state becomes significantly faster supply base reduction (i.e., a larger negative association with time).*

*During the Great Recession (disruptive event)*

PET states that systems exist in equilibrium until experiencing a radical shock which is defined as a short period of "revolutionary upheaval" (Gersick, 1991; Romanelli and Tushman, 1994). The Great Recession is widely acknowledged as a "transformative" event creating major changes in almost every aspect of the world's economy (Grusky et al., 2011; Roberts, 2009). With the massive loss of wealth worldwide, thousands of businesses closed their doors, leaving customers to search for products elsewhere. The global automotive industry was not insulated from these effects, and the buyer-supplier ego-networks of the focal firms were most likely impacted as well. The massive economic losses of the Great Recession resulted in many companies going out of business and the loss of some suppliers from the focal firms' networks (Roberts, 2009). PET models are predicated on the notion that the disruptive event period is chaotic turmoil which changes the deep structure of the system (Gersick, 1991). Buyer-supplier relationships represent the fundamental structure under investigation in this research, so we expect those structures to be significantly impacted during the Great Recession. Given the direction of economic impact (loss), we expect the size of the supply bases coming out of the Great Recession to be significantly smaller than the size of the supply bases entering the Great Recession. Formally, we offer our final hypothesized relationship:

*H3: The number of suppliers in the first year after the Great Recession is significantly smaller than the number of suppliers in the last year before the Great Recession.*

We utilized two different statistical techniques to investigate these research hypotheses: interrupted time series analysis (Box and Tiao, 1975) and two-sample t-tests to compare values at different points in time. Next, we describe our methodology.

## Methodology

Our study is based on a unique longitudinal sample of supply base sizes captured annually between 2004 and 2013. The research design utilized in this study is the interrupted time series analysis technique (Box and Tiao 1975), used extensively in other social sciences but only recently in SCM research. We utilize this approach to offer more robust insights on the topic of supply base management strategies than the cross-sectional data analysis traditionally seen in the SCM literature.

### *Data collection*

Our research utilizes secondary data sources to identify and track the associations between 38 buyers and 1,439 suppliers over a 10 year period (2004-2013). Following the lead of previous SCM research on buyer-supplier relationships and SBM, this research will focus on firms in the global automotive manufacturing industry (e.g., Carnovale and

Yeniyurt, 2014; Choi and Hartley, 1996; Choi and Kim, 2008; Gulati and Sytch, 2007; Helper, 1991). The auto industry is particularly well suited to supply base research because the car is a complex, mass-produced product consisting of 15,000-20,000 parts and subassemblies – most of which are acquired from suppliers (Lomi and Pattison, 2006).

To collect data, we first identified the buying firms within the automotive industry using the Mergent Online research database (Mergent, Inc, 2014) and validated that list against the 2013 top-50 worldwide auto manufacturers as published by the International Organization of Motor Vehicle Manufacturers (OICA, 2013). Table 1 describes the filtering process used to identify our final sample of 38 worldwide auto manufacturers and Table 2 identifies the complete list of companies which represent over 85% of all automobiles manufactured worldwide (*Ward's Automotive Yearbook*, 2014).

| Step | Filter Criteria (from Mergent Online database) | Results Returned |
|---|---|---|
| 1 | All firms from:<br>NAICS 336111 (“Automobile Manufacturing”),<br>OR<br>NAICS code 336112 (“Light Truck and Utility Vehicle Manufacturing”)<br>OR<br>SIC code 3711 (“Motor Vehicles and Car Bodies”). | 208 |
| 2 | Remove firms listed as "Inactive" in Mergent Online database | 140 |
| 3 | Remove private firms<br>(i.e. firms without ticker symbol or financial reports) | 93 |
| 4 | Remove firms that do not indicate production or sale of automobiles in Mergent Online "Business Summary"<br>(i.e. subsidiaries, parts manufacturers, holding or finance companies) | 45 |
| 5 | Remove firms not contained within FactSet/Revere LiveData Buyer-Supplier Relationships™ database | 40 |
| 6 | Remove firms incorporated after 2003 | **38***<br>**(Final sample size)** |

** Please note in 2008, General Motors Corporation became Motors Liquidation Company to process the liquidation of General Motors through bankruptcy. In 2009, General Motors was re-established as a new company with an incorporation date of 2009. Financial information and buyer-supplier relationships were gathered and combined as a continuous General Motors firm.*

Table 1. Database Filtering Process to Identify Final Sample Size for Research

| Company Name | |
|---|---|
| ANHUI ANKAI AUTOMOBILE CO | KAI MOTORS CORP |
| ASHOK LEYLAND LTD | MAZDA MOTOR CORP |
| AVTOVAZ | MITSUBISHI MOTORS CORP |
| BEIQI FOTON MOTOR CO LTD | NISSAN MOTOR CO LTD |
| BMW - BAYER MOTOREN WERKE AG | PACCAR INC |
| CNHTC JINAN TRUCK | PEUGEOT SA |
| DAIHATSU MOTOR CO LTD | RENAULT SA |
| DAIMLER AG | SAIC MOTOR CORP LTD |
| DONGFENG MOTOR GROUP CO | SPARTAN MOTORS INC |
| FAW CAR CO LTD | SSANGYONG MOTOR CO LTD |
| FIAT CHRYSLER AUTOMOBILES NV | SUZUKI MOTOR CO LTD |
| FORD MOTOR CO | TATA MOTORS LTD |
| FUJI HEAVY INDUSTRIES LTD | TESLA MOTORS INC |
| GENERAL MOTORS CO | TOFAS-TURK OTOMOBIL FABRIKAS |
| GREAT WALL MOTOR CO | TOYOTA MOTOR CORP |
| HONDA MOTOR CO | VOLKSWAGEN AG |
| HOTAI MOTOR CO | VOLVO AB |
| HYUNDAI MOTOR CO LTD | XIAMEN KING LONG MOTOR CO |
| ISUZU MOTORS LTD | ZAP MOTORS |

Table 2. List of Global Automotive Manufacturing Firms Used

After identifying the auto manufacturers, we utilized the FactSet/Revere Supply Chain Relationships™ (referred to as FactSet from this point forward) database to find the suppliers for each buying firm annually from 2004 to 2013. This commercially-available database captures firm-level buyer-supplier linkages through a proprietary process of information collection, extraction and validation (FactSet/Revere, 2014; Ramchandani, 2014). The total number of firms contained within the FactSet database is 178,330. FactSet examines various primary data sources such as a company's SEC reports, websites, analyst reports, company press releases, or executive interviews for any public acknowledgement of an inter-firm relationship (Birgisson and Porter, 2013). While we will examine the buyer-supplier relationships, FactSet captures many types of connections between firms (i.e., customer, competitor, distributor, investor, supplier, etc.), and uses the information to compile the most accurate network structure of important firm relationships (Ramchandani, 2014). The main driver for acknowledging a buyer-supplier relationship is the Financial Accounting Standards Board statement No. 131, which specifies that: "[a]n enterprise shall provide information about the extent of its reliance on its major customers. If revenues from transactions with a single external customer amount to 10 percent or more of an enterprise's revenues, the enterprise shall disclose that fact" (FASB, 1997; page 15). It is important to note that FactSet contains information on firms located worldwide and is not restricted to publicly-traded firms.

The FactSet database is structured in a "point in time" format which means that the relationship information can be accessed for any specific date between 2003 and today (Cahan et al., 2013; FactSet/Revere, 2014). When reported, FactSet provides the percentage of the supplier's revenue generated from sales to the buying firm. Currently,

this accounts for approximately 8% of the total relationships contained in the FactSet database, but according to FactSet, that percentage is growing over time. Unfortunately with such a small percentage of relationship weights available, this research is unable to utilize that capability. However, future researchers utilizing FactSet data will be sure to find tremendous value in augmenting their network research with relationship weights. A sample of the Factset buyer-supplier relationship data is shown in Table 3 below for General Motors, BMW and Fiat on December 31, 2011:

| Date | Buying Firm | Supplier Name | Supplier Ticker | Revenue Percent |
|---|---|---|---|---|
| 12/31/2011 | General Motors | American Axle & Manufact. Holdings, Inc. | AXL | 75 |
| 12/31/2011 | General Motors | Shiloh Industries, Inc. | SHLO | 34 |
| 12/31/2011 | General Motors | P.A.M. Transportation Services, Inc. | PTSI | 34 |
| 12/31/2011 | General Motors | Superior Industries International Inc. | SUP | 33 |
| 12/31/2011 | General Motors | Strattec Security Corp. | STRT | 24 |
| 12/31/2011 | General Motors | Delphi Corporation | DLPH | 21 |
| 12/31/2011 | General Motors | Lear Corporation | LEA | 20.9 |
| 12/31/2011 | General Motors | Magna International Inc. (USA) | MGA | 20 |
| 12/31/2011 | General Motors | Tenneco Inc. | TEN | 19 |
| 12/31/2011 | General Motors | Methode Electronics Inc. | MEI | 17.6 |
| 12/31/2011 | BMW | Harman International Industries Inc. | HAR | 21 |
| 12/31/2011 | BMW | Burelle SA | BUR:FR | 13.8 |
| 12/31/2011 | BMW | Magna International Inc. (USA) | MGA | 13 |
| 12/31/2011 | BMW | Plastic Omnium | POM:FR | 11.96 |
| 12/31/2011 | BMW | Lear Corporation | LEA | 10.9 |
| 12/31/2011 | BMW | Modine Manufacturing Co. | MOD | 10 |
| 12/31/2011 | BMW | Faurecia SA | FURCF | 8 |
| 12/31/2011 | BMW | Autoliv Inc.(ADR) | ALV | 5 |
| 12/31/2011 | BMW | Tower International | TOWR | 4 |
| 12/31/2011 | BMW | GKN PLC | GKNLY | 2 |
| 12/31/2011 | BMW | Sogefi SPA | SO:IT | 0.6 |
| 12/31/2011 | BMW | Grupo Financiero Interacciones SA | GFINTERO:MX | NULL |
| 12/31/2011 | BMW | Alcoa Inc. | AA | NULL |
| 12/31/2011 | BMW | SL Green Realty Corp. | SLG | NULL |
| 12/31/2011 | Fiat | Magna International Inc. (USA) | MGA | 13 |
| 12/31/2011 | Fiat | Tower International | TOWR | 11 |
| 12/31/2011 | Fiat | Sogefi SPA | SO:IT | 8.3 |
| 12/31/2011 | Fiat | CIE Automotive SA | CIE:ES | 5 |
| 12/31/2011 | Fiat | GKN PLC | GKNLY | 5 |
| 12/31/2011 | Fiat | Delphi Corporation | DLPH | 3 |
| 12/31/2011 | Fiat | Wiest S.A. | WISA3:BR | NULL |
| 12/31/2011 | Fiat | Beni Stabili Spa SIIQ | XZJBF | NULL |
| 12/31/2011 | Fiat | Goodyear Lastikleri T.A.S. | GOODY:TR | NULL |

Table 3. Sample Buyer-Supplier Relationship Data from December 31, 2011.

In total, our unique longitudinal panel dataset contains 12,622 buyer-supplier relationship observations over a 10-year window.

*Statistical Analysis*

To test our research hypotheses, we conduct an interrupted time series analysis (Box and Tiao, 1975). This approach is particularly well-suited for investigating statistical differences in the level (i.e., intercept) and trend (i.e., slope) for a variable of interest before and after a specific event (Shadish et al., 2002; Shadish and Sullivan, 2011; West et al., 1989). Interrupted time series is a well-established technique in disciplines like psychology (West et al., 1989), medicine (Wagner et al., 2002), and management (Lubitsh et al., 2005). Our research into strategy differences before and after the Great Recession is a natural fit for the use of interrupted time series analysis and the theoretical lens of PET.

We capture annual SB sizes (the dependent variable of interest) for the four pre-Recession years preceding 2008 (2004-2007) and the four post-Recession years after 2009 (2010-2013). Since the recession period is considered to be the disruptive event in our study, all measures for 2008 and 2009 are excluded from the analysis. In this way, we ensure the same number of observations on either side of the event. Although longer periods are preferable for longitudinal analyses, short and wide panel data (i.e., many firms and multiple years) is a common substitute in strategy research. According to Certo and Semadeni (2006), almost half of the strategy literature contains research with no more than seven years of data.

Data preparation was done using Microsoft Excel 2010® and data analysis was conducted in SAS v9.4 (*SAS*, 2012). Our analysis used the mixed linear models (MIXED) procedure with an AutoRegressive ("ar1") correlation structure. This allows for robust regression coefficient estimation even in the presence of high correlations

between repeated SB size measurements (Ballinger, 2004; Kroes and Manikas, 2014; SAS Institute, Inc, 2008).

The model tested in this research has "size of supply base" as the dependent measure of interest. We define this as the number of direct suppliers to auto manufacturer (*i)* in year (*t)*. "Year" is coded as -4 to -1 for the years 2004 to 2007 and 1 to 4 for years 2010 to 2013. In this way, "Year" = 0 indicates the recession time period (2008 and 2009). A dummy variable (*I*) is created to represent whether the disruptive event has occurred for each observation (*I*="0" before the recession and *I*="1" after the recession). According to Wagner et al. (2002), $\beta_0$ estimates the baseline level of SB size in the last period before the Great Recession (2004); $\beta_1$ estimates the SB trend during the pre-recession years – this represents the "baseline trend" of the model (2004-2007); $\beta_2$ estimates the level change in SB size between the last pre-recession period (2007) and the first post-recession (2010); and $\beta_3$ estimates the change in the SB trend between the years before the recession compared with the years after the recession (2004-2007 vs 2010-2013). Therefore, the sum of $\beta_0$ and $\beta_2$ is the SB level in the first post-recession year (2010) and the sum of $\beta_1$ and $\beta_3$ is the SB trend after the Great Recession (2010-2013) (Wagner et al., 2002). Specifically, we analyze the following mixed model:

$$size\ of\ supply\ base_{it} = \beta_0 + \beta_1(Year_{it}) + \beta_2(I_{it}) + \beta_3(Year_{it} * I_{it}) + \beta_4(Rev_{it}) + \beta_5(COGS_{it}) + \beta_6(Payables_{it}) + e_{it}$$

Our analyses also added control variables to account for firm-specific differences. Following the extant literature, "Revenue" is used as a proxy for firm size (Hendricks and

Singhal, 2003). We included cost of goods sold ("COGS") and accounts payable ("Payables") as indicators of the propensity of the buying firm to outsource production of goods used in their end products. The error term $e_{it}$ represents the random variability not explained by the model.

Results

All algorithms converged successfully without errors. The analysis (shown in Table 4 below) demonstrates that there are significant differences in both the direction and magnitude of the SB size trends.

| **Independent Variable** | **Estimate** | **Standard Error** | **Pr > \|t\|** |
|---|---|---|---|
| Intercept | -7.6196 | 4.8064 | 0.1214 |
| | | | |
| **Annual Change in Supply Chain measures** | | | |
| Year | **-3.8059*** ** | 1.0251 | 0.0003 |
| I | -4.1937 | 2.4217 | 0.0846 |
| (Year * I) | **12.2445*** ** | 1.4922 | <.0001 |
| | | | |
| **Control Variables** | | | |
| Revenue | **0.000698*** ** | 0.000162 | <.0001 |
| COGS | -0.00015 | 0.000229 | 0.5184 |
| Payables | 0.000278 | 0.000524 | 0.5965 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| ChiSq | 288.57 | | |
| Pr > ChiSq | <.0001 | | |
| Number of Observations Read | | 289 | |
| Number of Observations Used | | 287 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 4. Change in Number of Suppliers

Prior to 2008 (pre-Recession), the number of suppliers used by the world's auto manufacturers was declining at the annual rate of 3.8 per year per manufacturer ($\beta_1$=-3.8059, p=0.0003). The negative coefficient for *YEAR* (i.e., $\beta_1$<0) demonstrates that the number of suppliers was decreasing over time; while the p-value of 0.0003 shows that the decrease is highly statistically significant. Thus, our research finding supports H1, suggesting that firms across the automotive industry were reducing the size of their supply bases prior to the Great Recession. Our finding also supports the SBM literature at the time, which suggested that firms were reducing their SB size, presumably, to generate deeper relationships with the remaining suppliers (Choi and Hartley, 1996; Choi and Krause, 2006; Ogden and Carter, 2008).

In our analysis, the post-recession trend in supply base sizes is represented by the $(Year_{it} * I_{it})$ factor. Any pre-recession years have $I_{it}$ = 0 and all post-recession years have $I_{it}$ = 1. The post-recession supply base size trend is the sum:

$$\beta_1 + \beta_3 = -3.8059 + 12.2445 = 8.4386$$

The positive coefficient (8.4386) demonstrates that the number of suppliers is dramatically increasing over time and the p-value for $\beta_3$ (p<0.0001) shows that the trend is highly significant. We find support for H2a, which posits that after the massive disruption of the Great Recession, the size of the automakers' supply bases have been rapidly *growing.* Obviously, our research does not find support for H2b, which hypothesized that the size of supply bases was shrinking at a significantly faster rate after the Great Recession.

These findings are interesting given that literature has suggested that the process of supplier identification, qualification, contract negotiation and integration is a long and expensive process (Handfield and Nichols, 2004). Removing suppliers from the SB would seem to be a comparatively quick and inexpensive task. The world's auto manufacturers have clearly moved away from SB *reduction* to prioritize SB *expansion* as their post-recession SBM strategy. In terms of magnitude, the post-recession SB growth rate of 8.4386 ($\beta_1 + \beta_3$) is over 2 times faster than the rate of SB decline before the recession (-3.8059).

Finally, our research sought to gain insight into supply base changes during the Great Recession. Contrary to our Hypothesis 3, our research finds that the change in supply base size between the last year before the recession (2007) and the first year after the recession (2010) was not significant ($\beta_2$=-4.1937, p=0.0846). Since this p-value was relatively close to our significance cut-off α=0.05, we conducted a two-sample t-test comparing 2007 and 2010. Table 5 below confirms that the number of suppliers in 2007 is not statistically different than the number of suppliers in 2010 (p=0.3697).

| Supply Base Size Comparison | Mean Difference | Std Err | t Value | Pr > \|t\| |
|---|---|---|---|---|
| (Number of Suppliers 2010) - (Number of Suppliers 2007) | -1.1429 | 1.257 | -0.91 | 0.3697 |

Table 5. Comparison of Number of Suppliers Pre- and Post-Recession.

Our data shows that SB reduction activities did not continue throughout the Great Recession – conceivably representing a period of re-assessment of SBM strategies. We

conducted sensitivity analysis to better understand the supply base changes which occurred in 2008 and 2009.

*Sensitivity Analysis*

Our sensitivity analysis re-considers the time periods defining the disruptive event in the PET model. Since the Great Recession is considered to have ended in mid-2009 (Grusky et al., 2011; Roberts, 2009), our alternative model considers 2009 to be the first post-recession year, while only excluding the 2008 data as during the recession. The statistical results (shown in Table 6) and interpretation of the SB trends for the alternative model was nearly identical to the original model.

| Independent Variable | Estimate | Standard Error | Pr > \|t\| |
|---|---|---|---|
| Intercept | **-12.8279**** | 4.4864 | 0.0069 |
| | | | |
| **Annual Change in Supply Chain measures** | | | |
| Year | **-4.0305***** | 1.0878 | 0.0003 |
| I | -1.7593 | 2.6558 | 0.5083 |
| (Year * I) | **10.154***** | 1.5011 | <.0001 |
| | | | |
| **Control Variables** | | | |
| Revenue | **0.000804***** | 0.00017 | <.0001 |
| COGS | -0.00035 | 0.000242 | 0.1503 |
| Payables | **0.001399**** | 0.00053 | 0.0087 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| ChiSq | 294.74 | | |
| Pr > ChiSq | <.0001 | | |
| Number of Observations Read | | 325 | |
| Number of Observations Used | | 323 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 6. Change in Number of Suppliers including 2009

The pre-recession slopes were both negative and highly statistically significant, while the post-recession slopes were all positive, more than double the pre-recession decline and highly statistically significant. Based on the consistency of our analyses, we feel confident in our original model and interpretations.

