6-2021

Examining the Influence of Source Dependence on Supplier Performance in the USAF Organic Supply Chain

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EXAMINING THE INFLUENCE OF SOURCE DEPENDENCE ON SUPPLIER PERFORMANCE IN THE USAF ORGANIC SUPPLY CHAIN

THESIS

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AFIT-ENS-MS-21-J-040

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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AFIT-ENS-MS-21-J-040

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THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics and Supply Chain Management

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June 2021

AFIT-ENS-MS-21-J-040

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AFIT-ENS-MS-21-J-040

Abstract

Due to the diminishment of manufacturing sources needed to sustain aging weapon systems, the USAF has become highly dependent on sole sourcing to fulfill their spare part requirements. From 2017 to 2019, approximately 57% of total purchases for spare parts were sole sourced, with less than 7% of repairable parts being dual sourced. When suppliers are the sole source for a component due to high specificity of requirements or government restrictions to data rights, it generates dependency within the buyer-seller relationship. Furthermore, if the USAF's level of dependence outweighs the supplier's reliance toward the USAF, it can create undesired supplier performance during the procurement process. This research used linear regression to investigate the relationship between source dependence, supplier size, and various performance categories for 326 suppliers managed by the 448th Supply Chain Management Wing. The five supplier performance categories in the study included timeliness, cost control, quality, business relations, and regulatory compliance. The research found that the USAF's dependence on sole sourcing had a small but statistically significant influence on all five aspects of supplier performance, with timeliness having the most negatively influenced relationship. Additionally, supplier size in terms of contract volume was found to have a small but statistically significant relationship with all performance categories except for cost control. Future research should consider other potential drivers of performance scores such as supplier age, length of business relationship, and physical distance between suppliers and their buying agency.

Acknowledgments

I would like to express my sincere appreciation to all the faculty and staff that guided me through this academic journey. During the uncertain and difficult times of the COVID-19 pandemic, your efforts did not go unnoticed as you all navigated around these challenges to ensure a quality education for my cohort. I would also like to send additional gratitude to Dr. Glassburner. Your mentorship and expertise helped me, both personally and academically, as I strived toward the completion of this thesis. Furthermore, I could not have asked for a better group of classmates to share this experience with. You all aided in my professional growth and I wish you all the best of luck in future endeavors. Lastly, I would like to thank my family for your love and support throughout the duration of this program.

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EXAMINING THE INFLUENCE OF SOURCE DEPENDENCE ON SUPPLIER PERFORMANCE IN THE USAF ORGANIC SUPPLY CHAIN

I. Introduction

Background

The U.S. Air Force (USAF) on average spends $4 billion every year to purchase and repair the spare parts needed for weapon system sustainment (Mills et. al, 2018.) This high cost often constitutes for a significant proportion of total operations and support (O&S) expenditures, which have steadily increased over the years due to the decreased reliability of aging USAF weapon systems. From 1999 to 2016, the annual growth rate of O&S costs per flying hour increased between the range of three and seven percent annually. Naturally, it is expected for these O&S costs to rise as aircraft age increases, especially during the end-of-life phase, when airframes begin to degrade and require more maintenance. However, the aftermarket supply chains for spare parts are also adversely impacted by aircraft age as the availability of manufacturing and repair sources diminish over time (Trunkey, 2019.) This phenomenon is referred to as diminishing manufacturing sources and material shortages (DMSMS) and it has become a significant issue when managing the suppliers of critical spare parts for aging aircraft fleets. Furthermore, if a supplier becomes the sole source for a component due to specificity of requirements or government restrictions to data rights, it creates dependency within the buyer-seller relationship. This can become problematic for the buying organization if there is a high level of dependence on the supplier that outweighs the supplier's dependence on the buyer for future business. The supplier can potentially leverage this dependence to gain power over the buyer and may lead to undesired supplier performance during the procurement process (Kull and Ellis, 2016.)