*Post Hoc Analyses*

To more fully understand the apparent dramatic shift in SB trends, we conducted further *post hoc* tests on annual SB size comparisons. One critical assumption in the

extant supply base rationalization literature is that firms have a "target" or "optimal" SB size (Agrawal and Nahmias, 1997; Nam et al., 2011). Thus, one possible explanation for the dramatic increase in the post-recession SB trend is that the recession caused the automakers to lose more suppliers than planned so they were regaining their target SB size after the recession. We conducted paired t-test comparisons in consideration of this alternative explanation (selective results shown in Table 7 below and full results shown in Appendix A). Our results show that two years after the recession (2011), the supply base was significantly larger than it was in the last year before the recession (2007) (mean diff=10.5714, p=0.0003). This indicates that the post-recession growth is not an effort to recover suppliers lost during the recession. Our conclusion is further supported by the discovery that SB sizes three years after the recession (2012) had significantly surpassed the SB sizes before the reduction efforts began in 2004 (mean diff=17.7353, p=0.0009). And the size of the supply base continued to grow through 2013.

| Supply Base Size Comparison | Mean Difference | Std Err | t Value | Pr > \|t\| |
|---|---|---|---|---|
| (Number of Suppliers 2010) - (Number of Suppliers 2004) | -6.9706 | 3.7705 | -1.85 | 0.0735 |
| (Number of Suppliers 2011) - (Number of Suppliers 2004) | 5.0588 | 3.7185 | 1.36 | 0.1829 |
| (Number of Suppliers 2012) - (Number of Suppliers 2004) | **17.7353*** ** | 4.8594 | 3.65 | 0.0009 |
| (Number of Suppliers 2013) - (Number of Suppliers 2004) | **24.3529*** ** | 5.1272 | 4.75 | <.0001 |
| | | | | |
| (Number of Suppliers 2010) - (Number of Suppliers 2007) | -1.1429 | 1.257 | -0.91 | 0.3697 |
| (Number of Suppliers 2011) - (Number of Suppliers 2007) | **10.5714*** ** | 2.6423 | 4 | 0.0003 |
| (Number of Suppliers 2012) - (Number of Suppliers 2007) | **23.0286*** ** | 4.5885 | 5.02 | <.0001 |
| (Number of Suppliers 2013) - (Number of Suppliers 2007) | **29.4000*** ** | 5.2068 | 5.65 | <.0001 |
| | * p < 0.05 | | | |
| | ** p < 0.01 | | | |
| | *** p < 0.001 | | | |

Table 7. Comparison of Pre- vs Post-Recession Number of Suppliers.

We are left to conclude that the steep growth in supply base sizes after the recession is not the pursuit of a target supply base size defined before the recession, but instead, represent a dramatic shift in policy or philosophy toward supply base management.

## Contributions, Limitations and Future Research

This study contributes to the field of supply base management research in multiple ways. Most importantly, our results demonstrate a clear shift in SBM strategy embraced by practicing managers, yet mostly unacknowledged in the academic literature. For the past 25 years, researchers have promoted the SB reduction strategy used by Japanese auto manufacturers in the early 1980's. This became a critical component of the "lean manufacturing" or the "Toyota Production System" philosophy (Aláez-Aller and Carlos Longás-García, 2010). However, utilizing the analytical approach of interrupted time series analysis on a unique longitudinal dataset, our results demonstrate that practicing managers have clearly changed their SBM strategies after the Great Recession.

Punctuated equilibrium theory suggests that long periods of steadiness are "punctuated" with short bursts of radical upheaval which fundamentally change the system balance (Gersick, 1991). Our research suggests that the Great Recession represents such a period of disruption which altered the strategy of supply base management. The traditional equilibrium of utilizing fewer suppliers has been replaced with a new equilibrium of seeking rapid supply base expansion.

Recall that the number of suppliers in the SB was not significantly different between the last pre-recession year (2007) and the first post-recession year (2010) ($p=0.3697$). This suggests that while the SB size was being reduced each of the four years prior to the "Great Recession," supply base sizes were not significantly reduced *during* the two year recession (2008-2009). The post-recession growth in SB size would be expected to stagnate at or below pre-recession levels if the firms were seeking a "target" supply base level. Yet by 2011, supply base sizes had exceeded their 2004 level before embarking on the SB reduction strategies – and continued to grow each of the next two years. This evidence shows that firms were not attempting to regain pre-recession "target" SB sizes, but instead, were intentionally and consistently *increasing* their number of suppliers after the Great Recession.

Another major contribution of this research is the demonstrated benefits of longitudinal investigations. Modern computing power and rapid access to digital information have allowed the creation and use of datasets such as the FactSet/Revere Supply Chain Relationships™ database. Adopting powerful analysis techniques from other disciplines allows unique insights not available through traditional SCM cross-sectional investigations. We were able to demonstrate that prior to 2008, manufacturing firms were practicing SB reduction strategies as demonstrated by the negative relationship between year and number of suppliers. Our longitudinal research also showed that after 2010, these firms now pursue SB expansion strategies at more than double the rate of previous reduction. The extant research on supply base management is well-established, yet our longitudinal investigation demonstrates a clear departure from the traditional literature.

There may be many explanations for the apparent change in SBM strategies. We offer a couple potential reasons that appear sound and we believe warrant further investigation:

1) Supply chain risk mitigation. Perhaps the economic impacts of the Great Recession forced buying firms to increase their supply base sizes to insulate their processes from the operational and financial risks caused by supply chain disruptions (Blackhurst et al., 2011; Käki et al., 2015; Sarkar et al., 2012; Zsidisin and Wagner, 2010).

2) Rate of technological advancement. Suppliers have been found to provide market and technological expertise to the buying firm which leads to increased firm performance (Azadegan and Dooley, 2010; Swink et al., 2007). Buying firms may seek relationships with more suppliers as a competitive requirement to keep pace with the rapid pace of technological advances and market changes.

3) Sheth's "Rule of Three." The "rule of three" (Sheth and Sisodia, 2002) would suggest that the reduced SB sizes in the pre-recession period were the result of mergers involving suppliers. This would shrink the SB as acquired suppliers became part of other companies already in the SB. Following this "rule of three" logic, the post-recession expansion of the SB would be the natural "de-merging" or spin-off of companies previously acquired.

While we believe this research represents an early endeavor along a promising stream of longitudinal SBM inquiries, our investigation has three primary limitations.

First, our sample size consists of 38 large, multinational corporations. SBM strategies represent an integral part of all firms' success, and it is not clear whether our research findings would be generalizable to small/medium enterprises (SMEs). Furthermore, this study is limited to auto manufacturers and may not apply across all industries. We suggest future research replicate our study with a heterogeneous sample of large, medium and small firms across multiple industries as a further step toward generalizability. Second, our buyer-supplier networks are generated from the FactSet database of publically-acknowledged relationships. Their methodology is tailored toward the most significant buyer-supplier relationships by capturing and validating all public filings, interviews, and analyst reports. While we feel confident that FactSet contains the most impactful buyer-supplier relationships, we must acknowledge that their database is not exhaustive. Future research should consider additional sources of buyer-supplier relationships as they become available. Finally, this study examines each firm's supply base as if existing in isolation. Since we examine a single industry (automotive), it would seem reasonable to assume that suppliers may be shared between buying firms. The dynamics and implications of those shared relationships on SBM strategies are ignored in this study. Future researchers should consider the impacts of shared suppliers between networks of competing firms within and across industries.

In sum, our research demonstrates to the managerial community and academic literature that SBM strategy has changed after the Great Recession. From a managerial perspective, a supply network represents a complex system of decision-making which can only be controlled to a limited extent (Carter et al., 2015; Pathak et al., 2007). Our research has uncovered evidence of a dramatic shift in SBM strategies as a result of the

disruptive event called the “Great Recession.” Decision-makers, today, face a new competitive environment in which SB reduction has been deliberately replaced by SB expansion. Punctuated equilibrium theory suggests that this chaotic upheaval was not an anomaly and, instead, it is almost certain to be punctuated again.

# FRIENDS OF MY ENEMIES: A POWER PERSPECTIVE ON COMPETITIVE NETWORKS AND FIRM PERFORMANCE

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Abstract

Supply chain management research has demonstrated the importance of the buyer-supplier network in creating competitive advantage for the buying firm. From the supply network perspective, the presence of one buyer-supplier relationship impacts all the other buyer-supplier and supplier-supplier relationships. Yet, the research literature assumes that the configuration of the network is centrally controlled by the buying firm. This dissertation work expands the definition of the supply network to include the buying firm's competitors and explores the organic changes in the new many-to-many supply network – which we call the "competitive network." Drawing upon power-dependence theory, we examine the relationship between structural changes and firm performance. This research also proposes a new network metric which captures changes in the power relationship between a buying firm and its supply base. The analyses are based on a unique longitudinal dataset of annual supply networks for 38 worldwide auto manufacturers over a 10-year period. We provide new information on the debate between the benefits of dense or sparse networks (i.e., network closure vs structural holes). Our research demonstrates that the Great Recession represented a dramatic shift in supply base management strategies. Firms were pursuing dense networks in the years before the Great Recession; however, they have changed dramatically to seek sparse networks in the post-recession years. Contrary to this strategy shift, we find that dense networks are associated with better firm performance. The contributions of this study as well as recommendations for future research are discussed.

*Key words*: supply networks, supply base management, power, interrupted time series

## Introduction

No firm can exist without suppliers, and increasingly, the competitive success of an organization is the result of its network of relationships (Meehan and Wright, 2012). Suppliers may be sources of efficiency, quality, innovation and profitability for a buying firm (Autry and Griffis, 2008; Bellamy et al., 2014; Dyer and Hatch, 2004). Previous research (Chapter 2 of this Dissertation work) demonstrated that after the Great Recession, firms have been expanding their supply base sizes at a dramatic rate. In this research project, we seek to understand whether that supply base expansion occurs through partnering with existing suppliers who work with their competitors or the addition of new suppliers to the network. Network theory offers research support for both predictions. Coleman's (1988) theorization of "Network Closure" suggests that dense networks provide superior information flow and monitoring dynamics which benefit all nodes in the network. Conversely, Burt (1992) suggests that "structural holes" can provide opportunities for information asymmetry which benefit some nodes in the network. By examining the annual supply networks and financial data for 38 global automotive firms between 2004 and 2013, we seek to gain insights into how the networks change over time and which network theory is associated with increased firm performance. We also utilize power-dependence theory to propose a new metric called Structural Dependence which seeks to quantify a buying firm's power within the overall network structure.

Traditionally, researchers have investigated buyer-supplier associations as a series of one-to-one dyadic relationships existing in isolation (e.g. Choi and Hong, 2002; Choi and Hartley, 1996; Ellram, 1990; Hahn et al., 1990; Ogden and Carter, 2008). However,

the combined buyer-supplier dyads aggregate to create a complex, inter-connected supply network (Choi et al., 2001; Choi and Krause, 2006). Nearly all supply chain research conceptualizes this network on the assumption that the buying firm holds the power to "effectively manage" their supply network, creating operational and/or financial benefits (Bellamy et al., 2014). Yet, anecdotal evidence suggests that buying firms may be impacted by supply network issues outside of the buying firm's control. For example, Choi and Kim (2008) describe one such situation:

> "Automaker 1 was experiencing great difficulty managing one of its major suppliers because the supplier also worked with Automaker 2, which was having difficulty selling its cars. Automaker 2 had placed undue financial and operational burdens on the supplier, which eventually led the supplier to declare bankruptcy. Automaker 1, a successful manufacturer, was forced to deal with problems that originated elsewhere. A senior executive said, 'In the future, when we select a major supplier, we are going to review carefully who its key customers are.'" (p. 6)

The supply networks of any two firms are traditionally assumed to operate independently. However, the above example demonstrates that a firm's competitors may indirectly impact performance within the focal firm's supply network. By extending our definition of the supply base to include the buying firm's competitors, we are also expanding the structure of the firm's network and capturing suppliers shared by multiple buying firms. We suggest that multiple competitor buying firms and their combined supply bases constitute a complex many-to-many system of relationships, which we call

the "competitive network." This expanded competitive network definition is specific enough to define the participants; yet it is generic enough to allow for flexible network boundaries when participants enter or leave over time.

The power of one firm to influence the activities, priorities and even investments of another firm is implicit within all inter-firm relationships (Dahl, 1957; Emerson, 1962). The extant supply chain literature recognizes the critical role that power plays, yet there is not a consensus on the direction of impact and as well as the source of that power (Maloni and Benton, 1997; Meehan and Wright, 2012). Some researchers claim that power is a property of the organization (Cox, 1999; Cox et al., 2004). In this view, a firm can be considered "powerful" in all buyer-supplier relationships. Other disciplines suggest that power is an attribute of the relational exchange (Busch and Wilson, 1976; Cheng et al., 2001; Nielson, 1998; Webster and Wind, 1972; Wilson, 2000). In other words, a firm may be considered to have the power advantage in one dyadic relationship, while simultaneously being at a power disadvantage in another dyadic relationship. Our study builds upon social network theory, which has been increasingly applied to explain the influence of embeddedness on firm performance (Borgatti and Li, 2009; Choi and Kim, 2008; Kim, 2014). The concept of structural embeddedness is a node-level metric that characterizes each firm's position within a supply network (Choi and Kim, 2008; Echols and Tsai, 2005; Holm et al., 1999; Provan, 1993; Uzzi, 1996; Zukin and DiMaggio, 1990), and can be measured in many ways (i.e., betweenness, eigenvalue, etc.). We utilize the degree centrality definition of embeddedness (Wasserman and Faust, 1994), which measures the total number of ties to other nodes within the network, to propose a new metric called "Structural Dependence."

We believe our expanded competitive network concept and structural dependence metric offer unique theoretical contributions to the supply network literature and creates many future research avenues. We also feel this project offers managerial insights into the performance impact of competitive network structures. The remainder of this paper is organized as follows. Section 2 provides a brief review of the relevant literature; Section 3 offers a series of testable hypotheses; Section 4 outlines our methodology; and Section 5 offers a brief discussion of the contributions, limitations, and future research directions.

## Literature Review

Our study is grounded in three distinct research streams which combine to motivate a holistic project and grow the knowledge base in all three. This study primarily extends the current research area of supply networks (Choi et al., 2001). By extending the definition of firms which should be considered part of the focal firm's supply network, we reveal previously neglected performance implications. To accomplish this goal, our study utilizes the concepts of power-dependence theory (Emerson, 1962) and extend supply chain management literature by introducing a new metric called "Structural Dependence". Our longitudinal investigation employs the techniques and metrics of social network analysis (Wasserman and Faust, 1994) to quantify the metrics of interest.

*Supply Networks*

Many research studies have shown that the relationship between a buying firm and its suppliers may affect opportunities for growth and long-term success for the buying firm (Choi and Hartley, 1996; Handfield and Nichols, 2004; Koufteros et al., 2012; Mena et al., 2013a; Wu and Choi, 2005). Traditionally, these investigations explore different strategies for defining the optimal number of suppliers and how to manage the relationships (e.g. Choi and Hong, 2002; Choi and Hartley, 1996; Ellram, 1990; Hahn et al., 1990; Ogden and Carter, 2008). The fundamental assumption in most of the early literature was that these relationships can be managed as a series of one-to-one dyadic relationships existing in isolation. More recent literature has recognized that the inter-related nature of buyer and supplier firms is more accurately represented as a supply network (Borgatti and Li, 2009; Galaskiewicz, 2011; Kim et al., 2011). The network perspective has moved the field from considering "one-to-one" buyer-to-supplier relationships to considering "one-to-many" buyer-to-suppliers relationships. This shift in perspective also considers the impact of previously-neglected supplier-to-supplier interrelationships (Granovetter, 1985; Mena et al., 2013b; Wu and Choi, 2005).

Conceptual research suggests that many of the dynamics within the supply base emerge organically as firms adapt, individually or collectively, to changes in their environment (Choi and Krause, 2006; Pathak et al., 2007). Thus, a supply base is analogous to a complex system operating as inter-related elements (organizations) having different functions and interactions (Checkland, 1993). Supply chain management research has applied the systems perspective when investigating issues such as: supply

disruption risks (Choi and Krause, 2006; Fiksel, 2006), new product development (Azadegan, 2011; Koufteros et al., 2005) and sustainability (Wu and Pagell, 2011). Of particular relevance to this study, the work of Bozarth et al. (2009) represents an early examination of the association between the structure of the supply base and firm performance.

Network theory suggests that there are informational and resource benefits available to each firm based on its position within the network (Granovetter, 1973). To illustrate the concept of embeddedness, consider a focal firm (A) tied to another firm (B) in a dyadic relationship (Figure 2 below).


Figure 2. Dyadic Relationship between Firms A and B.

This dyadic structure was the original definition used for buyer-supplier research. However, the presence of one dyadic link between Firm A and Firm B impacts all other dyadic links between Firm A and its suppliers. To capture the dynamics of an economic system, a larger network of nodes is required (Cook and Emerson, 1978). If each of these firms are tied to another firm (C), the result is a triadic group of firms shown in Figure 3. The triad becomes the smallest unit which allows for representation of buyer-supplier interrelationships (Choi and Wu, 2009; Wu and Choi, 2005).

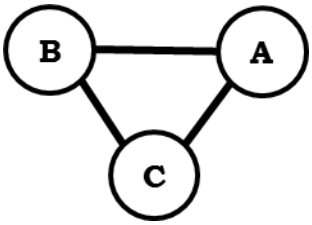

Figure 3. Triadic Relationship between Firms A-B-C.

At this point, each firm in the network is connected to all other firms in the network. Now, consider each of the three firms in the triadic relationships to also be connected to other firms (D, E, and F). These new firms may be connected to one, two or three of the original nodes as well as to other new nodes – and so on. Eventually, the full complement of nodes is identified and the interrelationships combine to create the emergent network of interest (Choi et al., 2001) as demonstrated in Figure 4.

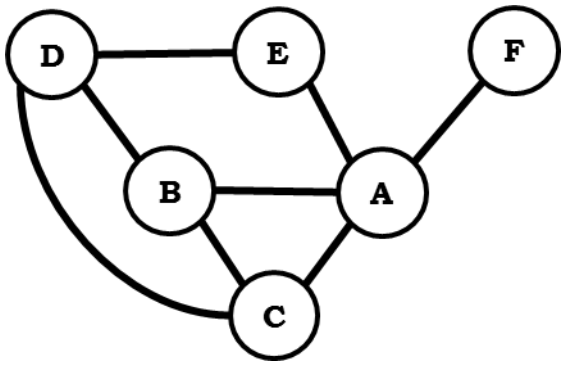

Figure 4. Network of Relationships between Firms A-B-C-D-E-F.

We must also include the indirect (weak) ties to consider the network representation complete (Granovetter, 1973). These weak ties represent connections between nodes which are facilitated *through* another node. The ties between firms C-F, B-E and E-F, in Figure 5 below, are all indirect ties facilitated by node A. Now, we can see the complete structure of the network through the direct (strong) or indirect (weak) ties (Choi and Kim,

2008; Granovetter, 1973; Kim, 2014). Notice that Firm A has the most direct connections (solid lines) with other firms in the network, while Firm F only is connected to other firms through Firm A. Thus, we may consider the position of Firm A within the overall network as a "gate-keeper" of information flow (Gulati, 1995; Gulati and Gargiulo, 1999).

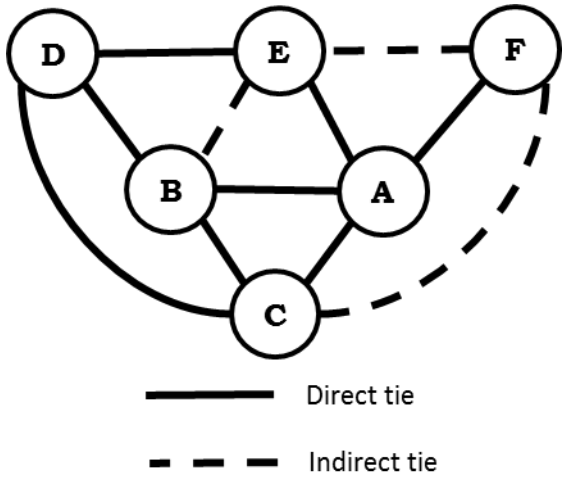


Figure 5. Complete Network Structure of Direct and Indirect Ties

Conceptualizing a supply base in this way, network theory provides a practical lens from which to consider the benefits and consequences of the focal firm's structural position (Kim, 2014). Researchers are able to investigate how the pattern of network ties promote the formation and collapse of inter-firm ties as well as exploring the success or failure of the focal firm (Echols and Tsai, 2005; Galaskiewicz, 2011). The network literature is divided into two distinct research streams: structural holes (Burt, 1992) and network closure (Coleman, 1988). Both of these well-established theories suggest that a firm's network structure can be considered an asset and a source of competitive advantage (Boyer et al., 2000; Burt, 2001; Galaskiewicz, 2011). Thus, the assumption is

that more successful firms are better connected within the network. However, these two theories take diametrically opposed views on what it means to be "better" connected.

Each node creates information on technology development, market demand changes, pricing information, etc. That information flows readily between nodes which are directly connected, forming a group of nodes (Burt, 2001, 1992; Granovetter, 1973). However, for firms separated by a structural hole, the flow of information must flow through the intermediary firm (Ahuja, 2000; Granovetter, 1973; Wu and Choi, 2005). Burt's notion is that when firms are connected, they all have similar access to similar information at the same time. However, structural holes create advantages for the firms which span the gap by controlling the flow of non-redundant information (Burt, 2004, 2001). Burt (2001) describes the competitive advantage of these "gate-keeper" nodes this way:

> "Information can be expected to spread across [a network], but it will circulate within groups [of nodes] before it circulates between groups [of nodes]…The result is that [firms] are not simultaneously aware of opportunities in all groups. Even if information is of high quality, and eventually reaches everyone, the fact that diffusion occurs over an interval of time means that [firms] informed early or more broadly have an advantage." (page 34)

Thus, the firm which spans a structural hole controls the diffusion of "non-redundant" information across the network. They gain access to new information which is in addition to the information already shared within the group of nodes. *Tertius gaudens*

(translated as "the third who benefits") is the term given to this "gate-keeper" role which allows the spanning firm to react first and creates a competitive advantage (Burt, 2001).

The "closure" argument motivated by Coleman (1988) is that firms benefit from a strongly interconnected supply base. The central notion is that in a dense network where every node is interconnected, everyone has access to the same information at the same time. Coleman (1988) says:

> "Information is important in providing a basis for action. But acquisition of information is costly. At a minimum it requires attention which is always in scarce supply." (page S104)

In the case of supply networks, Coleman's argument suggests that while buyers and suppliers establish a tie based on the flow of goods, they are also gaining direct access to the flow of information available to all other connected firms. This rapid transmission of information provides a mechanism for reducing risk and increasing trust among firms in the network (Coleman, 1988). For example, reputation concerns would prevent individual nodes from attempting to unjustifiably raise prices because they would risk losing credibility and business from the rest of the nodes (Granovetter, 1985). Therefore, Coleman's argument is that dense networks ensure efficient information flow and risk reduction which allows for increased performance of all nodes.

The central characteristic of both structural holes and network closure conceptualizations is that the structure of a firm's network relationships can be considered an asset for the firm. Each of these viewpoints is related to the density of the network. Following the lead of existing research, we utilize network analysis to explore

the performance benefits associated with a focal firm's network (Wasserman and Faust, 1994). In this research, we extend the research stream on supply networks in two ways: 1) we recognize that the focal firm's competitors are part of the supply network connected through the focal firm's suppliers; and 2) the group of suppliers utilized by the focal firm (e.g., the firm's supply base) are a subset of the suppliers connected to the buyers within the competitive network. In this way, a focal firm is embedded within its own supply network as well as the aggregated supply networks of its competitors who share suppliers. Utilizing the embeddedness concept and network analysis approach, this research seeks to explore the performance impacts of changes in the network structure of the extended competitive network.

*Network Analysis*

Network theory began in the field of sociology as an attempt to understand the patterns of interactions among actors within groups (Carnovale and Yeniyurt, 2014; Choi and Kim, 2008). Actors in this sense could represent any discrete entities of interest, such as individuals, buildings, corporations, cities, countries, etc. (Wasserman and Faust, 1994). Relationships between the actors are defined as "exchange in one relation … contingent upon exchange (or non-exchange) in the other direction" (Cook and Emerson, 1978; p. 725). For example, Firm A sends goods to Firm B contingent upon Firm B sending money to Firm A – thus, Firm A and Firm B have a network tie between them. The presence or absence of ties between actors affect the performance and dynamics of the supply network as a whole (Choi and Kim, 2008; Echols and Tsai, 2005;

Galaskiewicz, 2011; Kim, 2014; Wasserman and Faust, 1994). Following the lead of earlier SCM research, our supply network is conceptualized as a collection of buyers and suppliers engaged in "value-added" activities with their on-going relationships representing the network ties (Anderson et al., 1994; Bellamy et al., 2014; Borgatti and Li, 2009; Choi and Krause, 2006; Kim, 2014).

Network theory emphasizes that each buyer-supplier relationship is embedded within a larger network of ties with and between other actors. The performance of each actor is, therefore, impacted by the individual actions of the firm as well as its position within the network (Granovetter, 2005, 1985; Gulati et al., 2000). The extant literature has examined the network from the perspective of a single focal firm. A "buyer network" consists of a buyer and all of its suppliers; a "supplier network" consists of a single supplier and all of its buyers; and a "focal-organization" network which is a multi-tier network of a focal firm's suppliers and buyers (Kim, 2014). We combine these traditional definitions into one cohesive definition of the "competitive network," which consists of all buying firms which compete for suppliers and all of the suppliers competing for buying firms. This expanded view is built upon the observation that two firms tied together in a supply network can be both directly and indirectly tied to other firms as part of a larger business network (Anderson et al., 1994).

The extant literature has amassed an impressive array of measures to describe the structural position of a firm within an inter-organizational network. For an excellent overview, see Borgatti and Li (2009). This research utilizes the "degree centrality" metric, which is the number of links between the focal node and other nodes in the

network (Wasserman and Faust, 1994). Degree centrality can be further decomposed into "in-degree centrality" if the directionality of the relationship is toward the focal node, or "out-degree centrality" if the directionality of the relationship is away from the focal node. In the competitive network, the out-degree centrality of a supplier $(O_j)$ would be the number of partnerships it has with buying firms and is considered a measure of how embedded the supplier is within the competitor base. Likewise, the in-degree centrality of the buying firm $(I_i)$ is the number of partnerships it has with suppliers. This represents how embedded the buyer is within the aggregated supply base.

Previous researchers have demonstrated the performance impacts of the position of a firm within a network (Ahuja, 2000; Anderson et al., 1994; Azoulay et al., 2010; Gilsing et al., 2008; Gulati and Sytch, 2007; Holm et al., 1999). However, these studies have been cross-sectional and do not consider changes over time. Our research extends the use of network theory in SCM research in two ways. First, we redefine the supply network of a single focal firm into an overall competitive network of buying firms and all of their suppliers. Second, we utilize longitudinal data to explore the relationship between changes within the network structure and performance changes in the buying firms. Building upon power-dependence theory, when the structure of the network changes, the power of the focal firm relative to its suppliers changes, which ultimately affects the financial performance of the buying firm (Cook and Emerson, 1978; Emerson, 1962).

*Power-Dependence Theory*

While there are a number of earlier conceptualizations of power, it is Emerson (1962) who defines power as "the ability of an actor to influence another to act in the manner that they would not have otherwise" (page 32). In this seminal work, he suggests that power can only exist in a dyadic relationship when each actor seeks to acquire resources controlled by the other party. If the success of party A depends on its ability to access resources controlled by party B – and party B similarly requires resources controlled by party A – then there exists "mutual dependence" between the parties. According to Emerson, party A has power over party B when party A needs the resources from party B less than party B needs the resources of party A. In this way, power and dependence are inter-twined and are formally defined by Emerson (1962) on page 32 as follows:

> "Dependence: The dependence of actor A upon actor B is (1) directly proportional to A's motivational investment in goals mediated by B, and (2) inversely proportional to the availability of those goals to A outside of the A-B relation."

Pfeffer and Salancik (1978) apply Emerson's philosophy to the context of buyer-supplier relationships and is one generally-accepted conceptualization of power (Meehan and Wright, 2012). The fundamental premise is that power in an exchange relationship is a relative concept determined by which firm is more dependent on the other firm for needed resources. Previous research on inter-firm power has focused on the dynamics of the relationships (Cox et al., 2004; Hingley, 2005); the use of power in exchanges (Benton and Maloni, 2005); or the broader social consequences of power (French and Raven, 1959). The concept of power has a wide scope and therefore requires precise

context-specific definitions for research (Dahl, 1957; Emerson, 1962; French and Raven, 1959; Pfeffer and Salancik, 1978). This may be one reason there are very few empirical studies that investigate the impact of buyer-supplier relationship power. Thus, many debates on the bases and impacts of power with the supply network remain unresolved (Chicksand, 2015; Meehan and Wright, 2012).

Much of the supply chain management literature views power in inter-organizational relationships as an attribute of an organization (Hingley, 2005; Maloni and Benton, 2000; Pulles et al., 2014). Yet, one organization's dependence on another is not only contingent on the criticality of the resources sought, but also proportional to the availability of alternative sources (Emerson, 1962; Gulati and Sytch, 2007; Kim and Wemmerlöv, 2015; Pfeffer and Salancik, 1978) The Exchange Power Matrix (shown in Table 8 below) is a 2x2 matrix mapping the relative utility and scarcity of resources controlled by each firm in a buyer-supplier exchange (Cox, 2001). The quadrants are interpreted as:

- "Supplier Dominance" - resources controlled by the supplier have high utility for the buying firm and are scarce. The buyer is dependent on the supplier.
- "Buyer Dominance" – resources controlled by the buyer have high utility for the supplier and are scarce. The supplier is dependent on the buyer.
- "Independence" – relative utility and scarcity are both low. These are commodity-type products where there are plenty of buyer and seller options available to both firms. Neither firm is dependent on the other.

- "Interdependence" – relative utility and resource scarcity are both high. These are specialty products which provide competitive advantage for the buying firm so they want to engage in dedicated relationships with the supplier. Both are dependent on the other.

| Attributes of Buyer Power Relative to Supplier | | |
|---|---|---|
| High | **BUYER DOMINANCE** | **INTERDEPENDENCE** |
| | Few buyers / many suppliers<br>Buyer has high % share of total market for supplier<br>Supplier is highly dependent on buyer for revenue with limited alternatives<br>Supplier switching costs are high<br>Buyers switching costs are low<br>Buyers account is attractive to supplier<br>Supplier offerings are commoditized and<br>Buyer search costs are low<br>Supplier has no information asymmetry advantages over buyer | Few buyers / few suppliers<br>Buyer has relatively high % share of total market for supplier<br>Supplier is highly dependent on buyer for revenue with few alternatives<br>Suppliers switching costs are high<br>Buyer switching costs are high<br>Buyers account is attractive to supplier<br>Supplier offerings are not commoditized and are<br>Buyer search costs are high<br>Supplier has significant information asymmetry advantages over buyer |
| | **INDEPENDENCE** | **SUPPLIER DOMINANCE** |
| | Many buyer / many suppliers<br>Buyer has relatively low % share of total market<br>Supplier is not dependent on buyer for revenue and has many alternatives<br>Supplier switching costs are low<br>Buyer switching costs are low<br>Buyers account is not particularly attractive to<br>Supplier offerings are commoditized and standardized<br>Buyer search costs are relatively low<br>Supplier has only limited information asymmetry advantage over buyer | Many buyers / few suppliers<br>Buyer has low % share of total market for<br>Supplier is not at all dependent on the buyer for revenue and has many alternatives<br>Supplier switching costs are low<br>Buyer switching costs are high<br>Buyers account is not attractive to the supplier<br>Supplier offerings are not commoditized and are customized<br>Buyer search costs are very high<br>Supplier has high information asymmetry advantages over buyer |
| Low | | |
| | Low | High |
| | **Attributes of Supplier Power Relative to Buyer** | |

Table 8. Exchange Power Matrix adapted from Cox (2001).

While this matrix has garnered a substantial amount of research for the authors (e.g. Cox, 2004, 2001; Cox et al., 2004), the evaluation is applied as a cross-sectional comparison

and neglects the dynamic nature of changes over time. The attribution of generalized power as a characteristic defined by the relative dependency between the firms summarizes Emerson's central notion:

> "…to say that "X has power" is vacant, unless we specify "over whom"…power is a property of the…relation; it is not an attribute of the actor" (Emerson, 1962; page 32)

The recent shift in buyer-supplier research embracing an integrated network view suggests the need for empirical studies using the supply network as the level of analysis rather than the dyad (Anderson et al., 1994; Meehan and Wright, 2012). The system perspective suggests that segregating the buyer-supplier power evaluations into dyadic comparisons misses the emergent nature of the complex dynamics (Choi et al., 2001). As stated in Pfeffer and Salancik (1978), my research must recognize that "[o]rganizations are embedded in an environment comprised of other organizations" (page 2). In fact, the first comparison attribute of each quadrant in Cox's (2001) Exchange Power Matrix is the number of buying firms versus the number of supplier firms. Competition within our newly-defined competitive network is between buying firms for supply resources and marketshare, while supplier firms are competing for buying firms as customers. Our research does not seek to fill a "gap in the literature," but rather, seeks to extend the literature by: 1) expanding the definition of the supply network beyond the current firm-specific concept, and 2) investigating the relationship between the structure of the expanded competitive network and the performance of the buying firms over time. Specifically, we investigate how the collection of dyadic relationships existing within a

supply network combine to define power and impact firm performance. Note that the traditional firm-specific supply network is a subset of our expanded definition of the overall competitive network. Thus, the overarching research question can be formalized as:

> *Research Question: When the supply network definition is expanded to include competitor firms, how do changes in the structure of the competitive network impact performance of the buying firms over time?*

Hypothesis Development

There is very little (if any) empirical research which explores the association between changes in a firm's supply network structure and changes in its financial performance over time. Building upon existing network research, we utilize a unique longitudinal dataset to analyze how changes in the competitive network impact firm financial performance changes. The techniques and concepts of social network analysis enable us to move beyond studying individual firm ego-networks to instead consider the structure including all firms in the competitive network (Galaskiewicz, 2011; Wasserman and Faust, 1994). The critical feature of this approach is that all firms are considered to be interdependent and a relationship between any two firms creates opportunities or restrictions that impact all other firms (Burt, 1992; Granovetter, 1985; Gulati et al., 2000; Rowley, 1997).

Research conducted earlier in this dissertation work found that the number of suppliers in a firm's supply base has been growing dramatically after the Great Recession of 2008-2009. We are now interested in the pattern of that growth. Building upon the

two diametrically opposed philosophies within the network literature discussed above, we investigate both possible viewpoints. On one side, Burt (1992) argues for the advantages to firms within a "sparse" network where information asymmetries translate into competitive advantage. From the opposite view, Coleman (1988) argues that "dense" networks reduce risks and increase firm responsiveness to environmental changes due to the rapid transmission of information through the network. Our longitudinal investigation allows this research to explore the association between changes in network structure and changes in firm performance. We will be able to provide a first glimpse into which direction the networks are heading and the resulting performance implications.

*Percentage of Shared Suppliers*

Coleman (1988) argues for the benefits of "dense" networks in terms of information flow and risk reduction. Suppliers that work with multiple buying firms are also able to achieve economies-of-scale in the purchase of raw materials. The resulting decrease in costs for the manufacturers will attract more buying firms – further increasing the benefits of economies of scale. As Toyota's response to the Aisin fire demonstrated, even if a supplier does not provide exactly the same product as other suppliers, they create similar and related products that would garner economies-of-scope benefits (Nishiguchi and Beaudet, 1998). The increased expertise would create opportunities for increased innovations which attract more buying firms. These reinforcing loops lead to lower prices and faster technological advances. This increasingly dense network is

characterized by nodes that are connected to one another and have many connections to common partners (Uzzi, 1997).

Alternatively, Burt (1992) promotes the notion that competitive advantage can be gained by firms which partner with suppliers who do not partner with the competitor firms. These "unique" suppliers provide non-redundant information which cannot flow to other firms within the competitive network without communication via the focal firm as a "gate-keeper" node. The non-redundancy allows for exclusive technology introductions as well as early information on environmental changes. The development of partnerships with unique suppliers can generate a competitive advantage for the buying firm (Burt, 2001; Cook and Emerson, 1978). Following the logic of Coleman and Burt, we offer competing hypotheses on the trend of percentage of shared suppliers over time.

*H1a: The percentage of shared suppliers within the buying firm's supply base increases over time.*

*H1b: The percentage of shared suppliers within the buying firm's supply base decreases over time.*

Firm performance may be captured in a variety of ways. Following extant literature, we will analyze firm performance through four specific metrics: Return-On-Assets, Return-On-Investment, Return-On-Sales and Tobin's q (Deloof, 2003; Ebben and Johnson, 2011; Farris and Hutchison, 2003, 2002; García-Teruel and Martínez-Solano,

2007; Hofmann and Kotzab, 2010; Kroes and Manikas, 2014). Table 9 below shows the calculations and short descriptions for our firm performance measures.

| Measure | Abbreviation | Description | Calculation |
|---|---|---|---|
| Return On Assets | ROA | Efficiency of the firm at using its assets to generate earnings | $\left(\frac{Net\ Income}{Total\ Assets}\right)$ |
| Return On Investment | ROI | Efficiency of all investments relative to their costs | $\left(\frac{Net\ Income}{Total\ Invested\ Capital}\right)$ |
| Return On Sales | ROS | Company's operational efficiency. Also known as "Operating Profit Margin" | $\left(\frac{Net\ Income}{Total\ Revenue}\right)$ |
| Tobin's q | TOBINSQ | Firm's market value per dollar of replacement costs of assets | $\left(\frac{Market\ Cap + LongTerm\ Debt + Net\ Current\ Liabilities}{Value\ of\ Total\ Assets}\right)$ |

Table 9. Firm Performance Measures (adapted from www.investopedia.com).

The benefits of an increasingly dense network can be expected to increase responsiveness to environmental changes due to rapid information flow (Coleman, 1988; Cook and Emerson, 1978). Also, the increasing number of shared suppliers can translate into lower costs-of-goods-sold via economies of scale to the supplier who is now producing more for the additional firms. Following Coleman's network closure logic, we offer the following series of hypothesized relationships:

*H2a: The percentage of shared suppliers is positively associated with ROA.*

*H3a: The percentage of shared suppliers is positively associated with ROI.*

*H4a: The percentage of shared suppliers is positively associated with ROS.*

*H5a: The percentage of shared suppliers is positively associated with Tobin's q.*

Again, Burt's notion of the advantage of structural holes would suggest the opposite relationships. The introduction of "unique" suppliers to the supply base creates structural holes which are only bridged by the buying firm. The new suppliers offer non-redundant information to the buying firm which creates a competitive advantage (Burt, 2001, 1983). Therefore, we offer the competing hypotheses:

*H2b: The percentage of shared suppliers is negatively associated with ROA.*

*H3b: The percentage of shared suppliers is negatively associated with ROI.*

*H4b: The percentage of shared suppliers is negatively associated with ROS.*

*H5b: The percentage of shared suppliers is negatively associated with Tobin's q.*

*Structural Dependence*

Analyzing the change in the percentage of shared suppliers within the supply base and their association with firm performance provides an interesting but incomplete picture of the network dynamics. Our definition of "shared suppliers" is a binary measure: "1" if the supplier partners with at least one other buying firm and "0" otherwise. Thus, we are missing an indication of magnitude of change. To overcome this limitation, we introduce a new metric to the literature called "Structural Dependence." Structural Dependence is used to more thoroughly operationalize the changing aspects of buyer-supplier relations within the competitive network. A detailed

description is introduced in the Dependent Variables portion of the Methodology section, but briefly the formula for Structural Dependence is shown below:

$$Structural\ Dependence_{it} = \sum_{j=1}^{N_S} \left[ a_{ij} * ln \left( \frac{\left(\frac{I_i}{N_S}\right)}{\left(\frac{O_j}{N_M}\right)} \right) \right]$$

Conceptually, this new metric is the difference between the number of alternative suppliers for the buyer versus the number of alternative buyers for the supplier. Emerson's (1962) power-dependence theory suggests that the firm with fewer alternatives relative to the other firm is more structurally dependent.

Earlier, we found that ego-networks of each buying firm is growing, yet Coleman's dense network view would say that more buying firms should be partnering with fewer suppliers (Coleman, 1988). This would indicate that the total number of relationships ("degree centrality") for each supplier would be increasing. On the other hand, Burt's structural holes notion would argue that buying firms are seeking suppliers with fewer relationships or even unique suppliers (Burt, 1992). The degree centrality of each supplier would be reduced in this case. For example, suppose a supplier moved from partnering with 2 buying firms to 5 buying firms. This transition would support Coleman's dense network view; its degree centrality would increase 2.5 times; yet we would simply measure it as a shared supplier in both periods. Likewise, if the supplier moved from 5 buyers to 2 buyers in support of Burt's theory, it would still be considered a shared supplier in both periods. We propose an additional metric, called "Structural

Dependence", which is designed to capture the directionality and magnitude of buyer-supplier network changes.