Typically, poor performance during the fulfillment of federal contracts can result in adverse consequences for the supplier, such as the denial to obtain future contracts or termination of the relationship (Manuel, 2015.) However, if there is only one supplier that can manufacture or repair a critical component, the USAF is typically forced to continue business with them. Leaders of the USAF have long recognized negative procurement outcomes associated with sole sourcing, which led to HQ USAF/A4 addressing it in their 2019 Strategic Sustainment Framework (AF/A4, 2019.) The second line of effort (LOE) of this framework lays out the plan to improve enterprise material support by building resilient supply chain capabilities. In this LOE, they propose that the USAF should develop new sources of supply and invest in the dual sourcing of critical workloads (AF/A4, 2019.) Additionally, within the USAF's organic supply chain at the 448th Supply Chain Management (SCMW), there are several ongoing efforts to identify and mitigate the risk of dependence toward sole sources of supply. One of the focal points for this initiative is the Strategic Alternative Sourcing Program Office (SASPO) which is structured within the 448th SCMW. The SASPO is charged with developing alternative sources of supply or repair that can be leveraged to combat the negative effects of diminishing sources within USAF organic supply chain. By increasing market competition, the SASPO aims to increase spare parts availability while reducing costs and lead times (Wishon, 2020.) Ultimately, the optimization of procurement outcomes through alternative sourcing methods will be crucial for aging weapon systems that have been adversely impacted by the diminishment of manufacturing sources.

Problem Statement

Every year, more than 80% of the USAF's demand requirements for critical spare parts are fulfilled through organic and contract repair, while the rest are met through new purchases. The problem is that most of these parts only have a single source of repair or supply, leaving them highly susceptible to disruptive outcomes during the procurement process. From 2017-2019, approximately 57% of total purchases for new spare parts went toward a sole source and less than 7% of new buys for repairable parts were dual-sourced (AF/A4, 2019.) When you think of supply chain disruptions, most often acts of god such as tornadoes, hurricanes, wildfires, or even the recent COVID-19 pandemic come to mind. However, disruptions can also be caused by breakdowns in supply due to DMSMS, obsolescence, or even supplier performance factors such as quality issues, delinquent deliveries, or no-bids against sole sourced items. These breakdowns in supply can result in lengthy procurement lead times which can subsequently contribute to supply related downtime of aircraft, referred to as NMCS hours in the USAF. In addition to adverse performance costs, the monetary costs of lengthy lead times can also be significant. It is estimated that one day of administrative lead time drives $3.44M of spare parts inventory for the USAF. Ultimately, being able to reduce the USAF's dependence on sole source suppliers by increasing market competition through competitive acquisition, can reduce risk and procurement costs. (AF/A4, 2019.)

Purpose Statement

Due to the diminishment of manufacturing sources for aging weapon systems, the USAF has become highly reliant on sole sources of supply to fulfill their spare part requirements, even if there is a history of poor procurement outcomes. The aim of this study is to examine the relationship that varying levels of dependence toward sole sources of supply has with the procurement outcomes in terms of supplier performance. Additionally, this research also strives to study the relationship of supplier size in terms of contract volume with performance outcomes.

Research Questions

Through a quantitative research framework, this study answered the following questions of interest:

RQ 1: To what extent does the USAF's dependence on sole sourcing influence the performance outcomes of suppliers within the USAF organic supply chain?

RQ 2: How does supplier size in terms of contract volume relate to supplier performance outcomes?

Research Focus

First, the literature is reviewed to understand spare parts logistics as it relates to procurement, strategic sourcing decisions, and supplier performance. The literature review also covers relevant studies within the context of defense logistics and federal contracting as government processes can often vary from commercial practices. Next, the data collection process and methodological applications used in this research are outlined. Furthermore, the statistical analysis of linear regression models are presented and the relationships between the variables of interest are explained. Lastly, recommendations and research limitations related to this study are outlined for both supply chain managers and future researchers.