We conceptualize Structural Dependence as essentially the total number of alternative suppliers available to the buying firm versus the total number of alternative buyers available to the supplier firms (Emerson, 1962; Pfeffer and Salancik, 1978). The vast array of alternative buyers means the "shared" suppliers are not beholden to any individual manufacturer partner suppliers. Changes in network density change the ratio of buyers and suppliers which shifts the dependency relationships between the firms (Cook and Emerson, 1978; Pfeffer and Salancik, 1978). Since the power differential between manufacturer and supplier is the critical driver of our Structural Dependence measure, we can further investigate the theories of network closure versus structural holes. Coleman's network closure view would suggest that more buying firms would be partnering with a smaller number of suppliers. This transition would indicate that the number of alternative buyers for the supplier was greater than the number of alternative suppliers for the buyer. Within our new metric, that would indicate a reduction of Structural Dependence over time. On the other hand, Burt's structural holes view would suggest that buying firms are finding suppliers with reduced ties to other buying firms in the competitive network. This shift to a sparse network over time would indicate that the buyer had more alternatives than the suppliers which causes the Structural Dependence measure to increase. We offer the following two formal competing hypotheses:

*H6a: Structural Dependence is negatively associated with time.*

*H6b: Structural Dependence is positively associated with time.*

Structural Dependence is a measure introduced to consider the magnitude of changes in competitive network relationships. The foundational arguments still hold true for the benefits found in Coleman's network closure theory as well as the contrasting advantages proposed in Burt's structural holes theory. Structural Dependence is intended to provide a more nuanced metric which reflects more than a binary measure. A decrease in Structural Dependence suggests that the buying firm has fewer alternatives relative to its suppliers, which supports network closure theory where fewer suppliers are partnering with a larger number of buying firms (Coleman, 1988). The dense network means that buying firms are more likely to reap the benefits of price reductions, technology investments, environmental change information, etc. Therefore, we extend the firm performance benefits of dense networks to the following hypotheses:

*H7a: Structural Dependence is negatively associated with ROA*

*H8a: Structural Dependence is negatively associated with ROI*

*H9a: Structural Dependence is negatively associated with ROS*

*H10a: Structural Dependence is negatively associated with Tobin's q*

On the other hand, we also have the competing viewpoint for the benefits of a sparse network reflected in an increase in Structural Dependence (Burt, 1992). The low volume of connections between nodes suggests that information passes slowly throughout the network (Granovetter, 1973). In the competitive network, "unique" suppliers (defined as suppliers to a single buying firm) provide a source of information asymmetry

within the network that can result in technology or cost leadership. Thus, buying firms in sparse networks can gain competitive advantages because they share few suppliers. However, unique suppliers have no alternative network partners, which makes them vulnerable to price and product pressures. These relationship dynamics suggest that the buying firm is able to achieve lower costs and exploit technological advances through sparse networks. Therefore, we offer our final competing hypotheses:

*H7b: Structural Dependence is positively associated with ROA*

*H8b: Structural Dependence is positively associated with ROI*

*H9b: Structural Dependence is positively associated with ROS*

*H10b: Structural Dependence is positively associated with Tobin's q*

## Methodology

In this section, we describe the data sources, variables, and statistical techniques used to test our hypothesized relationships. Following the lead of extant SCM literature on buyer-supplier relationships and supply base management, this research will focus on firms in the global automotive manufacturing industry (e.g. Carnovale and Yeniyurt, 2014; Choi and Hartley, 1996; Choi and Kim, 2008; Gulati and Sytch, 2007; Helper, 1991). The auto industry is particularly well suited to supply base research because the car is a complex, mass-produced product consisting of 15,000-20,000 parts and subassemblies – most of which are acquired from suppliers (Lomi and Pattison, 2006). We begin by identifying the buying firms in the auto industry and gather their annual

COMPUSTAT firm performance data for the years 2004-2013. Then we utilize those buying firms as inputs to the FactSet/Revere Supply Chain Relationships™ (referred to as FactSet from this point forward) database to construct the annual supply base networks consisting of 38 buyers and 1,439 suppliers for the same years. In total, our unique longitudinal panel dataset contains 12,622 buyer-supplier relationship observations and the corresponding firm performance data over a 10-year window.

*COMPUSTAT and Mergent Online*

Mergent Online and COMPUSTAT both provide the Standard Industrial Code (SIC) and North American Industry Classification System (NAICS) codes for any selected firm within their databases. Both databases also allow for searching by SIC or NAICS code to identify competitors within the same industry – which is an important step in developing our list of competitor buying firms. Throughout this research, we will utilize the following definitions:

*Supply base* - the ego-network of an individual auto manufacturer (buying firm) (Choi and Krause, 2006).

*Competitor base* – the complete list of auto manufacturers (buying firms) competing upstream for suppliers and downstream for marketshare.

*Aggregated supply base* – the full list of suppliers used in the ego networks of the competitor base.

The identification of the "competitor base" (buying firms) within the automotive industry is gathered through Mergent Online (Mergent, Inc). Table 10 below shows the filtering criteria used to refine the list of buying firms from 200+ automotive firms to the 38 firms used in this study.

| Step | **Filter Applied (* using Mergent Online database)** | **Results Returned** |
|---|---|---|
| 1 | All firms from:<br>NAICS 336111 ("Automobile Manufacturing"),<br>OR<br>NAICS code 336112 ("Light Truck and Utility Vehicle Manufacturing")<br>OR<br>SIC code 3711 ("Motor Vehicles and Car Bodies"). | 208 |
| 2 | Firms listed as "Active" in Mergent Online database | 140 |
| 3 | Remove private firms<br>(i.e. firms without ticker symbol or financial reports) | 93 |
| 4 | Remove firms that do not indicate production or sale of automobiles in Mergent Online "Business Summary"<br>(i.e. subsidiaries, parts manufacturers, holding or finance companies) | 45 |
| 5 | Contained within FactSet/Revere LiveData Buyer-Supplier Relationships database | 40 |
| 6 | Incorporated before 2003 | **38*<br>(Final sample size)** |

** Please note in 2008, General Motors Corporation became Motors Liquidation Company to process the liquidation of General Motors through bankruptcy. In 2009, General Motors was re-established as a new company with an incorporation date of 2009. Financial information and buyer-supplier relationships were gathered and combined as a continuous General Motors firm.*

Table 10. Database Filtering Process to Identify Final Sample

We begin by combining the members of three primary industry classification codes: NAICS 336111 ("Automobile Manufacturing"), NAICS code 336112 ("Light

Truck and Utility Vehicle Manufacturing"), and SIC code 3711 ("Motor Vehicles and Car Bodies"). The results were augmented with the 2013 top-50 worldwide auto manufacturers as published by the International Organization of Motor Vehicle Manufacturers (OICA, 2013). This initial list contained 208 global auto manufacturing firms in the competitor base. We removed any firm that is not "active" in Mergent Online, which reduced our list to 140 firms. Next, we eliminated any private firms with no ticker symbol or financial information available in Mergent Online – which brings the number of competitors to 93. We then checked the "business summary" of each firm for words or phrases indicating the production and sale of automobiles rather than components, financing, or holding companies. We also eliminated subsidiaries which left 45 firms in the competitive base of the auto industry. Our final two selection criteria were that the auto company was contained within the FactSet database and that the firm was incorporated before 2003. This ensured that we have a complete dataset for analysis for each firm in the competitive base. The final list contains 38 global automobile competitor firms for analysis in our study. Table 11 shows our final list of auto manufacturing firms which represent over 85% of all automobiles manufactured worldwide in 2013 (*Ward's Automotive Yearbook*, 2014). Please note in 2008, General Motors Corporation became Motors Liquidation Company to process the bankruptcy proceedings General Motors. In 2009, General Motors was re-established as a new company with an incorporation date of 2009. Financial information and buyer-supplier relationships were gathered and combined as a single, continuous General Motors firm.

| Company Name | |
|---|---|
| ANHUI ANKAI AUTOMOBILE CO | KAI MOTORS CORP |
| ASHOK LEYLAND LTD | MAZDA MOTOR CORP |
| AVTOVAZ | MITSUBISHI MOTORS CORP |
| BEIQI FOTON MOTOR CO LTD | NISSAN MOTOR CO LTD |
| BMW - BAYER MOTOREN WERKE AG | PACCAR INC |
| CNHTC JINAN TRUCK | PEUGEOT SA |
| DAIHATSU MOTOR CO LTD | RENAULT SA |
| DAIMLER AG | SAIC MOTOR CORP LTD |
| DONGFENG MOTOR GROUP CO | SPARTAN MOTORS INC |
| FAW CAR CO LTD | SSANGYONG MOTOR CO LTD |
| FIAT CHRYSLER AUTOMOBILES NV | SUZUKI MOTOR CO LTD |
| FORD MOTOR CO | TATA MOTORS LTD |
| FUJI HEAVY INDUSTRIES LTD | TESLA MOTORS INC |
| GENERAL MOTORS CO | TOFAS-TURK OTOMOBIL FABRIKAS |
| GREAT WALL MOTOR CO | TOYOTA MOTOR CORP |
| HONDA MOTOR CO | VOLKSWAGEN AG |
| HOTAI MOTOR CO | VOLVO AB |
| HYUNDAI MOTOR CO LTD | XIAMEN KING LONG MOTOR CO |
| ISUZU MOTORS LTD | ZAP MOTORS |

Table 11. List of Global Automotive Manufacturing Firms in Study

Annual financial data reported by publically traded firms is amassed in the COMPUSTAT database, which contains archival data back to the early 1900's (Standard and Poor's, 2014). This study will use COMPUSTAT annual information to create the dependent measures of firm performance: Return on Assets (ROA), Return on Investment (ROI), Return on Sales (ROS), and Tobin's q. To calculate these metrics, the following annual indictors (shown in COMPUSTAT abbreviation and descriptor) are gathered for each selected firm:

- Company Name
- FYEAR -- Data Year – Fiscal
- CURNC -- Native Currency Code
- AT -- Assets – Total
- DLC -- Debt in Current Liabilities – Total
- DLTT -- Long-Term Debt – Total
- INVT -- Inventories – Total

- LT -- Liabilities – Total
- RE -- Retained Earnings
- RECT -- Receivables – Total
- COGS -- Cost of Goods Sold
- REVT -- Revenues – Total
- CAPX -- Capital Expenditures
- CSHO -- Common Shares Outstanding

Market Capitalization, a critical component of Tobin's q, is provided through COMPUSTAT only in "as reported" currency. For instance, many European firms report their annual financial statements in Euros, while many Japanese firms report their financial statements in Yen. Since we are utilizing an international group of buying firms, we standardize the currency of financial reports to US Dollars. For consistency, we calculate Market Capitalization as the Number of Shares Outstanding multiplied by the Closing Stock Price on the date of the financial report. Mergent Online contains daily stock closing prices back to 1997 and can be provided in any currency selected. The currency conversion rate on the date of the financial report is used so firm financial measures are consistently represented for each firm.

*FactSet/Revere Supply Chain Relationships™ LiveData*

This research is based primarily on the unique, longitudinal buyer-supplier relationship data available through the FactSet/Revere Supply Chain Relationships™ database. For simplicity, we will refer to the research database as "FactSet." This is a commercially-available database which captures firm-level buyer-supplier linkages through a proprietary process of information collection, extraction and validation (FactSet/Revere, 2014). The total number of firms contained within the FactSet database

is 178,330. FactSet examines various primary sources such as a company's SEC annual reports, websites, analyst reports, company press releases, or executive interviews for any public acknowledgement of an inter-firm relationship (Birgisson and Porter, 2013). While we limit our study to buyer-supplier relationships, FactSet captures many types of connections between firms (i.e., customer, competitor, distributor, investor, supplier, etc), and uses the information to compile the most accurate network structure of important firm relationships (Ramchandani, 2014). The main driver for acknowledging a buyer-supplier relationship is the Financial Accounting Standards Board statement No. 131, which specifies that: "An enterprise shall provide information about the extent of its reliance on its major customers. If revenues from transactions with a single external customer amount to 10 percent or more of an enterprise's revenues, the enterprise shall disclose that fact" (FASB, 1997; page 15). It is important to note that the FactSet database contains relationship information for worldwide firms and the companies listed are not restricted to publicly-traded firms.

The FactSet database is structured in a "point in time" format which means that the relationship information can be accessed for any specific date between 2003 to today (Cahan et al., 2013; FactSet/Revere, 2014). When reported, FactSet provides the percentage of the supplier's revenue generated from sales to the buying firm. Currently, this accounts for approximately 8% of the total relationships contained in the FactSet database, but according to FactSet, that percentage is growing over time. Unfortunately with such a small percentage of relationship weights available, this research is unable to utilize that capability. However, future researchers utilizing FactSet data will be sure to find tremendous value in augmenting their network research with relationship weights. A

sample of the Factset buyer-supplier relationship data is shown in Table 12 below for General Motors, BMW and Fiat on December 31, 2011:

| Date | Buying Firm | Supplier Name | Supplier Ticker | Revenue Percent |
|---|---|---|---|---|
| 12/31/2011 | General Motors | American Axle & Manufact. Holdings, Inc. | AXL | 75 |
| 12/31/2011 | General Motors | Shiloh Industries, Inc. | SHLO | 34 |
| 12/31/2011 | General Motors | P.A.M. Transportation Services, Inc. | PTSI | 34 |
| 12/31/2011 | General Motors | Superior Industries International Inc. | SUP | 33 |
| 12/31/2011 | General Motors | Strattec Security Corp. | STRT | 24 |
| 12/31/2011 | General Motors | Delphi Corporation | DLPH | 21 |
| 12/31/2011 | General Motors | Lear Corporation | LEA | 20.9 |
| 12/31/2011 | General Motors | Magna International Inc. (USA) | MGA | 20 |
| 12/31/2011 | General Motors | Tenneco Inc. | TEN | 19 |
| 12/31/2011 | General Motors | Methode Electronics Inc. | MEI | 17.6 |
| 12/31/2011 | BMW | Harman International Industries Inc. | HAR | 21 |
| 12/31/2011 | BMW | Burelle SA | BUR:FR | 13.8 |
| 12/31/2011 | BMW | Magna International Inc. (USA) | MGA | 13 |
| 12/31/2011 | BMW | Plastic Omnium | POM:FR | 11.96 |
| 12/31/2011 | BMW | Lear Corporation | LEA | 10.9 |
| 12/31/2011 | BMW | Modine Manufacturing Co. | MOD | 10 |
| 12/31/2011 | BMW | Faurecia SA | FURCF | 8 |
| 12/31/2011 | BMW | Autoliv Inc.(ADR) | ALV | 5 |
| 12/31/2011 | BMW | Tower International | TOWR | 4 |
| 12/31/2011 | BMW | GKN PLC | GKNLY | 2 |
| 12/31/2011 | BMW | Sogefi SPA | SO:IT | 0.6 |
| 12/31/2011 | BMW | Grupo Financiero Interacciones SA | GFINTERO:MX | NULL |
| 12/31/2011 | BMW | Alcoa Inc. | AA | NULL |
| 12/31/2011 | BMW | SL Green Realty Corp. | SLG | NULL |
| 12/31/2011 | Fiat | Magna International Inc. (USA) | MGA | 13 |
| 12/31/2011 | Fiat | Tower International | TOWR | 11 |
| 12/31/2011 | Fiat | Sogefi SPA | SO:IT | 8.3 |
| 12/31/2011 | Fiat | CIE Automotive SA | CIE:ES | 5 |
| 12/31/2011 | Fiat | GKN PLC | GKNLY | 5 |
| 12/31/2011 | Fiat | Delphi Corporation | DLPH | 3 |
| 12/31/2011 | Fiat | Wiest S.A. | WISA3:BR | NULL |
| 12/31/2011 | Fiat | Beni Stabili Spa SIIQ | XZJBF | NULL |
| 12/31/2011 | Fiat | Goodyear Lastikleri T.A.S. | GOODY:TR | NULL |

Table 12. Sample Buyer-Supplier Relationship Data from December 31, 2011.

In this research, we define the ego network as the group of first-tier suppliers connected to an automobile manufacturer OEM who build, market and sell automobiles under their own brand (Carnovale and Yeniyurt, 2014). The "competitive network" is defined as the aggregation of ego networks -- inter-connected through suppliers who partner with more than one auto manufacturer OEM. From this competitive base, we generate the annual ego networks using FactSet and the financial performance indicators from COMPUSTAT for each firm. Combining the individual ego networks, we create

the competitive network for the worldwide auto industry annually from 2004 to 2013. The data collected from FactSet is used to create an annual buyer-supplier matrix, where each cell represents whether a relationship exists between the buying firm and the supplier in the particular examined.

*Statistical Analysis*

The network and performance metrics for this study were consolidated and calculated within Microsoft Excel®, while the statistical analysis was completed using SAS v9.4 (*SAS*, 2012). Ordinary Least Squares Regression would be unable to generate statistically-accurate results because our data is clustered by firm (Ballinger, 2004; Kroes and Manikas, 2014; Liang and Zeger, 1986). Instead, we followed the Interrupted Time Series Analysis technique (Box and Tiao, 1975) used earlier in this work. Our study on the number of suppliers suggested that the Great Recession represented a time of statistically significant change in supply base management strategies used by automotive firms. Utilizing similar statistical techniques, we extend the earlier work by examining our network data in more detail. Significant trends and/or indications of strategy changes related to buying firms' Structural Dependence is explored. We utilize the mixed linear models (MIXED) approach for analyzing panel data. This approach allows for robust regression coefficient estimation when there is high correlation between measurements (Ballinger, 2004; Kroes and Manikas, 2014; SAS Institute, Inc, 2008). In our dataset, the financial performance measures for a given firm are highly correlated from one period to the next. Additionally, the network structure characteristics also exhibit high correlation

between periods. The population-averaged approach in the MIXED procedure is used in our models to explore the relationship between changes in measures of supply network structure ($Percentage\ of\ Shared\ Suppliers,\ Supply\ Base\ Power$) and changes in firm financial performance (*Return on Assets, Return on Investment, Return on Sales, Net Income, Tobin's q, Stock Price*).

In general, there are many options for the link function implemented within mixed linear models. Previous research has established that repeated time-series financial measurements exhibit a first-order autoregressive correlation between time periods (Kroes and Manikas, 2014; Liang and Zeger, 1986). Thus, our investigation tests the hypothesized relationships between network structure and firm performance using the one-period AutoRegressive ("ar1") link function.

*Dependent Variables*

This research will define performance for the buying firm through multiple metrics which have been utilized in previous finance and supply chain research: Return on Assets (Das et al., 2006; Droge et al., 2004; Kim, 2009); Return on Investment (Chen et al., 2004; Flynn et al., 2010; González-Benito, 2007); Return on Sales (Kristal et al., 2010; Vickery et al., 2003); and Tobin's q (Lindenberg and Ross, 1981; Wernerfeld and Montgomery, 1988). Utilizing COMPUSTAT as the source of annual financial data for each buying firm, we are able to consider ROA, ROI and ROS.

Return on Assets (ROA) is an operational measure which shows how efficiently the firm utilizes its assets to generate net income (Dess and Robinson, 1984; Gale, 1972).

A large ROA number shows that the firm is effectively increasing revenue while using fewer assets. Return on Investment (ROI) is closely related to ROA but measures how well the firm converts its capital investments into net income. ROI is primarily a cash flow metric that compares gains to costs. Return on Sales (ROS) examines how much profit is generated for each dollar of sales. ROA, ROI and ROS can all vary substantially across industries; however they are appropriate for comparing firms in this study because we are analyzing competitors within a single industry.

Tobin's q is a critical factor in assessing the apparent worth of a firm and is also used later in this research project. Tobin's q is defined as the ratio of the market capitalization of a firm divided by the replacement value of its assets (Lindenberg and Ross, 1981; Wernerfeld and Montgomery, 1988). Since it is a dimensionless metric, Tobin's q allows for comparisons across firms without adjustments (Kroes and Manikas, 2014; Lang and Stulz, 1994). Increased Tobin's q measures represent increased perceived value of the firm within the investment community. A Tobin's q value between 0 and 1, means that the cost to replace the firm's assets is greater than the value of its stock. Thus, the stock would be considered undervalued in the market. Conversely, a Tobin's q ratio that is greater than 1 means that the market considers the firm to be more valuable than simply the sum of its assets.

*Independent Variables*

This research is investigating the relationship between competitive network structure and buying firm performance. To quantify both constructs for analysis, we

leverage the concepts of ego networks and embeddedness from social network theory (Wasserman and Faust, 1994). For clarification, we will use the following general diagram as a reference for the definitions of our specific network measures:

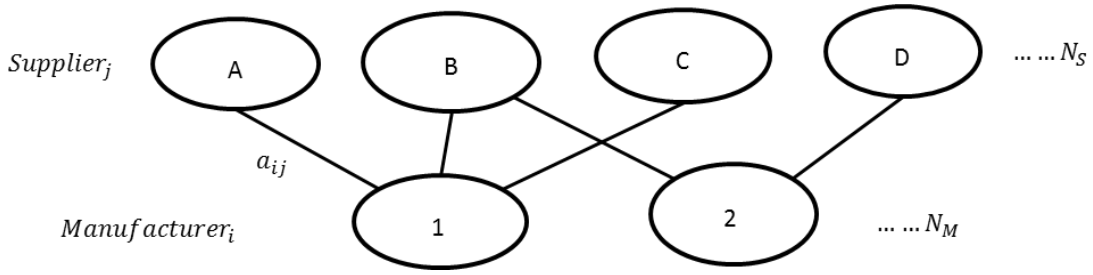


Figure 6. Generic Competitive Network.

The competitive network contains a total of $N_M$ manufacturer firms and a total of $N_S$ supplier firms. Each $a_{ij}$ is a binary variable with a value of 1 if a relationship between manufacturer $i$ and supplier $j$ exists -- and a value of 0 otherwise.

The ego network for a buying firm is the collection of supplier firms to which it is directly connected (Borgatti and Halgin, 2011; Carnovale and Yeniyurt, 2014). Ego networks have been studied as critical influencers of innovation (Ahuja, 2000), knowledge sharing (Holm et al., 1999), communication (Granovetter, 1973), and economic outcomes (Granovetter, 2005). We will investigate how the number of suppliers in the buying firm's ego network changes over time and how those changes may be related to firm performance metrics. Formally, we define the size of the ego network for any manufacturer $i$ at time $t$ as:

$$Size\ of\ Ego\ Network_{\ it} = \sum_{j=1}^{N_S} a_{ijt} \ \forall i \ \forall t$$

Network density is defined as the percentage of potential connections between members of the network which are active (Uzzi, 1997; Wasserman and Faust, 1994). Therefore, we may conceptualize the density of the competitive network as the extent to which suppliers are shared among manufacturers. The ego network of a manufacturer will contain some unique suppliers which only work with the focal firm and some shared suppliers who work with at least one other manufacturer in the competitive base. We are interested in how the percentage of shared suppliers changes over time, and how the percentage of shared suppliers is associated with firm performance. For any manufacturer $i$ at time $t$, the percentage of shared suppliers in the ego network is:

$$Percentage\ Shared\ Suppliers_{it} = \frac{\sum_{j=1}^{N_S} a_{ijt} * I(i,j,t)}{Size\ of\ Ego\ Network_{it}} \quad \forall i \ \forall t$$

$$where\ I(i,j,t) = \begin{cases} 1\ if\ \sum_{i=1}^{N_M} a_{ijt} > 1 \\ 0 \quad otherwise \end{cases}$$

Embeddedness is traditionally a node-level metric which represents the importance of a node within the overall network (Gnyawali and Madhavan, 2001; Zukin and DiMaggio, 1990). Embeddedness can be conceptualized in multiple ways, including "degree centrality" of the node, which is the number of links between the focal node and other nodes in the network (Wasserman and Faust, 1994). Degree centrality can be further decomposed into "in-degree centrality" if the directionality of the relationship is toward the focal node, or "out-degree centrality" if the directionality of the relationship is away from the focal node (Wasserman and Faust, 1994). In our competitive network, the

out-degree centrality of a supplier $(O_j)$ would be the number of partnerships it has with buying firms. We think of this as how embedded the supplier is within the competitor base. Likewise, the in-degree centrality of the buying firm $(I_i)$ is the number of partnerships it has with suppliers which represents how embedded the buyer is within the aggregated supply base.

In his seminal work on power and dependence, Emerson (1962) found that differences in the number of alternatives between two nodes in a network impacts the performances of the nodes. The node which has more alternatives has the "power" in the relationship; while the node with fewer alternatives is more "dependent." Utilizing this foundational concept, we define Structural Dependence of any dyadic relationship within the competitive network to be the ratio of the firms' embeddedness. Formally, we define the Structural Dependence of any manufacturer $i$ at time $t$ to be:

$$Structural\ Dependence_{it} = \sum_{j=1}^{N_S} \left[ a_{ij} * ln \left( \frac{\left(\frac{I_i}{N_S}\right)}{\left(\frac{O_j}{N_M}\right)} \right) \right]$$

The use of the logarithm within the power calculation seeks to provide interpretable value to the metric. A negative value for any $M_i, S_j$ relationship means that the supplier has more alternatives than the buyer. Similarly, positive value shows that the buyer has more alternatives relative to the supplier. A score of zero indicates that the two sides have equal alternatives and therefore the power has been effectively removed from the relationship. Our new Structural Dependence measure for any firm $i$ at time $t$ is the sum of these dyadic comparisons across all suppliers within the competitive network.

*Control Variables*

The investigations within this research control for year, firm size, and cost of goods sold as a percentage of accounts payable. From the beginning of 2008 through the middle of 2009, the world experienced the most devastating global economic crisis since the Great Depression (Grusky et al., 2011). During this period (known as the "Great Recession"), the combined wealth of worldwide businesses, real estate and financial assets was reduced over $11 trillion USD (Roberts, 2009). Since we have annual data from 2003 to 2014, we include a control variable for year (*Year*) to account for environmental changes inherent to the competitive landscape which affected all competitors. We also include a variable (*Year_Sq*) as the square of Year to acknowledge a possible non-linear effect of time.

The natural logarithm of annual revenue (*lnRev*) is used as a proxy measure to control for firm size. Following the lead of previous research, we do not use total assets to avoid multicollinearity issues since total assets is contained within the calculation of Tobin's q (our dependent variable) (Hendricks and Singhal, 2003; Kroes and Manikas, 2014). We use the natural logarithm of annual revenue as the control variable because of the non-linear relationship that has been shown to exist between revenue and Tobin's q (Eroglu and Hofer, 2014; Kroes and Manikas, 2014).

Finally, we include a control variable we refer to as "Propensity to Outsource" (*Prop_Out*) which is defined as accounts payable as a percentage of cost of goods sold. This measure is intended as a proxy for representing corporate strategies on "make vs buy" decisions. For a given cost of goods sold level, firms that tend toward outsourcing

will see a lower asset base and increased accounts payables. While firms that elect to "make" their required products in-house will see increased assets and much lower accounts payables. This study utilizes Return on Assets as a critical firm performance metric, therefore we utilize Propensity to Outsource in an attempt to remove corporate philosophy from our dependent measure of interest.

It should be noted that we acknowledge the real possibility that there are some buyer-supplier relationships that are not captured in the FactSet data and therefore not included in our analysis. However, since our outcome of interest is the buying firm performance, it seems unlikely that a supplier would make a significant impact on performance and not be acknowledged by the buyer, the supplier or an industry analyst. FactSet captures buyer-supplier relationships that are reported in 10K reports, acknowledged in executive interviews or documented in press releases, thus we can be fairly confident that overall, we have captured the critical suppliers from the perspective of buying firm performance.

## Results

The central issue in this research is how changes in the competitive network impact the performance of the buying firms. Earlier, this research project showed that the 4 years leading up to the Great Recession marked a period of significant supply base reductions; yet after the Great Recession, the number of suppliers has been growing significantly. The current analysis is focused on the manifestation of changes within the network and how those changes impact firm performance. We test the competing

theories of network closure (Coleman, 1988) and structural holes (Burt, 1992) to evaluate their associations to firm performance: 1) Return on Assets; 2) Return on Inventory; 3) Return on Sales; and 4) Tobin's q ratio. We seek unique insights on these relationships utilizing a longitudinal sample of data spanning 10 years. The model coefficient estimations and significance levels were generated through the mixed linear models (MIXED) procedure in SAS v9.4 (*SAS*, 2012). All algorithms converged successfully without errors.

*Percent Shared Suppliers*

Our research is primarily based in the area of agreement between Coleman and Burt – the density of the network as a critical characteristic influencing the performance of the firms involved. Initially, we seek to understand how the percentage of a firm's supply base that is shared with its competitors changes over time. An increase in the percentage of shared suppliers would seem to support Coleman (1988)'s view of the benefits of network density. Conversely, finding that shared supplier percentages decrease over time would support Burt (1992)'s view of the attractiveness of structural holes. Because of the longitudinal nature of our dataset, this research is uniquely positioned to provide a perspective on these competing hypotheses.

Following the statistical approach of interrupted time series analysis, we find the change in percentage of shared suppliers is not statistically significant in the years before the Great Recession ($p=0.4457$). Likewise, the change in percentage of shared suppliers is not significant after the Great Recession ($p=0.5042$). Finally, there is no significant

difference in the trend before and after the Great Recession (*p=0.2665*). Overall, we do not find support for either H1a or H1b, indicating that buying firms within the competitive network are working with a consistent percentage of shared suppliers. Table 13 below shows the results for the statistical model.

| **Independent Variable** | **Estimate** | **Standard Error** | **Pr > \|t\|** |
|---|---|---|---|
| Intercept | **-0.3614*** | 0.1566 | 0.0267 |
| | | | |
| **Annual change in Supply Chain measures** | | | |
| Year | 0.01427 | 0.01868 | 0.4457 |
| I | -0.05515 | 0.04952 | 0.2665 |
| (Year * I) | 0.01898 | 0.02837 | 0.5042 |
| | | | |
| **Control Variables** | | | |
| ln(Rev) | **0.1088***** | 0.01428 | <.0001 |
| Prop_Out | -0.04725 | 0.1411 | 0.7381 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| ChiSq | 177.91 | | |
| Pr > ChiSq | <.0001 | | |
| Number of Observations Read | | 289 | |
| Number of Observations Used | | 287 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 13. Results for Percentage of Shared Suppliers

Recall that our definition of shared suppliers required only that the supplier work with at least one other buying firm in addition to the focal firm. The lack of statistical significance suggests that the Great Recession did not change firms' strategies with respect to sourcing from shared or unique suppliers. This result was further supported

when *post hoc* analysis considering *Year* as a continuous variable also lacked statistical significance (*p=0.0665*).

The Percentage of Shared Suppliers was hypothesized to create a competitive advantage for firms either by gaining access to non-redundant information or ensuring the rapid transmission of information. We tested each of these theories by comparing the Percentage of Shared Suppliers to firm performance over time. As shown in Table 14 below, only Return on Sales showed a slightly significant association with firm performance (*p=0.046*). The negative coefficient (*β=-0.2655*) suggests that as the percentage of shared suppliers increases, the return on sales decreases, lending support to hypothesis H4b and Burt's theory on the benefit to Structural Holes. Other than that single instance, the remainder of the hypotheses H2a/b, H3a/b, H4a and H5a/b did not find statistical support.

| | Intercept | Percent Shared Suppliers | Year | lnRev | Propensity to Outsource |
|---|---|---|---|---|---|
| ROA | **-0.4507*** ** (<.0001) | -0.05824 (0.1506) | 0.002477 (0.6233) | **0.04935*** ** (<.0001) | 0.1426 (0.1266) |
| ROI | **-0.7378*** (0.0319) | -0.1062 (0.5982) | 0.008401 (0.6978) | **0.07219*** (0.0499) | 0.4463 (0.3282) |
| ROS | **-2.2127*** ** (<.0001) | **-0.2655*** (0.046) | 0.002087 (0.9023) | **0.2308*** ** (<.0001) | **0.6771*** (0.0276) |
| Tobin's q | **4.2421*** ** (<.0001) | 0.1444 (0.5003) | 0.04965 (0.1141) | **-0.2993*** ** (<.0001) | **-2.4785*** ** (<.0001) |
| | | | * p < 0.05 | | |
| | | | ** p < 0.01 | | |
| | | | *** p < 0.001 | | |

Table 14. Firm Performance Impacts of Change in Percentage of Shared Suppliers.

Since the percentage of shared suppliers did not change over time and did not substantially impact firm performance, the benefits which caused firms to dramatically increase their supply base sizes are still unknown. Next we explore the competitive network through our new Structural Dependence metric.

*Structural Dependence*

Previously, we showed that buying firms have changed their supply base management strategy from reduction to expansion. However, the large and significant changes in the number of suppliers in the supply base are not reflected in changes to the percentage of shared suppliers. In fact, our investigation showed that there is no

significant trend in the percentage of shared supplies over the 10 years studied. The seeming contradiction between large changes in the number of suppliers and no changes in the percentage of shared suppliers might instead suggest that it is the number of competitors which partner with a supplier that is changing. We proposed a new metric called Structural Dependence as a mechanism to capture these changes in magnitude. If a buying firm increases the number of suppliers within its ego-network, the result is an increase in its number of alternatives and an increase in its Structural Dependence. However, if the supplier partners with another competitor, the number of alternatives for the supplier increases which reduces the Structural Dependence for the buying firm. The changes in magnitude captured by Structural Dependence reflect decisions that are both in control of the focal firm (i.e., number of suppliers) and out of its control (i.e., other competitors the supplier adds). In this regard, Structural Dependence focuses on the larger phenomena of changes in the competitive network as opposed to simply looking at changes in the individual ego-networks.

The first task in our analysis is to investigate changes in Structural Dependence over time. Again, we followed the analytical approach of interrupted time series analysis and using the MIXED model with "ar1" link function in SAS. Our results demonstrate that, unlike percentage of shared suppliers, the Structural Dependence metric does reflect significant changes in both magnitude and direction over time. In the years leading to the Great Recession, Structural Dependence was declining annually ($\beta_1$*=-14.1428, p=0.0048*). The negative coefficient for *Year* lends support to H6a which suggests that Coleman's view of the benefits of network closures were driving supply base management decisions prior to the Great Recession. Buying firms were willing to

relinquish some relative power to partner with suppliers who also partnered with their competitors. Obviously, finding support for H6a in the pre-Recession years means that our data does not find support for H6b which was based on Burt's argument for the benefits of structural holes.

Interestingly, the Structural Dependence metric indicates a distinct change in supply base management strategy in the years after the Great Recession. The indicator variable "I" is used to segregate periods before and after the Great Recession for analysis purposes. The highly significant "I" variable in this research (*p=0.0087*) suggests that the Great Recession represented an intervention resulting in a clearly different strategy environment. The negative coefficient ($\beta_2$=*-28.9241*) shows that the trend direction was reversed after the Great Recession. In this case, Structural Dependence went from steadily decreasing to dramatically increasing. The post-recession trend in Structural Dependence is represented by the sum of *Year* and (*Year * I*):

$$\beta_1 + \beta_3 = -14.1428 + 46.9536 = 32.8108$$

The positive coefficient ($\beta_1 + \beta_3 = 32.8108$) demonstrates that the Structural Dependence is dramatically increasing annually since the Great Recession and the p-value for $\beta_3$ ($p<0.0001$) shows that the trend is highly significant. The years since the Great Recession lend support to H6b which aligns to Burt's theory of Structural Holes. Just as in the Chapter 2 analysis of number of suppliers, the post-recession trend is more than double the pre-recession rate – and in the opposite direction. Buying firms have clearly shifted their supply base management strategy since the Great Recession to pursue

partnerships with suppliers connected to fewer of their competitors. Table 15 below shows the Structural Dependence statistical analysis results.

| Independent Variable | Estimate | Standard Error | Pr > \|t\| |
|---|---|---|---|
| Intercept | **-205.92**** | 75.7243 | 0.0099 |
| | | | |
| **Annual change in Supply Chain measures** | | | |
| Year | **-14.1428**** | 4.9735 | 0.0048 |
| I | **-28.9241**** | 10.9408 | 0.0087 |
| (Year * I) | **46.9536***** | 6.8966 | <.0001 |
| | | | |
| **Control Variables** | | | |
| ln(Rev) | **28.3744***** | 7.2339 | 0.0001 |
| Prop_Out | -35.4917 | 35.1017 | 0.313 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| ChiSq | 488.91 | | |
| Pr > ChiSq | <.0001 | | |
| Number of Observations Read | | 289 | |
| Number of Observations Used | | 287 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 15. Results for Structural Dependence

With this clear shift in strategy, our research concludes by seeking to understand the association between this dramatic shift in Structural Dependence and firm performance. The results of our investigation provide a stark contrast to our results when analyzing Percentage Shared Suppliers. Structural Dependence was negatively and significantly associated with every aspect of firm performance as shown in Table 16.

| | Intercept | Structural Dependence | Year | lnRev | Propensity to Outsource |
|---|---|---|---|---|---|
| ROA | **-0.5239*** ** (<.0001) | **-0.00028** ** (0.0042) | 0.00269 (0.5817) | **0.05632*** ** (<.0001) | 0.1431 (0.1192) |
| ROI | **-1.0467** ** (0.003) | **-0.00117** ** (0.0034) | 0.01229 (0.5547) | **0.1117*** ** (0.0006) | 0.3735 (0.399) |
| ROS | **-2.4455*** ** (<.0001) | **-0.00112*** ** (0.0009) | 0.003212 (0.8458) | **0.2505*** ** (<.0001) | **0.6625*** (0.0287) |
| Tobin's q | **4.3432*** ** (<.0001) | 0.000362 (0.5826) | 0.05083 (0.1071) | **-0.3044*** ** (<.0001) | **-2.4819*** ** (<.0001) |
| | | | * p < 0.05 | | |
| | | | ** p < 0.01 | | |
| | | | *** p < 0.001 | | |

Table 16. Firm Performance Impacts of Change in Structural Dependence

The negative coefficient for Structural Dependence when associated with ROA (*β=-0.00028, p=0.0042*); ROI (*β=-0.00117, p=0.0034*); and ROS (*β=-0.00112, p=0.0009*) all provide support for hypotheses H7a, H8a and H9a. These support Coleman's theory of network closure. Our investigation finds that buying firms in the competitive network increase their financial performance as they decrease their Structural Dependence. Network density increases help all buying firms to increase their operational efficiencies. Interestingly, our investigation does not find statistical support for a relationship between Structural Dependence and Tobin's q ratio (*p=0.5826*). It appears that the investment community has yet to recognize a firm's network structure as an asset.

*Post Hoc Analyses*

The goal of this research is to investigate the phenomena of structural changes within the competitive network. One of the possibilities that we must consider is that the relationship between our variables of interest is non-linear. To investigate that possibility, we included non-linear factors for Year into our models for Percentage Shared Suppliers as well as Structural Dependence. In both cases, the non-linear relationships were not significant and the remaining variables did not change in direction or significance. We also investigated the possibility that there is a lag between network changes and firm performance changes. We created a lag variable by associating the network structure from one previous year to the firm performance in the current period. In this case, none of the lagged metrics were significant in our data. After concluding both of these analyses, we gain confidence in our methodological approach, our models and our results. The results of these *post hoc* analyses are available from the lead author upon request.

## Contributions, Limitations and Future Research

This dissertation research contributes to the managerial community and academic literature on buyer-supplier networks in multiple ways. First and most importantly, we expand the definition of the supply network to include the competitors of the buying firm as well as their suppliers. The maturing research stream of supply networks recognizes that the existence of each buyer-supplier relationship impacts all other relationships in the buyer's upstream supply network. Since suppliers can also work with multiple

competitor buying firms, it seems logical that the existence of one buyer-supplier relationship also impacts all other relationships in the supplier's downstream network. Thus, our competitive network expands the one-to-many supply network of traditional SCM research to the more realistic many-to-many network environment in which no firm is singularly able to manage. Our results demonstrate that buying firms affect each other through their shared supplier connections, and we provide empirical evidence of the significant impact on firm performance. From a managerial perspective, this research recognizes that a supply network is "ultimately a complex web of decision-making" (Pathak et al., 2007; page 572). Practicing supply chain managers can improve the operational efficiency of their firm (defined as ROA, ROI, and ROS) by partnering with suppliers to their competitors. Our research demonstrates and even perhaps quantifies the importance of the network structure within which firms operate -- beyond their own ego network.

This study also contributes to the debate on network closure versus structural holes. By utilizing a longitudinal dataset, we are able to generate insights into how competitive network structures have changed over time. Our results again support our earlier results which suggested that the Great Recession represented a critical time when supply base management strategies changed. Prior to the recession, firms were following Coleman (1988)'s vision of network closure where firms were partnering with a decreasing number of suppliers. However, after the recession, that strategy clearly changed and buying firms now seek to find suppliers with fewer ties to their competitors – supporting Burt (1992)'s view of the benefits to structural holes. While many investigations are published in the SCM literature investigating the firm performance

links to network structure, this work represents one of (if not the only) longitudinal work on the subject. Furthermore, most of the extant literature is survey or case study based. This work represents a novel contribution to the discussion through the use of longitudinal, secondary data. Our intent is that this powerful dataset will become the basis for many future research projects into an intriguing research stream on competitive networks.

Finally, we propose a new network metric to capture the importance of a firm's supply base within the competitive network. Our new metric of Structural Dependence offers another aspect to be included in risk evaluations and is based upon the concept of power/dependence in buyer-supplier relationships. Our research challenges the widely published belief that buying firms are able to "manage their supply networks." Instead, our research shows that the decisions affecting firm performance may reside within the emergent competitive network structure – outside the control of any one firm. Practicing managers may currently consider only their alternatives when evaluating potential suppliers, but we have demonstrated that the suppliers' alternatives also play a significant role in determining firm performance. This research highlights the interrelatedness of buyers, suppliers and competitors so a firm's current success does not eventually ruin its future performance.