Methodology

A series of linear regression models were utilized to understand the relationship between source dependency, contract volume, and various aspects of supplier performance. In this case, supplier performance is captured through supplier evaluations that were derived from the Contractor Performance Assessment Reporting System (CPARS.) The performance metrics used as dependent variables in this study include timeliness, cost control, quality, business relations, and regulatory compliance.

Assumptions/Limitations

One major limitation of this study was the ability to capture dependence and other aspects of the buyer-seller relationship from the supplier's perspective. The contract data provided by the 448th SCMW primarily included information that pertains to details of the buyer's perspective. Another limitation is that the measures of supplier performance captured through CPARS are subjective in nature, which can be subject to biases. However, the use of CPARS data has been used in other studies to investigate drivers of supplier performance, and to our knowledge is the best existing data source for supplier performance.

II. Literature Review

Chapter Overview

The intent of this chapter is to lay out the fundamental knowledge needed to understand sourcing decisions in federal acquisition, the tradeoffs associated with these decisions, and how they impact procurement outcomes in terms of supplier performance. First, the theories of transaction cost economics and resource dependence theory are investigated to determine which theoretical lens could be used to explore the research problem at hand. Then, after-sales supply chains are explored to provide context of organizational structure and critical processes used in the sustainment of the USAF's organically managed aircraft. Next spare parts logistics will be covered to understand how demand changes throughout product lifecycle and how that impacts sourcing decisions. The procurement process will also be covered as it is important to understand differences in commercial and federal procurement. Lastly, relevant studies regarding supplier performance management and strategic sourcing will be discussed to identify gaps in literature and pave the path forward for this study.

Transaction Cost Economics

A theory commonly explored within the context of SCM is transaction cost economics (TCE) which has been used to explain firm behavior in the governance of transactions between organizations (Defee et. al, 2010.) A fundamental idea behind TCE theory is that firms strive to optimize costs within the organization when making transactional agreements and exchanges with outside organizations for products or services (Williamson, 1979.) In TCE, these transactions usually take the form of a contract when a buyer makes an economic exchange with an outsourced supplier. The subsequent costs associated with these transactions can vary depending on specificity, sourcing decisions, and the buyer-seller relationship (Pint and Baldwin, 1997.) Another area of interest within the realm of TCE is the impact of supply chain integration on transaction costs. It is argued that vertical integration of the supply chain can reduce costs by centralizing command over the supply chain to minimize inefficient negotiations with outsourced entities (Williams, 1979; Gibbons, 2010). This discussion on integration relates closely to the TCE literature on source dependence. Dependence typically occurs when there is a high degree of specificity needed to produce a requirement. When dependence increases between the buyer and supplier, it can aid in maintaining governance of the relationship and encourages continuity. As dependency decreases, the buying firm must rely on competition to establish governance which can result in increased costs in the procurement process (Williamson, 2008.)

Resource Dependence Theory

Along with TCE, resource dependence theory (RDT) is also frequently used to explain relational exchanges between buyers and suppliers. TCE commonly explores the themes of specificity, uncertainty, and transactional frequency in the literature. Whereas RDT argues that transactional exchanges are impacted by social aspects of the buyer-seller relationship and investigates factors such as the strength of communication, commitment, and stability of the relationship (Pfeffer and Salancik, 1978; Fink et. al 2006). The body of literature using RDT has mainly investigated firm dependence and its influence on procurement strategies. There are varied arguments on how dependency should be defined. However, similarly to TCE, many have used specificity to measure dependence between a buyer and seller (Fink et. al, 2006.) Other researchers used criticality of requirements and the buyer's perception of importance to define dependence (Anderson and Weitz, 1989; Ganesan, 1994). Ultimately, the fundamental concept of RDT is to explain how outcomes are impacted when an organization does not possess or control all conditions needed to fulfill requirements (Hanfield, 1993.)