This research study extends the body of knowledge on supply networks in the SCM literature and represents a novel contribution to the research stream of power in buyer-supplier relationship. However, this research has three primary limitations. First, our sample is limited to the worldwide automotive industry. This limitation is in-line

with many previous supply network investigations, yet our study would benefit greatly through replication with a more diverse sample of industries. Also, many of the firms in our study are large, multi-national organizations. We believe our research findings would be helped toward generalizability through the inclusion of a more diverse population of small- and medium-sized enterprises (SMEs). Secondly, our networks are defined based only on the firms contained within the FactSet database. We recognize that this list is not exhaustive and it is likely that we have neglected some critical buyer-supplier relationships in our analysis. We leave it for future researchers to find additional buyer-supplier longitudinal datasets to triangulate our findings. Also, the current version of FactSet only tracks the existence of a buyer-supplier relationship as a binary variable. While it is being populated with as much relationship strength data as possible, future research would benefit greatly from a metric for determining "weights" of buyer-supplier relationships. Finally, we measure firm performance only as ROA, ROI, ROS and Tobin's q. The SCM and Finance literature have many other metrics which may be used to quantify firm performance. Borrowing from other literature bases and incorporating those evaluations into future research into performance within the competitive network will generate deeper understanding.

Supply chain managers have been assumed to control the structure of the network in which they participate. Our view of the supply base has moved from considering a series of one-to-one relationships to considering the supply base as a system (Choi et al., 2001). This research demonstrates that the time to expand the definition of the network again to include all buyers, suppliers and their interrelationships. From this competitive

network perspective, no firm can centrally manage the network yet the performance of each firm is affected by their collective relationships.

# FUNDING THE ORGANIZATION THROUGH SUPPLY CHAIN FINANCE: A LONGITUDINAL INVESTIGATION

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Abstract

Supply chain finance (SCF) is an emerging phenomenon which allows firms to fund the organization through its supply chain relationships. This is achieved through a combination of shrinking inventories, collecting money from customers faster, and simultaneously delaying payments to suppliers. Utilizing Inventory Theory to illustrate the firm's SCF benefits, our results demonstrate that inventory strategy changes have the largest and longest-lasting impacts on the firm's financial performance. Interestingly, changing the firm's payment terms result in only small, short-term effects. Based on our findings, we also offer suggestions to future research extensions in exploring the emerging field of supply chain finance.

*Keywords*: supply chain finance, inventory management, cash flow management

## Introduction

Supply chain management is the coordination among multiple partners linked through the downstream flow of materials, the upstream flow of cash, and information flowing in both directions (Gupta and Dutta, 2011). Traditionally, supply chain management has focused on the material flow of physical goods from manufacturers to end consumers. However, the recent global economic downturn demonstrated that managing financial flows within the supply chain can be as important as managing physical flows of goods and services (Lind et al., 2012). In a 2007 survey by Demica Limited, the majority of banks claimed to either offer or be actively developing a range of trade finance products to meet the growing demand from their clients. One executive at Citibank estimated that Citibank alone transacts an estimated $2.1 trillion (USD) per day in trade financing, which typically includes loans to suppliers for the purchase of raw materials, components and finished goods. Given that 2013 U.S. GDP was less than $17 trillion (USD), this is a substantial amount of activity designed to primarily support sourcing operations around the world.

New trade financing products narrowly classified as supply chain finance (SCF) programs, have been defined as "managing, planning, and controlling all the transaction activities and processes related to the flow of cash among [supply chain] stakeholders in order to improve their working capital" (More and Basu, 2013). However, our definition of SCF goes far beyond those practices of simply "factoring" and "reverse-factoring" inventories and receivables. Broadly speaking, SCF addresses the strategies used by firms to fund their internal operations as well as the solvency of their external supply chain partners. SCF is not just finance plus supply chain management. There is a

symbiotic effect existing within the combination of supply chain management and finance that makes the whole greater than the sum of its parts. The amount of attention garnered by banks and the complex dynamics present within SCF strategies substantiate the impact SCF programs will likely have on all supply chain members in the future. As finance is related to organizational funding, our expanded definition of supply chain finance is:

> *Using the supply chain to fund the organization, and using the organization to fund the supply chain.*

While the extant literature has explored many aspects of the physical flows of supply chains (for an overview, see Kouvelis, Chambers, & Wang, 2006), there has been very little research investigating the corresponding supply chain financial flows (Gupta and Dutta, 2011; Lind et al., 2012).

SCF encompasses the firm's strategy for using its supply chain and financial partnerships to develop savings, generate profits and efficiently manage assets for all members of the supply network. SCF enables managers at the focal firm and its suppliers access to financial instruments which mitigate supply chain risk. In addition, SCF complements standard corporate finance activities by reducing the firm's reliance on outside funding sources and maximizing profitability.

A number of large, international companies are now operating SCF programs to extend payment terms with their major suppliers while also ensuring the financial viability of their suppliers (ACCA Global, 2014). As an example, Figure 7 below

illustrates the cash conversion cycle for Apple, Inc. from 1985 to 2014. Prior to 1995, Apple paid its suppliers before receiving payment from customers (positive cash conversion cycle). Following 1999, Apple received payments from customers before paying their suppliers (negative cash conversion cycle). Demonstrating a clear shift in corporate strategy, Table 17 shows the supply chain component metrics for Apple from 1995 to 1999. Inventories on-hand dropped from over 80 days to less than 2 days; the number of days to get paid by customers dropped from almost 64 days to 40.5 days; and starting in 1996, the number of days to pay suppliers increased from 33 days to 68 days. Correspondingly, Apple's financial performance (shown in Figure 8) has been steadily increasing since 2001.

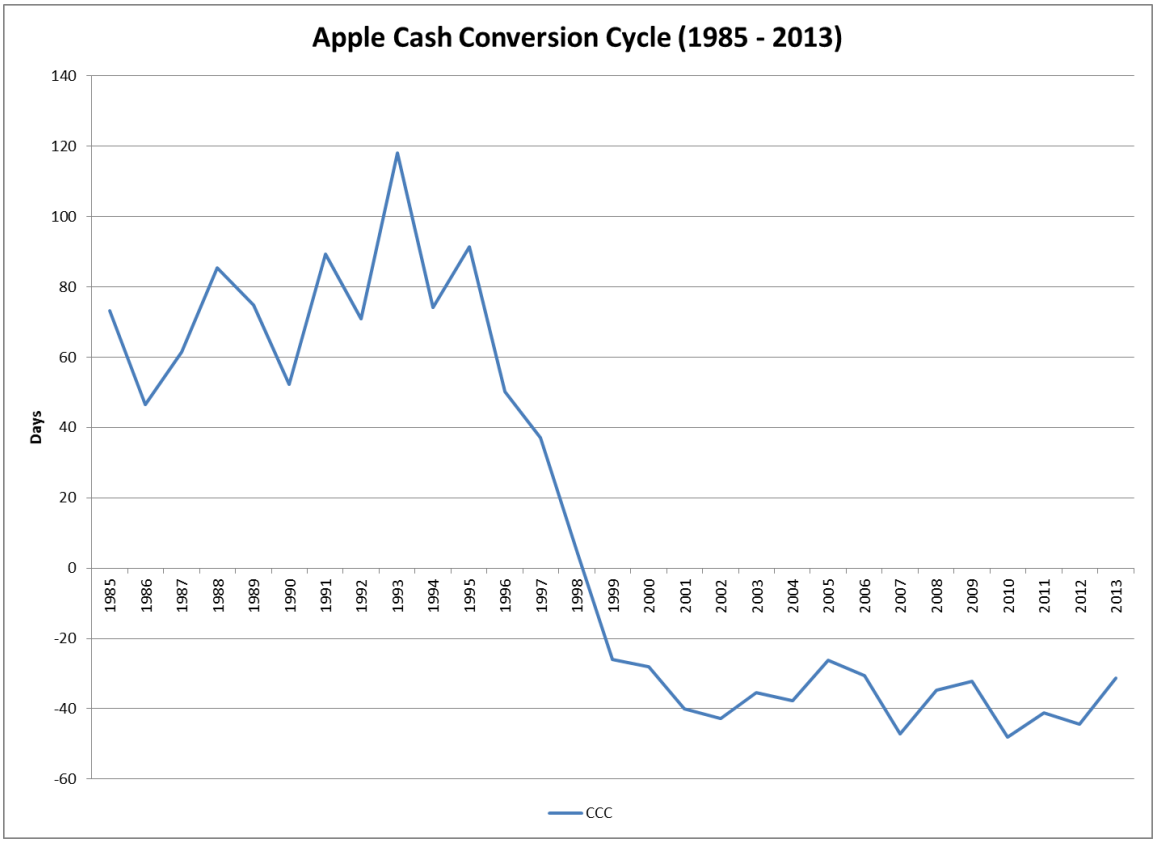

Figure 7. Cash Conversion Cycle for Apple, Inc. (1985-2013).

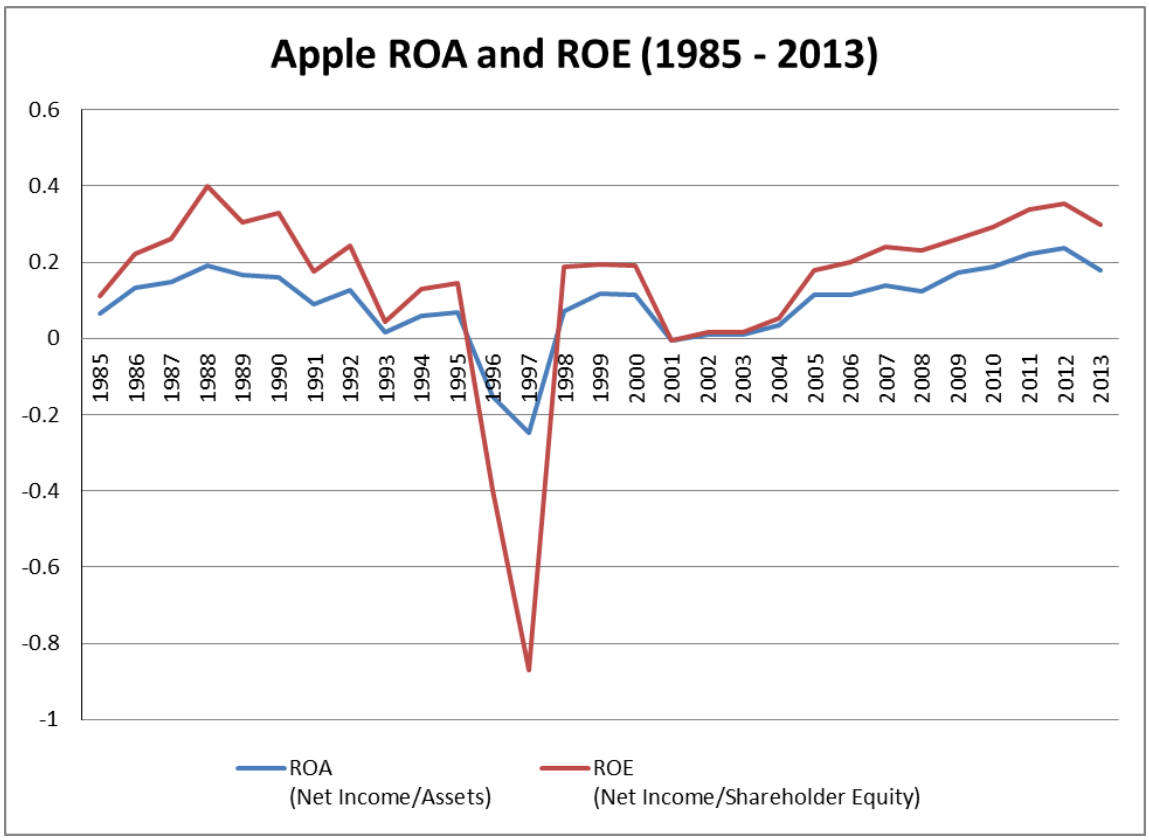


Figure 8. Return on Assets and Return on Equity for Apple, Inc. (1985 – 2013).

| Year | Company | Days Inventory On-Hand | Days Sales Outstanding | Days Payables Outstanding | Cash Conversion Cycle | Tobin's q |
|---|---|---|---|---|---|---|
| 1995 | APPLE | 80.212 | 63.715 | 52.646 | 91.281 | 0.857 |
| 1996 | APPLE | 27.745 | 55.531 | 33.151 | 50.125 | 0.727 |
| 1997 | APPLE | 28.508 | 53.351 | 44.687 | 37.172 | 0.886 |
| 1998 | APPLE | 6.543 | 58.673 | 60.316 | 4.900 | 1.424 |
| 1999 | APPLE | 1.677 | 40.522 | 68.086 | -25.887 | 2.031 |

Table 17. Annual Supply Chain Finance Metrics for Apple, Inc. (1995 – 1999).

Motivated by Apple's dramatic shift in strategy and resulting corporate success, we utilize COMPUSTAT data to investigate the relationships between supply chain finance components and firm performance among the 2013 Fortune 500 firms. Grounded in

inventory theory, we test a number of hypotheses relating the strategies of supply chain finance to the performance of the world's most successful firms. Formally, we seek to address the following research question:

> *Research Question: What is the relationship between changes in a firm's supply chain finance components (Days Inventory, Days Payables, Days Sales, Cash Conversion Cycle) and changes in its financial performance?*

The rest of this paper is organized as follows. Section 2 reviews the relevant literature; Section 3 develops our hypotheses; Section 4 details our methodology; and Section 5 summarizes our results. Section 6 concludes with a discussion of our contributions, limitations, and suggestions for future research.

## Literature Review

The literature exploring SCF is just beginning to form and has not yet attracted the attention of mainstream supply chain management researchers (Kroes and Manikas, 2014; More and Basu, 2013). This research extends the emerging literature in supply chain finance (SCF) as well as contributing to the mature research stream of inventory theory. The phenomenon of SCF provides new viewpoints from which to view inventory theory and hopefully launches new research which accurately reflects leading-edge business practices.

*Inventory Theory*

Research into the link between inventory levels and firm performance (i.e., inventory theory) was initially motivated by the success of the Japanese auto manufacturers on the 1970s and 1980s (Chen et al., 2005). The implementation of Japanese-type "just–in-time" production practices was expected to improve manufacturing operations by reducing inventories, increasing quality and creating shorter throughput times (Chen et al., 2005; Hofer et al., 2012). Inventories came to be viewed as a burden and an asset that should be reduced as much as possible (Cannon, 2008; Chen et al., 2005; Eroglu and Hofer, 2011). The financial markets reward inventory reductions and punish firms that allow their inventories to escalate. Claycomb et al. (1999) found that JIT implementations associated with reduced inventory levels led to improved financial performance. However, inventories also benefit firms by playing the necessary role of buffer against demand uncertainty (Hopp and Spearman, 2001).

However, there has been relatively little research into the direct relationship between firm performance and inventory levels. The research that has been done generated inconsistent results (Capkun et al., 2009; Eroglu and Hofer, 2014). Some research has found significant positive relationships between inventory performance and financial performance of the firm (Capkun et al., 2009; Chen et al., 2005; Hofer et al., 2012). On the other hand, some researchers found both improved inventory turnover associated with increases in overall firm performance in some firms, while in other firms inventory turnover was associated with *decreased* firm performance (Cannon, 2008). More recent studies explored potential explanations for these apparent conflicting results.

Eroglu and Hofer (2011) find that the significance and the association between inventory performance and firm performance is both non-linear and varies by industry. However, their study only examines manufacturing firms over the time period 2003-2008. Capkun et al. (2009) examine the inventory-performance relationship for firms between 1980-2005 and find a consistent "strong correlation between inventory performance and financial performance across a broad array of manufacturing industries" (page 802).

Another potential cause of the seeming inconsistency in results is the use of inventory turnover $\left(\frac{COGS}{Inventory}\right)$ to operationalize inventory performance (Cannon, 2008; Capkun et al., 2009). These studies focus on finding optimal levels of materials once they are received into inventory (asset), while ignoring the cash flow implications of accounts payable (liability) and accounts receivable (asset). Figure 9 below is adapted from Jose et al. (1996) and depicts the traditional flow of materials and cash.

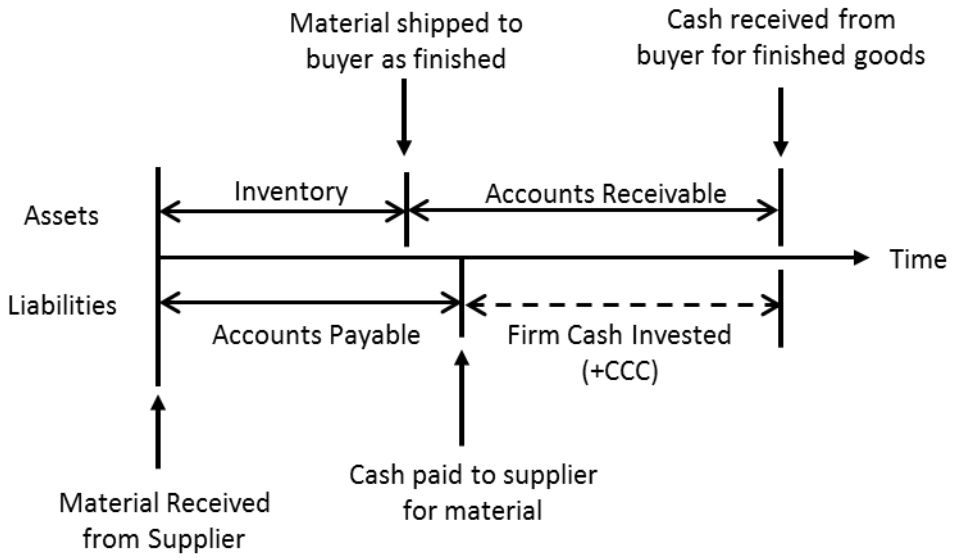


Figure 9. Traditional Cash and Material Flows (adapted from Jose et al 1996).

When the focal firm pays its suppliers before receiving payment from its buyers, the firm is reducing its cash position which necessarily has a negative impact. However, as Figure 10 demonstrates, if the focal firm extends its payables term and reduces its receivables term, the net result could be that the firm gets paid from the buyer *before* paying its suppliers.

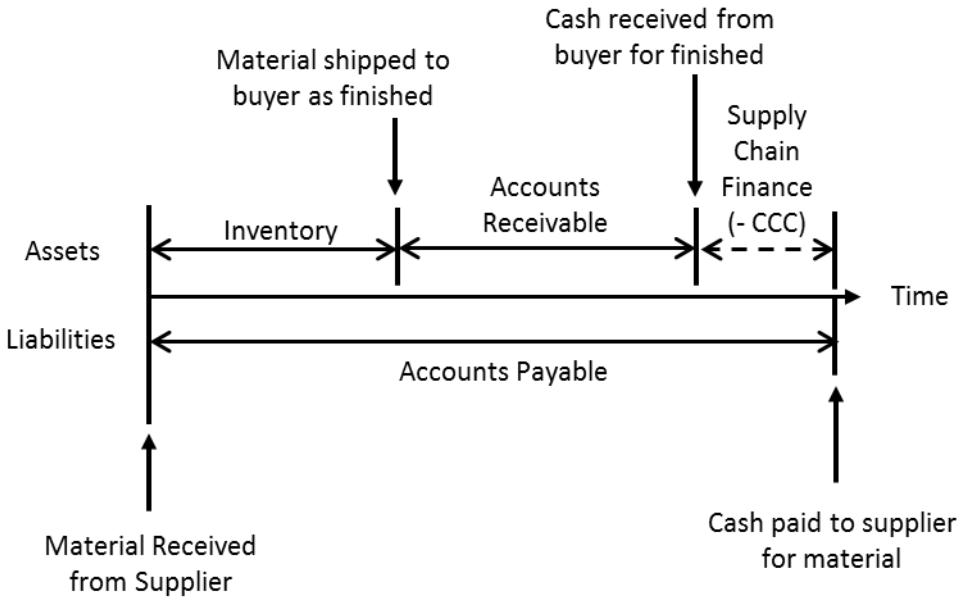


Figure 10. Supply Chain Finance Example (adapted from Jose et al 1996)

In this case, the upstream supply chain is funding the organization and increasing its financial performance without changing inventory levels. These critical mechanisms, which we define as supply chain finance, have been ignored in previous research into the inventory-performance relationship. In this study, we seek to extend the literature on inventory theory by incorporating the newly emerging research focus on supply chain finance.

*Supply Chain Finance*

There have not been many studies that explicitly examine the impact of SCF in the existing literature, although numerous academic studies have examined cash flow management in other operational contexts (Wuttke et al., 2013). A firm's cash flow can be manipulated in three ways: 1) changes in the accounts receivables term (i.e., Days of Sales Outstanding (DSO)) which conceptually is the time from when goods are sold until the revenue is collected by the firm; 2) changes in inventory (i.e., Days of Inventory Outstanding (DIO)) which represents the firm's inventory on-hand at the current sales rate; or 3) adjustments to the accounts payables term (i.e., Days Payables Outstanding (DPO)) which is the time that a firm takes to pay its vendors (Kroes and Manikas, 2014). When assessing a firm's cash flow management strategies, we can either track the individual measures of these cash flow levers or evaluate metrics which are composites of these measures. Cash Conversion Cycle (CCC) is the composite measure which combines the three measures (DSO, DIO, DPO) into a single metric that can be considered to represent the liquidity of the firm (Jose et al., 1996; Kroes and Manikas, 2014). The critical measure in our study as an indicator of firm financial performance is Tobin's q, which is the ratio of the market value of the firm to the replacement value of its assets (Lindenberg and Ross, 1981; Wernerfeld and Montgomery, 1988). If the value of Tobin's q ratio is between 0 and 1, that means that the cost to replace firm assets is greater than the value of its stock. Thus, the stock would be considered undervalued in the market. Conversely, a Tobin's q ratio that is greater than 1 means that the market considers the firm to be more valuable than simply the sum of assets it owns. In the context of supply chain finance, assets that are controlled by the firm may reside outside

the firm's boundaries and be owned by its suppliers and/or customers. Table 18 details each of the measures used in our study as well as providing the calculations.

| Measure | Abbreviation | Description | Calculation |
|---|---|---|---|
| Days of Sales Outstanding | DSO | Average number of days required to collect revenue after a sale is made. | $(\frac{Accounts\ Receivables}{Revenues}) * (Number\ of\ Days\ in\ a\ Period)$ |
| Days of Inventory Outstanding | DIO | Average number of days that inventory is held before it is sold. | $(\frac{Inventory}{Cost\ of\ Goods\ Sold}) * (Number\ of\ Days\ in\ a\ Period)$ |
| Days of Payables Outstanding | DPO | Average number of days a company takes to pay creditors | $(\frac{Accounts\ Payable}{Cost\ of\ Goods\ Sold}) * (Number\ of\ Days\ in\ a\ Period)$ |
| Cash Conversion Cycle | CCC | Duration (in days) required to convert cash invested in supplies into cash collected from customers. | $Days\ Inventory\ Outstanding - Days\ Payables\ Outstanding + Days\ Sales\ Outstanding$ |
| Tobin's q | TOBINS_Q | Firm's market value per dollar of replacement cost of assets | $(\frac{Equity\ Value + Book\ Value\ of\ Long-term\ Debt + Net\ Current\ Liabilities}{Value\ of\ Total\ Assets})$ |
| Annual Sales | SALES | Annual sales in US$ Millions (proxy for firm size) | Annual Net Sales ($) |
| Debt to Assets Ratio | DEBT | Ratio of debt to total firm assets | $(\frac{Total\ Long-Term\ Debt}{Total\ Assets})$ |

Table 18. Data and Measures (adopted from Kroes and Manikas, 2014).

Cash flow management strategies have been investigated through a variety of financial metrics, including Asset Turnover (Ebben and Johnson, 2011); Return-On-Assets (García-Teruel and Martínez-Solano, 2007); Invested Capital (Ebben and Johnson, 2011); and Return-On-Investment (Ebben and Johnson, 2011). Farris and Hutchison (2002) demonstrate the importance of extending accounts payable to upstream suppliers, reducing inventory, and collecting accounts receivable sooner from downstream customers. These three metrics (described in the Methodology section) combine to create the Cash Conversion Cycle (or cash-to-cash cycle) and are the basis for firm performance improvements at Dell and Cisco beginning in the early-2000's (Farris and Hutchison, 2002).

The belief that reduced DSO, reduced DIO and increased DPO should lead to better firm performance is promoted in the literature through case studies (Farris and Hutchison, 2002). However, previous empirical cross-sectional research has not found evidence of significant, predicable relationships between firm performance and the components of CCC (DIO, DSO, DPO) (Kroes and Manikas, 2014). Studies have found partial agreement with the traditional notion of the impact of CCC, when shorter DSO and DIO were found to be associated with increased gross income – however, shorter DPO (not longer DPO) was found to be associated with increased gross income (Deloof, 2003). Similarly, shorter DSO and DIO periods were found to be associated with increased ROA. Yet again, it was shorter DPO (not longer DPO) that was associated with higher ROA performance (García-Teruel and Martínez-Solano, 2007). Still other researchers have found that shorter DSO is associated with increased firm profitability as predicted, however longer CCC (not shorter CCC) is related to higher profitability (Gill et al., 2010). Interestingly, recent longitudinal research suggests that DPO may not be significantly related to performance at all (Kroes and Manikas, 2014).

Though the previous literature on cash flow management has created a substantial knowledge-base around the comparative importance of cash positioning as it relates to firm performance (Gupta and Dutta, 2011; Steinle and Schiele, 2008), there has been a lack of application of these concepts in inventory-performance relationship research (Hofer et al., 2012; Kroes and Manikas, 2014). Previous research using cross-sectional data also neglects the potential of time-lag effects where changes in one dimension may impact changes in another dimension at some point in the future. A few studies have begun to recognize some of the dynamic nature of cash flow management, but even these

compare changes in cash flow against static performance indicators (Ebben and Johnson, 2011; García-Teruel and Martínez-Solano, 2007). We extend the body of knowledge through the use of longitudinal data to contribute to both the inventory theory and supply chain finance literature. Our research examines changes in metrics over time to provide unique insights into the inventory-performance relationship.

## Hypothesis Development

There is very little empirical research which has explored the relationship between a firm's SCF strategies and the resulting financial performance changes (Kroes and Manikas, 2014). Building upon the foundation of earlier inventory theory research, we analyze how changes in the firm's SCF strategy impacts its financial performance over extended time. Our investigation allows us to discern the most impactful SCF strategy for changing a focal firm's financial performance. Working capital performance is measured through the cash conversion cycle (CCC), which is a linear combination of three cash flow metrics (DSO, DIO, DPO). Each of these measures represents a specific component of the firm's Cash Flow Statement or Balance Sheet, and combine to create a measure of the firm's liquidity management strategy (Jose et al., 1996).

Previous research has found that the relationship between inventories and firm performance is non-linear (Eroglu and Hofer, 2011). This is not surprising based on the vast conceptual and analytical research on inventory theory which suggests that there is an "optimal" level of inventory for the firm. A deviation from that optimal level (either an increase or decrease) suggests that firm performance decreases (Chen et al., 2005). In

this research, we are not concerned with the curvilinear relationship between static inventory and performance metrics, but instead we investigate the linear rate-of-change relationships between each measure and overall financial performance.

*Days Inventory Outstanding (DIO)*

Days Inventory Outstanding (DIO) is defined as the average time that goods are held in inventory before they are sold (Kroes and Manikas, 2014). DIO is calculated as:

$$DIO\ (in\ days) = \left(\frac{Inventories}{COGS}\right) * 365$$

The relationship between inventory and firm performance is not simplistic. Inventory reduction initiatives create the potential to both damage supply chain performance while simultaneously increasing firm performance (Kroes and Manikas, 2014). Holding inventory represents a reduction in the firm's cash position as the funds invested in inventories are unavailable for other uses. On the other hand, reducing inventory levels may lead to rapidly changing order levels which will increase the bullwhip effect felt by its upstream partners (Lee et al., 1997). Firms may effectively overcome these concerns through advanced production techniques such as: lean manufacturing, vendor managed inventories (VMI), and perhaps automated replenishment systems (Hofer et al., 2012; Kroes and Manikas, 2014). Generally, the vast literature on Inventory Theory suggests that inventory reductions have a positive association with firm performance (Capkun et al., 2009; Chen et al., 2005; Eroglu and

Hofer, 2011). Therefore, we expect that as firms reduce their inventory faster, they should see a correspondingly faster increase in firm performance.

> *H1: The rate of change in Days Inventory Outstanding (DIO) is negatively associated with the rate of change in firm performance.*

*Days Payables Outstanding (DPO)*

Days Payables Outstanding (DPO) is defined as the average time that a firm takes before paying creditors (Kroes and Manikas, 2014). DPO is calculated as:

$$DPO\ (in\ days) = \left(\frac{Accounts\ Payable}{COGS}\right) * 365$$

As opposed to inventory measures which generally demonstrate that lower DIO is associated with improved firm performance, previous literature has not generated a clear relationship between DPO and firm performance (Kroes and Manikas, 2014). Farris and Hutchison (2002) show that top-performing firms have long DPO periods, yet García-Teruel and Martínez-Solano (2007) empirically demonstrate the shorter DPO periods are associated with better firm performance. Extending its payments to suppliers, the firm has the potential to negatively impact the overall supply network by hoarding cash at the focal firm while starving the cash flows upstream. Longer DPO may also harm the relationship with the supplier and the buying firm may be forgoing early payment incentives offered by the supplier (Fawcett et al., 2010). On the other hand, the longer DPO allows the firm to hold onto its valuable cash asset resources. Inventory theory

suggests that increases in operational efficiency and product quality lead to increased firm performance (Hofer et al., 2012). The larger cash reserves held by the firm create the resources necessary to purchase new and upgraded equipment as well as enabling more flexibility in adapting to changing markets (Stewart, 1995). Since the firm's cash position represents a critical asset in creating competitive advantage, we believe the benefits of elongated DPO periods outweigh the drawbacks. Thus, we posit that accelerating longer DPO terms will correspond with more rapid increases in firm performance:

> *H2: The rate of change in DPO is positively associated with the rate of change in firm performance.*

*Days of Sales Outstanding (DSO)*

Days Sales Outstanding (DSO) is defined as the average time from when a sale is made until the revenue is collected (Kroes and Manikas, 2014). DSO is calculated as:

$$DSO\ (in\ days) = \left(\frac{Accounts\ Receivable}{Revenue}\right) * 365$$

Firms seeking to fund the organization through their supply chain may entice early payments from their customers. The risk of not being able to collect outstanding receivables increases significantly when a firm extends the payment period for customers that purchase on credit (Kroes and Manikas, 2014). To combat this, firms are willing to accept less revenue in exchange for faster payment to minimize their risk and increase

payment probability (Wort and Zumwalt, 1985). In line with conceptual inventory theory, the cash received from a firm's customers may be used to pay their suppliers or invest in activities intended to improve product capabilities and generate additional sales (Hofer et al., 2012; Kulatilaka and Lin, 2006). Therefore, the more quickly payments are received (i.e., reduced DSO), the faster the firm can invest in those "forward-looking" activities which lead to firm growth. Our hypothesis may be formally stated as:

> *H3: The rate of change in Days Sales Outstanding (DSO) is negatively associated with the rate of change in firm performance.*

*Cash Conversion Cycle (CCC)*

Cash conversion cycle (CCC), also referred to as the "cash-to-cash" cycle, provides an overall indicator of the firm's cash position. This represents the average time the firm takes to convert cash payments made to suppliers into cash received from customers (Kroes and Manikas, 2014). CCC is calculated as a linear combination of DPO, DIO, and DSO – which may be positive or negative:

$$CCC = DSO + DIO - DPO$$

Since inventory theory suggests significant associations between each component of CCC and the firm's financial performance, the natural conclusion is that CCC should also have a significant association with firm performance. A positive CCC value means that the firm's cash was tied up in inventories and/or the firm paid its suppliers before receiving payments from customers. The corresponding decrease in liquidity as CCC

lengthens suggests that firms have a weaker financial position. An SCF strategy that leads to positive CCC values indicates that the firm is less flexible in adapting to changing market conditions, which could negatively impact future performance (Kulatilaka and Lin, 2006). On the other hand, an SCF strategy which leads to a negative CCC value would suggest that the firm has successfully used its supply chain partners to fund the organization. The firm had low inventory levels while receiving payments from customers before having to pay the firm's suppliers. In this case, the firm was not required to invest any cash into its operations which freed up cash resources to invest in other sales-generating growth activities (i.e., capital improvements, R&D, etc). Thus, our final hypothesized relationship is:

> *H4: The rate of change in CCC is negatively associated with the rate of change in firm performance.*

## Methodology

The research design used in this study is very similar to the one utilized by Kroes and Manikas (2014) in their study of the impacts of cash flow management on firm performance across eight fiscal quarters. This study offers more robust insights by examining data from 1985 to 2014 on 229 firms worldwide. We create a unique longitudinal sample by utilizing each firm's annual reporting metrics and calculating the corresponding SCF strategy components (DIO, DPO, DSO, and CCC) as well as the firm's financial performance measure (Tobin's q).

*Data Utilized*

Annual financial data reported by publically traded firms is amassed in the COMPUSTAT database (Standard and Poor's, 2014) and used in this study to create our longitudinal panel dataset. The firms selected for our study were identified on the 2013 Fortune 500 list (Fortune Magazine, 2013). Since our SCF strategy investigation explores the impact of inventories, we eliminate all firms from our sample that do not record any inventory on their financial statements. We also removed any privately-held firms whose financial data is not available through COMPUSTAT. Finally, we removed any firms delivering services from our sample. Utilizing this sample, we query the COMPUSTAT database to gather annual data on firm assets, liabilities, cost of goods sold, revenues, etc. for all years 1985 to 2014. In total, our sample consists of 30 years of annual data on 229 worldwide firms which generated 5,956 firm-year observations for our statistical analysis. The large number of firms and long evaluation period provides a robust sample enabling valid inferences to be made (Kroes and Manikas, 2014). The complete list of firms and COMPUSTAT variables used in our study is available from the lead author upon request.

*Measures*

The annual measures used in this research are calculated from the COMPUSTAT data and are consistent with measures found in previous studies of cash flow management and financial performance: DIO, DPO, DSO, CCC and Tobin's q (Deloof, 2003; Ebben and Johnson, 2011; Farris and Hutchison, 2003, 2002; García-Teruel and Martínez-

Solano, 2007; Hofmann and Kotzab, 2010; Kroes and Manikas, 2014). Table 18 above details the measures and their calculations. Dating back to initial research on Economic Order Quantities, researchers have demonstrated for decades that there are "optimal" inventory levels which maximize firm financial performance. This implies a negative quadratic inventory-performance association, in which the relationship between rates of change should be linear (i.e., second derivative). Therefore, after generating the annual static measures, we compute the metrics of interest for our study as the change in the cash flow measures: $\Delta DIO, \Delta DPO, \Delta DSO, \Delta CCC, and\ \Delta Tobin'sQ$. Each delta (Δ) value is calculated as the difference between the current year minus the previous year (i.e., $\Delta DIO_{2010} = DIO_{2010} - DIO_{2009}$). For instance, if the DIO decreased between 2009 and 2010, the $\Delta DIO_{2010}$ value would be negative. Utilizing the change metrics rather than the level of each measure also allows us to indirectly control for differences in corporate strategies between firms (Capkun et al., 2009). For example, a firm that seeks to provide the highest service levels for its customers may be forced to hold higher levels of inventory than optimal.

While there are many different financial performance metrics available, in line with existing cash flow research literature, this study utilizes Tobin's q to describe the firm's financial performance (Cannon, 2008; Chen et al., 2005; Kroes and Manikas, 2014). Tobin's q is defined as the ratio of the market value of a firm to the replacement value of its assets, where larger Tobin's q values represent superior financial performance of the firm (Cannon, 2008). Tobin's q has been shown to be a superior measure of relative firm performance compared to other accounting measures (Lindenberg and Ross, 1981; Wernerfeld and Montgomery, 1988). This research investigates the long-term

implications of SCF strategy decisions, thus, Tobin's q is an appropriate measure for this study because of its incorporation of market value (which incorporates the expected future value of firm performance) (Kroes and Manikas, 2014).

The investigations within this research control for year, debt level of the firm, firm size, and inventories as a percentage of assets. Firms that maintain high levels of debt may not benefit from improved cash flow positions because any freed up cash might be redirected to alleviate their debt obligations (Kroes and Manikas, 2014). To control for debt level, we incorporate the ratio of total long-term debt to assets for each firm annually. Annual revenue is used as a proxy measure to control for firm size instead of total assets to avoid potential multicollinearity issues since total assets is contained within the calculation of Tobin's q (our dependent variable) (Hendricks and Singhal, 2003; Kroes and Manikas, 2014). The natural logarithm of annual revenue is implemented as the control variable because of the non-linear relationship that has been shown to exist between revenue and Tobin's q (Eroglu and Hofer, 2014; Kroes and Manikas, 2014). Finally, we control for the percentage of annual total assets that are represented by inventories.

Recent research has suggested that the effect of inventories on firm performance varies significantly from one industry to the next (Eroglu and Hofer, 2011). As such, we incorporated the 6-digit NAICS code for each firm in our study as a control variable to account for industry-specific effects. Our results showed that industry was not significant in any model, and therefore, we removed industry code from the models presented. One possible explanation for the lack of significance may be our selected sample. Our sample

contains 229 firms from 132 distinct 6-digit NAICS codes. Perhaps the lack of multiple observations from most industries in our sample prevented the opportunity to find significant industry effects. We leave it to future researchers to explore this potentially interesting research extension.

*Statistical Analysis*

The statistical analysis for this study was completed using SAS v9.4 (*SAS*, 2012). We utilize the mixed linear models (PROC MIXED) approach to repeated-measures analysis of panel data. This is a generalization of the standard linear model which allows for robust regression coefficient estimation when there is high correlation of the data between the repeated measurements (Ballinger, 2004; Kroes and Manikas, 2014; SAS Institute, Inc, 2008). In our dataset, the SCF and financial performance measures for a given firm are highly correlated from one period to the next. The population-averaged approach in the PROC MIXED procedure estimates the average impact of SCF strategy decisions on firm performance across the population of 2013 Forbes Fortune 500 firms.

The dependent variable in our study ($\Delta Tobin'sQ_{it}$) represents the change in Tobin's q values between the current period ($t$) and the previous period ($t$-1) for each firm ($i$) in our sample. Formally:

$$\Delta Tobin'sQ_{it} = Tobin's\_Q_{it} - Tobin's\_Q_{it-1}$$

Similarly, the predictor variables in our study ($\Delta DSO_{it}, \Delta DPO_{it}, \Delta DIO_{it}, \Delta CCC_{it}$) are also calculated as the change in SCF component measures for each firm ($i$) between the

current period ($t$) and the previous period ($t$-1). Thus, the interpretation of our regression analysis is the relationship between rates-of-change. The control variables in our study for debt loading ($Debt2Assets$), firm size ($ln\_REV$), and year ($Year$) are included for the current time period ($t$) 1985-2014.

In general, there are many options for the link functions which can be implemented within mixed linear models. To test our hypothesized relationships between the SCF strategy measures and firm performance, we utilize a link function of AutoRegressive(1) within the REPEATED statement of PROC MIXED. Previous research has established that repeated time-series financial measurements, such as our SCF measures, exhibit a first-order autoregressive correlation between time periods (Kroes and Manikas, 2014; Liang and Zeger, 1986). Our investigation also explores the impact of lagged changes in SCF strategy variables on changes in firm performance. Existing literature confirms that cash flow changes made in one period may generate significant performance changes for up to one year (Capkun et al., 2009; Kroes and Manikas, 2014). Yet, *a priori* it is difficult (if not, impossible) to predict the exact time horizon for SCF changes to generate significant impacts on firm performance changes. Our experience, along with input from industry experts, suggests that changes in SCF strategies would not impact firm performance more than two years into the future, but for thoroughness, our models include SCF measures with lag periods of up to five years.

The models we test explore the relationship between changes in the three individual SCF strategy measures ($\Delta DIO, \Delta DPO, \Delta DSO$) and changes in firm performance ($\Delta Tobin's\_Q$). The significance of these changes over time is tested by

including the current change measure as well as the change measures for the previous five periods. For example, we specify the following model to test the significance of DIO over time (H1):

$$\Delta Tobin's\_Q_{it} = \beta_0 + \beta_1(\Delta DIO_{it}) + \beta_2(\Delta DIO_{it-1}) + \beta_3(\Delta DIO_{it-2}) + \beta_4(\Delta DIO_{it-3}) + \beta_5(\Delta DIO_{it-4}) + \beta_6(\Delta DIO_{it-5}) + \beta_7(Year) + \beta_8(ln\_Rev_{it}) + \beta_9(Debt2Assets_{it}) + e_{it}$$

Similar models were tested for $\Delta DPO$ and $\Delta DSO$. The sign and significance of the $\beta$ coefficients for each component model indicated the validity of our hypothesized relationships. The change measure ($\Delta DIO_{it}$) indicated the influence of the SCF strategy measure in the current period, while the lagged measures ($\Delta DIO_{it-1}$, $\Delta DIO_{it-2}$, etc) indicate the significance over time.