After-sales Service Supply Chains

Before diving into the highly relevant topics such as spare parts logistics, procurement, supplier performance, and strategic sourcing. It is imperative to understand the supply chain structure in which the USAF receives its support. The aircraft fleets owned and operated by commercial or defense agencies can be described as an installed base, which is defined as a system of products that have been sold and are still in use by the consumer (Dekker et. al, 2013.) Examples of installed bases include aircraft fleets, windmills, service antennas, and a variety of other support equipment. After the sale, these products are then serviced and maintained throughout its lifecycle through service contracts. These services are usually contracted out to the original equipment manufacturer (OEM), outsourced to another service organization, or maintained locally by the consumer (Dekker et. al, 2013.) The after-sales services for these installed bases have become a critical component for organizations across the globe as they can generate additional revenue for the OEM and service contractors (Cohen 2006.) For the consumers on the other hand, managing these services becomes a costly factor that drives O&S budgets as they make sourcing decisions on where to purchase and repair their spare parts (Trunkey, 2018.)

Traditional supply chains have often been defined as a network of upstream and downstream organizations that work together to create value for a customer in the form of a finished product (Christopher, 2016). Whereas service supply chains focus on the creation of value through services such as the management of information, processes, capacity, and funds (Ellram et al. 2004). After-sales service supply chains are a separate identity that create value through the repair, modification, maintenance, and technical support for products throughout the product lifecycle. Understanding these distinct differences between manufacturing and after-sales services is imperative, as each heavily influences supply chain structure and processes (Cohen et al. 2006). The foundational framework for supply chain management developed by Lambert and Cooper (1998) is organized into three vital elements: business processes, management components, and structure. They describe business processes as a group of key tasks that create valued output for a consumer, while the management components are the individual elements along the supply chain in which the processes are conducted. However, there are some differences in the processes for after-sales services. N. Saccani et. al. (2007) and Amini et al. (2005) identified the following processes as being critical in adding value for the end-item users: field technical assistance, spare parts logistics, and customer care. As the focus of this study will be on the suppliers for spare parts, the next section will give a brief overview on spare parts logistics and how they differ from manufacturing inventories.

Spare Parts Logistics

Kennedy et. al (2002) define spare parts as service or repair items that are used to maintain an installed base and keep capital equipment in a fully functioning state. The management of inventory for spare parts differ greatly from manufacturing inventories, in that they are highly dependent on the failure process and how the end-items are operated by the consumer. Whereas manufacturing inventories serve the purpose of maintaining the flow of a production line for finished goods. Manufacturing inventories are much easier to predict and govern due to the ability to control the rate in which inventory is consumed on the production line (Kennedy et. al, 2002.) While the requirements for spare part inventories are much more difficult to manage due to intermittent or lumpy demand patterns that are difficult to forecast (Huiskonen, 2001.) Additionally, the demand for spare parts changes as the end-item progresses throughout the product lifecycle, which is represented in the figure below. During the initial phase as the installed base is growing, the demand for spare parts is typically low. However, during the mature and end-of life phases, demand reaches its peak and eventually diminishes. The end-of-life or sustainment phase for products with long life cycles can become problematic for supply chain managers as the spare parts market begins to diminish and consumers become more reliant on sole sources of supply (Dekker et. al 2013.)

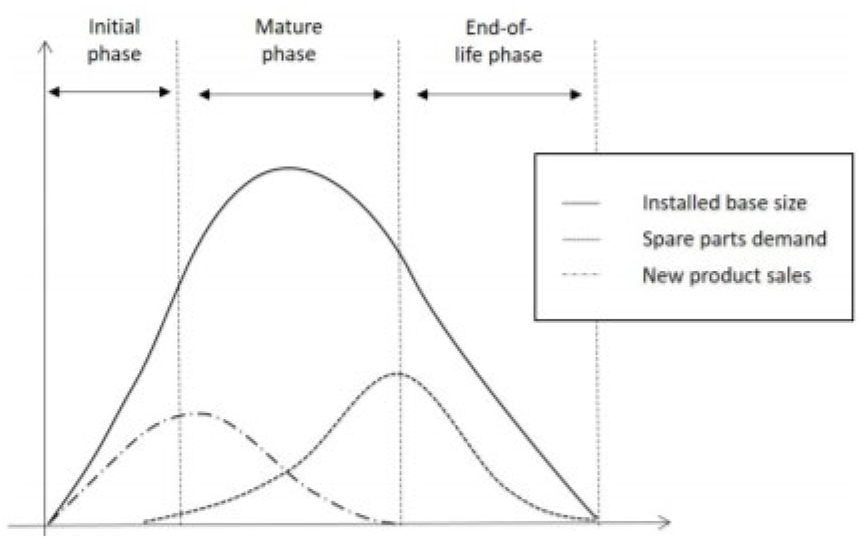


Figure 1: Product Life Cycle (Dekker et. al, 2013.)

Procurement Process

Obtaining the external services and materials needed to accomplish internal objectives is vital for any supply chain. In supply chain management, this process is referred to as either procurement or purchasing. These terms are often used interchangeably within the literature; however, procurement has become an umbrella term that encompasses the purchasing process (Pereira et. al, 2014.) Effective procurement and supplier management can lead to competitive advantage and maximize value creation for both the buying and selling organizations. Novack and Simco (1991) lay out the procurement process in the order in which it should occur. The process starts with a make or buy decision once the buying agency identifies the need for a product and outlines the specifications of the requirement. If they determine the part cannot be made internally, they conduct a market analysis, identify potential suppliers, and determine whether they can these suppliers can fulfill the demanded requirement. Once all potential suppliers have been prescreened, the buyer makes a final decision based on different factors such as price, quality, and service. However, the process does not end there. Lastly, after the final product has been delivered, an evaluation of the supplier's performance must be conducted to determine whether the buyer's needs were met to satisfaction in terms of quality, schedule effectiveness, and business relationship. This final step to the process is crucial as it can aid in future procurement decisions.

Federal Acquisition

The previous section gave perspective on how the procurement process plays out for many organizations. However, it is important to mention that the federal government's procurement process operates much differently than commercial industries due to budget constraints and federal regulations. For starters, the government often refers to the process as federal contracting or acquisition opposed to procurement or purchasing. In terms of regulation, all government members involved in acquisition must abide by the Federal Acquisition Regulation (FAR.) This body of statutory regulation is set in place to guide federal contracting officers in the acquisition process. Below are the four fundamental aspects of government procurement which are laid out in the FAR (Lamourex et. al, 2015.)

1. *Satisfy the End User in Terms of Cost, Quality, and Timeliness of the Delivered Product or Service*: The top priority of federal contracting is to ensure that end users have the materials and services needed to execute their missions. In the Air Force, end users would include the warfighter support and anything in support of sustaining and operating our weapon systems. All acquisition and contracting activity should be designed to ensure that end users receive their required level of support by (1) using commercial items when possible, (2) using suppliers that have displayed competence, and (3) by seeking out competition.
2. *Minimize Administrative Operating Cost:* Federal contracting officers should pursue every possible avenue before awarding contracts to ensure that they are wisely utilizing funds.
3. *Conduct Business with Integrity, Fairness, and Openness:* As previously mentioned, the government operates much differently than commercial organizations that are profit seeking. Federal institutions rely on taxpayers for income and because of that, there are additional regulations which ensure that there is transparency in the acquisition process.
4. *Fulfill Public Policy Objectives:* Lastly, those involved in the federal acquisition process must adhere to policies set forth by congress. These policies typically are meant to support commercial businesses opposed to the warfighter. This is to

ensure equal opportunities to small businesses who may be less established than large government contractors but are still able to fulfill the required level of support to the customer.