Following the same logic, we created the fourth model to explore the hypothesized relationship between changes in the SCF composite measure ($\Delta CCC$) and changes in firm performance ($\Delta Tobin's\_Q$) over time (H4). Formally, we specify the following model for investigation:

$$\Delta Tobin's\_Q_{it} = \beta_0 + \beta_1(\Delta CCC_{it}) + \beta_2(\Delta CCC_{it-1}) + \beta_3(\Delta CCC_{it-2}) + \beta_4(\Delta CCC_{it-3}) + \beta_5(\Delta CCC_{it-4}) + \beta_6(\Delta CCC_{it-5}) + \beta_7(Year) + \beta_8(ln\_Rev_{it}) + \beta_9(Debt2Assets_{it}) + e_{it}$$

Results

The central issue in this research is whether the world's most successful firms improve their financial performance through: 1) changes in the number of days of inventory being held; 2) changes in accounts payables terms with suppliers; 3) changes in accounts receivables terms with customers; or 4) do they fund the organization through combination of all three actions? Utilizing a longitudinal sample of data spanning 30 years, we seek unique insights on these long-term relationships. The model coefficient estimations and significance levels were generated through the mixed linear models (MIXED) procedure in SAS v9.4 (*SAS*, 2012). All algorithms converged successfully without errors.

We first consider the impact of changes in inventories (shown in table 19). Our research demonstrates that this is the most influential and longest lasting of the three SCF components on changes in firm performance. While the effect of DIO rate-of-change adjustments does not affect firm performance rates-of-change in the current year ($p=0.0667$), the highly significant impact in each of the three prior years establishes its importance as a critical SCF source with a lag effect. Interestingly, DIO was found to be the only SCF measure which had a significant effect on firm performance in multiple years. The largest impact on firm performance was seen one year later ($\beta=-0.00341$, $p<0.0001$) and nearly as large an impact two years later ($\beta=-0.00224$, $p<0.0001$). The statistically significant association continued to exist between DIO changes in firm performance changes three years later ($\beta=-0.00133$, $p=0.002$). Recall that our industry experts predicted firm performance may be impacted by inventory strategy changes for up to two years, yet our data demonstrates that the effects are significant for three years.

As expected, the coefficient estimations for DIO rates-of-change showed a negative relationship with rates-of-change in firm performance. The statistical finding of our analysis provides support for H1 which states that reductions in DIO have a significant impact on increasing firm performance over time. Previous studies have found a negative relationship between DIO and firm performance (Deloof, 2003; García-Teruel and Martínez-Solano, 2007; Kroes and Manikas, 2014), however our longitudinal analysis demonstrates that the reductions in DIO do not significantly impact the firm in the current period. Instead, our study shows that the impacts of inventory reduction strategies are realized over the following three years. Our data shows that firms must not necessarily expect short-term gains to be realized through inventory strategy changes. Rather, supply managers may be able generate sustained financial rewards through inventory reductions over the long term.

| Independent Variable | Estimate | Standard Error | Pr > \|t\| |
|---|---|---|---|
| Intercept | **0.19170*** | 0.0742 | 0.0104 |
| | | | |
| **Annual Change in SCF measures** | | | |
| Change in DIO (current year) | -0.00083 | 0.000453 | 0.0667 |
| Change in DIO (1 year prior) | **-0.00341***** | 0.00046 | <.0001 |
| Change in DIO (2 years prior) | **-0.00224***** | 0.000439 | <.0001 |
| Change in DIO (3 years prior) | **-0.00133**** | 0.00043 | 0.002 |
| Change in DIO (4 years prior) | -0.00044 | 0.000384 | 0.25 |
| Change in DIO (5 years prior) | -0.00045 | 0.000242 | 0.0644 |
| | | | |
| **Control Variables** | | | |
| Year | -0.00149 | 0.001542 | 0.3331 |
| ln_Rev | -0.01653 | 0.008441 | 0.0503 |
| Debt2Assets | -0.05442 | 0.06292 | 0.3872 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| Pr > ChiSq | 0.0007 | | |
| Number of Observations Read | | 5940 | |
| Number of Observations Used | | 4542 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 19. Rate-of-Change in Tobin's Q as a Result of One Unit Increase in Rate-of-Change in Days Inventory Outstanding.

Contrary to expectations, the findings from our analysis demonstrate that the effect of cash flow management strategies on firm performance is neither long-lasting nor largely impactful. Some researchers suggest that extending DPO withholds needed funds from supply network partners and indirectly harms the firm's performance (Hofmann and

Kotzab, 2010). Others have found that longer DPO horizons are associated with increased firm performance (Deloof, 2003). Our results (shown in Table 20) demonstrate that increasing the rate-of-change in DPO will accelerate the increases in firm performance immediately ($\beta$=0.00138, p=0.0094). The positive coefficient estimation and statistical significance provide support for H2, that increases in the rate-of-change in DPO will positively influence the rate-of-change in firm performance. However, the changes in DPO do not contribute significantly to changes in firm performance in following years. While intuitively, we would agree that extending payment terms and holding more cash should benefit the focal firm over time, the elongated sample of our study demonstrates that the performance benefit is only felt in the short-term. Supply managers should not consider longer payments as a strategy for sustained financial success; instead, it is a short-term boost which may serve to benefit the firm while waiting for the benefits of inventory reduction strategies. Thus, we can only claim partial support for H2. The lack of long-term significance may suggest a confounding factor influencing the relationship between DPO and performance, and we look forward to future research on this topic.

| Independent Variable | Estimate | Standard Error | Pr > \|t\| |
|---|---|---|---|
| Intercept | **0.23850**** | 0.07635 | 0.002 |
| | | | |
| **Annual Change in SCF measures** | | | |
| Change in DPO (current year) | **0.00138**** | 0.00053 | 0.0094 |
| Change in DPO (1 year prior) | -0.00114 | 0.000595 | 0.0556 |
| Change in DPO (2 years prior) | 0.00011 | 0.000603 | 0.8558 |
| Change in DPO (3 years prior) | 0.00052 | 0.000563 | 0.3527 |
| Change in DPO (4 years prior) | 0.00097 | 0.000523 | 0.0638 |
| Change in DPO (5 years prior) | -0.00004 | 0.00015 | 0.7916 |
| | | | |
| **Control Variables** | | | |
| Year | -0.00230 | 0.001596 | 0.1502 |
| ln_Rev | **-0.01886*** | 0.008723 | 0.0306 |
| Debt2Assets | -0.08234 | 0.06529 | 0.2073 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| Pr > ChiSq | 0.0114 | | |
| Number of Observations Read | | 5940 | |
| Number of Observations Used | | 4552 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 20. Rate-of-Change in Tobin's Q as a Result of One Unit Increase in Rate-of-Change in Days Payables Outstanding.

Previous research, based on cross-sectional or data over a short time horizon, has found significant relationships between DSO and firm performance (Farris and Hutchison, 2003; García-Teruel and Martínez-Solano, 2007; Kroes and Manikas, 2014). Reducing DSO by obtaining payments from customers sooner should certainly benefit

the firm through an increased cash position; however, our data (shown in Table 21) demonstrates that changes in DSO do not significantly influence firm performance in any period. One might be tempted to suggest that changes in DSO would create changes in future period performance as increased cash may be strategically invested, yet our analysis finds all time horizons are well outside the criterion for significance ($p<0.05$). We must conclude that there is not support for H3. Based on our research, supply managers who pursue shorter payment terms from their customers are not creating financial performance improvement, yet may be increasing the risk of damaging their viable customer base. The logic of decreasing DSO in order for the focal firm to increase performance through additional liquidity appears sound. However, the lack of evidence supporting that association in our extended data suggests that there may be other negating factors influencing the relationship over time.

| Independent Variable | Estimate | Standard Error | Pr > \|t\| |
|---|---|---|---|
| Intercept | **0.2383**** | 0.07604 | 0.002 |
| | | | |
| **Annual Change in SCF measures** | | | |
| Change in DSO (current year) | -0.00020 | 0.0008 | 0.7955 |
| Change in DSO (1 year prior) | -0.00054 | 0.0008 | 0.4817 |
| Change in DSO (2 years prior) | -0.00062 | 0.0007 | 0.3990 |
| Change in DSO (3 years prior) | 0.00080 | 0.0006 | 0.1964 |
| Change in DSO (4 years prior) | -0.00035 | 0.0006 | 0.5644 |
| Change in DSO (5 years prior) | -0.00001 | 0.0006 | 0.9852 |
| | | | |
| **Control Variables** | | | |
| Year | -0.00218 | 0.001603 | 0.1731 |
| ln_Rev | **-0.01792*** | 0.008714 | 0.0398 |
| Debt2Assets | -0.11900 | 0.0662 | 0.0723 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| Pr > ChiSq | 0.0936 | | |
| Number of Observations Read | | 5940 | |
| Number of Observations Used | | 4442 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 21. Rate-of-Change in Tobin's Q as a Result of One Unit Increase in Rate-of-Change in Days Sales Outstanding.

Finally, our analysis investigates the influence of changes in Cash Conversion Cycle (CCC) on changes in overall firm performance (shown in Table 22). As a composite measure, CCC represents the interconnected impact of supply chain partners on inventories as well as cash flow. Our analysis demonstrates that changes in CCC

create significant and long-lasting influences on firm performance. The associations between changes in CCC and changes in firm performance are significant in the current year ($\beta$=-0.00105, p=0.0039) as well as one and two years later (each $p<0.0001$). Similar to DIO, the direction of the rate-of-change CCC parameter estimates is negative and consistent across all time horizons. Our analysis finds support for H4 that decreasing changes in CCC is associated with increasing changes in firm performance over time. This suggests that supply managers must create integrated strategies to truly realize the benefits of supply chain finance. Payment term adjustments help the firm in the current period, while waiting for the inventory reduction strategy to generate long-term benefits. The significance of the aggregated CCC metric in the short and long term demonstrates that a comprehensive strategy is truly greater than the sum of its parts.

| Independent Variable | Estimate | Standard Error | Pr > \|t\| |
|---|---|---|---|
| Intercept | **0.19840**** | 0.07368 | 0.0076 |
| | | | |
| **Annual Change in SCF measures** | | | |
| Change in CCC (current year) | **-0.00105**** | 0.0004 | 0.0039 |
| Change in CCC (1 year prior) | **-0.00194***** | 0.0004 | <.0001 |
| Change in CCC (2 years prior) | **-0.00158***** | 0.0004 | <.0001 |
| Change in CCC (3 years prior) | -0.00059 | 0.0003 | 0.0816 |
| Change in CCC (4 years prior) | -0.00041 | 0.0003 | 0.1885 |
| Change in CCC (5 years prior) | -0.00015 | 0.0002 | 0.4913 |
| | | | |
| **Control Variables** | | | |
| Year | -0.00199 | 0.001534 | 0.1956 |
| ln_Rev | -0.01604 | 0.008402 | 0.0563 |
| Debt2Assets | -0.06280 | 0.06359 | 0.3234 |
| | | | |
| **Null Model Likelihood Ratio Test** | | | |
| Pr > ChiSq | 0.0102 | | |
| Number of Observations Read | | 5940 | |
| Number of Observations Used | | 4432 | |
| * p < 0.05 | | | |
| ** p < 0.01 | | | |
| *** p < 0.001 | | | |

Table 22. Rate-of-Change in Tobin's Q as a Result of One Unit Increase in Rate-of-Change in Cash Conversion Cycle.

## Contributions, Limitations and Future Research

Overall, our study contributes to the emerging field of supply chain finance in multiple ways. Most importantly, we expand the concept of supply chain finance beyond

the cash flow centric use in previous literature. Utilizing the mature research stream of conceptual inventory theory, our results demonstrate that changes in inventories carried by the focal firm have significant and long-term benefits in firm performance. While no immediate benefits are realized, accelerating inventory reductions will lead to increased firm performance for many years into the future. Supply chain managers can directly help fund the organization through extensive inventory coordination within a complex network of upstream and downstream partners. The focal firm must arrange with its suppliers to deliver raw materials later while also arranging to ship finished goods to its customers sooner. Our results show that supply chain finance is truly a synergistic relationship between the focal firm and its network partners. Cash flow management is not enough to improve performance. Instead, strategic inventory management decisions have the largest impact and drive firm growth for years into the future.

This study also demonstrates that the historical consideration of inventory-performance links or finance-performance links alone are ignoring a significant interaction of inventory and finance strategies. Changes in inventory were found to not significantly impact performance changes in the current period, but were highly impactful in future periods. On the other hand, changes in payables effected performance in the current period only and had no long-term significance. Yet, when these were combined with sales outstanding to create the CCC metric, the results were significant performance impacts in both current and future time-horizons. Therefore, researchers and practitioners must consider all aspects of CCC when creating SCF strategies – ignoring any one of the components would lead to less than optimal performance results.

Finally, we demonstrate the importance of longitudinal data over a long time horizon when exploring the performance impacts of SCF components. For example, previous studies have found significant relationships between DSO and firm performance using cross-sectional data (Farris and Hutchison, 2003; García-Teruel and Martínez-Solano, 2007), yet when analyzed over 30 years, the data generate no significant effects. It seems reasonable to assume that a time lag exists between SCF strategy implementation and the resulting impacts on firm performance. Supply chain managers may over-react to immediate impacts (or lack thereof) when evaluating strategy decisions, but the longitudinal view shows that the short-term observation may not represent long-term impact. Through the analysis of 30 years of data on the world's largest firms, we generate robust insights on the current year as well as effects from decisions in previous years. Our research challenges the widely accepted cash flow view on firm performance, and demonstrates the applicability and need for future longitudinal research.

This research area of supply chain finance is a new and quickly evolving domain within supply chain management and this study represents an early exploration of this promising stream of inquiry. While our research extends the body of knowledge of SCF and inventory theory, our investigation has three primary limitations. First, our sample firms are identified through the 2013 Forbes Fortune 500 list, which means that all firms in our study are huge, multinational corporations. SCF strategy changes require coordination by an influential focal firm, and it is not clear whether our research findings would be generalizable to small/medium enterprise (SME) firms. We suggest future research replicate our study with a heterogeneous sample of large, medium and small

firms as a further step toward generalizability. Second, we consider firm financial performance to be fully represented by Tobin's q as our dependent measure. Future research should consider other measures of firm performance (i.e., Revenue, ROA, ROI, etc) to expand our knowledge of the significance and differences in impacts of SCF strategies on different performance measures. Finally, while we recognize that the availability of SCF arrangements have increased dramatically over the last decade, our investigation considers that the focal firm implements SCF policies with all of its suppliers worldwide. Future research could explore the impacts of differing levels of SCF implements across firms of comparable size to better understand the impacts of cash flow management strategies.

Supply chain management is becoming increasingly important and our results suggest that supply chain managers play a critical role in firm performance. Inventory and financial management strategies may have been considered separate concepts in the past, but this research shows inter-connected SCF strategies generate synergistic performance benefits that are greater than the sum of its parts. Supply chain managers can actually fund the organization by working with upstream and downstream partners as well as banking institutions to create a comprehensive SCF strategy involving material and financial flows.

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# CONCLUSIONS

This dissertation research focuses on how the dynamics of the supply network change over time and impact firm performance. We contribute to the managerial community and academic literature on buyer-supplier relationships in multiple ways. We expand the definition of the supply network to include the competitors of the buying firm as well as their suppliers. This expanded competitive network view provides a more realistic understanding of the environment in which competitor firms operate. By investigating the structural changes in the many-to-many relationships within the competitive network, this research highlights that the focal firm is not centrally controlling the characteristics of its network. Changes to the network membership as well as changes to the inter-organizational relationships impact firm performance. We find that buying firms have shifted their strategy to supply base expansion after the Great Recession. Firms are adding suppliers to their network at more than double the rate they were removing suppliers just a few years before. Furthermore, the buying firms are expanding their supply bases by partnering with suppliers who are connected to a small number of their competitors, creating a more sparse network over time. The overall competitive network density is going down even though the more dense networks are associated with increased performance. We also propose a new network metric to capture the importance of a firm's supply base within the competitive network. Based upon the concept of power/dependence in buyer-supplier relationships, our metric of Structural Dependence offers another aspect to be included in risk evaluations. By utilizing empirical evidence to demonstrate the significant performance impact of competitive network structure, this research highlights the interrelatedness of buyers,

suppliers and competitors so a firm's current success does not eventually ruin its future performance. Finally, we demonstrate that buying firms need to focus on their supplier relationships for more than materials. Our research demonstrates that changing their cash strategies can benefit buying firms for the current as well as future periods.

Our study faces three primary limitations. First, our competitive network analyses focus on large, global firms in the automotive industry. While this limitation is common among supply network research, we suggest that future researchers extend our approach to small and medium sized firms across multiple industries. Second, we assume that the FactSet database provided the information necessary to accurately identify and quantify the dynamics of network partnerships over time. This dataset is extremely powerful and will hopefully become the basis for many future research projects. We are confident that the methodology used to collect this dataset allows us to capture the most relevant relationships; however we must acknowledge that the list of buyer-suppliers is not exhaustive. Future researchers will be able to take advantage of changes in the FactSet database which will capture the percent revenue and percent cost-of-goods-sold as "weight" metrics. This will add more insights to our findings and may shed further light on the whether sparse or dense networks are "best" for increasing firm performance. Lastly, we utilize just a few of the vast number of metrics to define firm performance. Financial measures used here are widely available and recognized as depicting firm efficiency, yet there are other measures which may be of interest to future researchers looking to expand this research. While this work represents the end product of our study, we hope that the insights generated here inspire future research into the competitive network and firm performance.

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# APPENDIX A

## COMPLETE T-TEST COMPARISON RESULTS

| Supply Base Size Comparison | Mean Difference | Std Err | t Value | Pr > \|t\| |
|---|---|---|---|---|
| (Number of Suppliers 2010) - (Number of Suppliers 2004) | -6.9706 | 3.7705 | -1.85 | 0.0735 |
| (Number of Suppliers 2011) - (Number of Suppliers 2004) | 5.0588 | 3.7185 | 1.36 | 0.1829 |
| (Number of Suppliers 2012) - (Number of Suppliers 2004) | **17.7353*** ** | 4.8594 | 3.65 | 0.0009 |
| (Number of Suppliers 2013) - (Number of Suppliers 2004) | **24.3529*** ** | 5.1272 | 4.75 | <.0001 |
| | | | | |
| (Number of Suppliers 2010) - (Number of Suppliers 2005) | -2.9412 | 2.3305 | -1.26 | 0.2158 |
| (Number of Suppliers 2011) - (Number of Suppliers 2005) | **9.0882** ** | 2.9621 | 3.07 | 0.0043 |
| (Number of Suppliers 2012) - (Number of Suppliers 2005) | **21.7647*** ** | 4.6762 | 4.65 | <.0001 |
| (Number of Suppliers 2013) - (Number of Suppliers 2005) | **28.3824*** ** | 5.1979 | 5.46 | <.0001 |
| | | | | |
| (Number of Suppliers 2010) - (Number of Suppliers 2006) | 0.7714 | 1.5141 | 0.51 | 0.6137 |
| (Number of Suppliers 2011) - (Number of Suppliers 2006) | **12.4857*** ** | 2.9849 | 4.18 | 0.0002 |
| (Number of Suppliers 2012) - (Number of Suppliers 2006) | **24.9429*** ** | 4.9212 | 5.07 | <.0001 |
| (Number of Suppliers 2013) - (Number of Suppliers 2006) | **31.3143*** ** | 5.4962 | 5.7 | <.0001 |
| | | | | |
| (Number of Suppliers 2010) - (Number of Suppliers 2007) | -1.1429 | 1.257 | -0.91 | 0.3697 |
| (Number of Suppliers 2011) - (Number of Suppliers 2007) | **10.5714*** ** | 2.6423 | 4 | 0.0003 |
| (Number of Suppliers 2012) - (Number of Suppliers 2007) | **23.0286*** ** | 4.5885 | 5.02 | <.0001 |
| (Number of Suppliers 2013) - (Number of Suppliers 2007) | **29.4*** ** | 5.2068 | 5.65 | <.0001 |
| | * p < 0.05 | | | |
| | ** p < 0.01 | | | |
| | *** p < 0.001 | | | |

# APPENDIX B

## PERMISSION TO USE PUBLISHED ARTICLE

Chapter 4 of this dissertation work on Supply Chain Finance has been published as co-authored work with Dr. Dale Rogers of Arizona State University. Dr. Rogers is a member of my Dissertation Committee and approves the inclusion of this work within my Dissertation. The citation for the published work is:

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