Supplier Performance Evaluations

The use of supplier performance evaluations has become vital in the procurement process due to an increased reliance on outsourcing in supply chains. These evaluations allow the buyer to measure how well the supplier was able to meet their expectations and provide feedback to the supplier (Hawkins et. al, 2020.) In accordance with the FAR, the performance of federal contractors must be evaluated to maintain quality of performance and provide information that can aid in future sourcing decisions (Manuel, 2015.) Federal contracts that exceed the simplified acquisition threshold of $150,000 are required to be evaluated and documented in the Contractor Performance Assessment Reporting System (CPAR.) In this system, the buying organization rates contractor performance based on various factors that encompass the fulfillment process. Below are the factors that are evaluated. During the evaluation, each factor is given a rating in addition to a narrative in support of the ratings.

- Technical – quality of product or services
- Cost Control – efforts to minimize and control costs.
- Schedule/Timeliness – ability to deliver products or services on time.
- Management – ability to maintain a satisfactory business relationship.
- Regulatory Compliance – ability to abide by environmental, safety, or other miscellaneous standards within the contract requirements.

Strategic Sourcing Strategies

There is extensive research on strategic sourcing and supplier management strategies within the supply chain body of literature. One of the most debated topics in sourcing is whether to invest into sole or multiple suppliers when procuring materials or services. This topic has recently been further investigated due to the increased interest of risk management and supply chain resilience in the literature over the past 20 years (Yu et. al, 2009.) There are three widely used approaches when determining the number of sources for an item. These include single sourcing, dual sourcing, and multiple sourcing. Single sourcing is when the purchasing entity decides to source from a single supplier even though there are multiple suppliers in the market that can accommodate the demanded requirement. Single sourcing is often confused with sole sourcing, which is when the buyer is forced to source from a single supplier because they are the only seller or manufacturer in that particular market (Newman, 1989.) Dual sourcing on the other hand refers to when the purchasing entity decides to source between two suppliers for the same item. While multiple sourcing refers to the purchase of an item from several suppliers. When setting aside the consideration of risk, there are solid arguments for both single and dual sourcing strategies to be made. Single sourcing has often been associated with improving the efficiency and productivity of firms. It also allows for the buyer and seller to develop a closer relationship and collaborate their efforts to ensure decisions are advantageous for both entities. Dual and multiple sourcing methods on the other hand, have often been used to increase competition between suppliers. This allows the buyer to leverage price within the market (Yu et. al, 2009.) All these strategies have their advantages and disadvantages.

In the literature discussing just-in-time (JIT) and lean initiatives, there is heavy favor toward single sourcing for the purpose of improving efficiency and productivity. However, as supply chains have globalized and become more complex over the years, they have become more vulnerable to disruptive events. This has cause debate of how buyers should manage sourcing decisions based on supply chain risk management. Newman (1989) warns of the long-term risks associated with single sourcing. While single sourcing may provide short-term cost savings, he argues that the supplier gains power over the buyer if they decide against rationing demand requirements among multiple suppliers. He states that dual or multiple sourcing is an effective strategy that reduces the risk of a monopolistic supply base. Ramasesh et al. (1991) agree with this assessment and further argue that multiple sourcing can also lead to higher reliability of on time deliveries and greater flexibility in management of requirements. Zsidisin et al. (2000) argues that investing in single source relationships with suppliers to reduce costs puts them at an increased state of risk. They emphasize that the risk associated with source dependence can be significantly reduced through the development of new suppliers. Lastly, they indicate that these efforts can result in improved communication and collaboration between the buyer and seller.

Source Selection Methods

Being able to understand what drives procurement outcomes such as contract price, supplier performance, and lead times is critical in the procurement process as it can be used to inform sourcing decisions that lead to improvements in cost, quality, and service levels. Source selection method has largely been considered in the literature to leverage procurement outcomes. Ittner et al. (1999) found that that using higher levels of non-price criterion in supplier selection resulted in greater buyer-seller relationships but sacrificed lower costs and product quality. Kaufmann et al. (2014) considered non-price and price performance metrics separately. They found that a rational selection method increased cost performance while experience-based intuition in source selection resulted in increased quality, innovation, and delivery timeliness. Landale and Rendon (2017) examined a series of government contracts to assess the impact of supplier selection method on lead times and CPARS performance metrics using multiple regression. The two primary source selection methods in this study were trade-off and low-price, technically acceptable (LPTA.) They found that the trade-off method resulted in higher lead times, but increased levels of supplier performance. Lastly, they suggested that the use of CPARS data as dependent variables is limited and that it should be explored further.

Summary

This chapter covered past literature and supply chain topics related to the research topic on hand. First, transaction cost economics and resource dependence theory were explored to provide a theoretical scope in which this research could be built upon. Next, relevant topics such as spare part logistics, procurement, and sourcing decisions were laid out in detail. Lastly, studies regarding federal contracting and supplier performance were investigated for gaps in the literature. Overall, it was found that there is limited research using CPARS performance metrics as dependent variables and that it is an area that warrants further research.

III. Methodology

Chapter Overview

This chapter covers the research design, variables, and methodology used to answer the research questions of interest. First, the quantitative design of this study is covered and linked back to the research question. Then the variables of interest are explained in detail to include data sources, collection methods, and the cleansing of data. Lastly, the method of linear regression is covered as it will be used extensively in the following chapter to provide statistical analysis of the data.

Research Design

This study used a quantitative research design to answer the following research question of interests:

RQ 1: To what extent does the USAF's dependence on sole sourcing influence the performance outcomes of suppliers within the USAF organic supply chain?

RQ 2: How does supplier size in terms of contract volume relate to supplier performance outcomes?

Data Collection and Descriptive Statistics

The primary interest of this study is to understand what effect source dependence has on supplier performance. To effectively capture the performance of suppliers within the USAF organic supply chain, performance data was collected from the Contractor Performance Assessment Reporting System (CPARS.) This system is used by all federal procurement agencies to maintain and track the performance of suppliers for contracts valued above $150,000. After the completion of contracts, suppliers are graded in a variety of areas to inform the ratee or future buyers on how well the supplier's satisfied the various aspects of their agreement. Depending on the specifications of the contracts, each contract is typically graded on the following criterion:

- Schedule/Timeliness – how well the supplier managed to deliver products or services within the specified time requirements.
- Cost Control – the extent to which the supplier was able to effectively forecast/control order cost and exhibit cost responsibility.
- Technical – the supplier's ability to maintain quality control and deliver products within parameters of the design specifications.
- Management or Business Relations – how well the supplier managed customer service and their ability to respond to problems, changes, or inquiries.
- Regulatory Compliance – the supplier's ability to stay within accordance to financial, environmental, safety, or labor requirements of the contract terms.

The 448th SCMW, which is primarily responsible for organically sustained aircraft in the USAF, manage the contracts for approximately 1166 tier 1 suppliers that manufacture or repair spare parts in support of these aircraft.

In the dataset generated from CPARS, performance ratings for the five graded areas for all 1166 suppliers from April 2018 to April 2021 were collected. Upon analyzing the data for cleanliness, about 436 suppliers had missing values and were removed from the dataset: resulting in datapoints for approximately 730 suppliers. Next, the aggregated ratings for each supplier were converted into a grade point average depending on the rating they received. In CPARS, the buying agency responsible for grading each criterion provides following ratings listed from worst to best; unsatisfactory, marginal, satisfactory, very good, and exceptional. As a method used in previous studies, a Likert scale of one to five was developed to match each possible rating. A one being assigned to the worst possible score of “unsatisfactory” and a five being assigned to the best possible score of “exceptional.” Once this was completed, a grade point average for each supplier and performance criterion was calculated.

Regarding the independent variables of this study, source dependence and supplier contract volume were the primary subjects of interest. Contract volume was incorporated in this study to give perspective of the supplier’s size. This variable was relatively easy to generate as it is simply the total count of contracts managed by the supplier during the time period of interest. Source dependency in this case is a metric tracked by the 448th Supply Chain Management Wing (SCMW) to determine the how reliant the USAF supply chain is on sole sources of supply or repair. The SCMW utilizes this source dependency metric to understand which suppliers are at higher risk to disruption. Each supplier within their supply chain risk model is given a score based on the USAF’s level dependency toward that supplier. A higher score indicates high risk, meaning that the USAF is highly dependent on that supplier and there is little to no competition in the acquisition process for the resources they provide. While lower dependency scores are associated with dual sourcing and increased competition in the acquisition process. The dependency score for each supplier is calculated based on Acquisition Method Codes (AMC) relative to the total volume of contracts managed by the supplier. Below is a description of AMCs used in the calculation.

- AMC 0 – The NSN was not assigned AMC 1 through 5 when it entered the inventory and has not yet completed the screening process.

- AMC 1 – Suitable for competitive acquisition for the second time or more.
- AMC 2 – Suitable for competitive acquisition for the first time.
- AMC 3 – Acquired for the second or subsequent time from a sole source.
- AMC 4 – Acquired for the first time from a sole source.
- AMC 5 – Acquired directly from a sole source contractor.

Upon request, the 448th SCMW provided a dataset containing contract data for the tier 1 suppliers managed by their organization. In this dataset, there were 27 variables that pertained to those individual contracts. As contract volume and source dependence are the primary independent variables of interest, the dataset was narrowed down to these variables for approximately 569 suppliers. Next, the resulting datapoints were then matched with the CPARS performance scores using the VLOOKUP function in excel. Due to suppliers with missing values and suppliers that did not match on either dataset, the final matched product resulted in datapoints for approximately 329 suppliers. Below are the descriptive statistics for all variables of interest in this study.

Table 1: Descriptive Statistics for Variables

Variable	*Mean*	*SD*	*Min*	*Max*
Schedule or Timeliness	3.35	0.52	1.00	5.00
Cost Control	3.43	0.39	2.60	5.00
Technical or Quality	3.45	0.47	2.50	5.00
Management or Business Relations	3.46	0.53	1.00	5.00
Regulatory Compliance	3.23	0.36	2.50	5.00
Source Dependence	4.38	1.67	1.00	10.00
Contract Volume	26.10	53.91	1	370

Threats to Validity

During the data collection process, limitations and potential threats to validity were discovered. The first being the inability to capture and measure dependence from the supplier's perspective. The source dependence metric provided by the 448th SCMW only captures the USAF's perspective of dependence toward suppliers. Therefore, if there was a lack of interdependence between the buyer (USAF) and a supplier, it was not captured in this study. Another limitation and potential threat to validity is the subjective nature of supplier performance reports, which are subject to biases. Being that the received CPARS dataset was aggregated, and the raters of these reports were unknown, it was impossible to detect potential biases in the dataset.

Research Method

The contract data obtained from the 448th SCMW and CPARS was utilized in a series of simple linear regression models to determine the relationship between source dependence and several supplier performance variables to include timeliness, cost control, quality, business relations, and regulatory compliance. The results of these regression models were then used to make statistical interpretations and explore the relationship between the variables of interest. The fundamental formula used for simple linear regression is:

$$y = \alpha + \beta x$$

where α is the y-intercept (constant variable) and β is the slope of the line.

Summary

This chapter reiterated the research questions of interest and covered the framework in which they could be answered. Each of the variables chosen for this study were then explained in detail in terms of data sources, data collection, and the cleansing process. Furthermore, threats to validity and limitations found during the data collection process were identified. Lastly, the methodology of linear regression was covered as it will be used in the following chapter to statistically interpret the relationship between the variables of interest.

IV. Analysis and Results

Chapter Overview

The intent of this chapter is to discuss the statistical findings for the research questions of interest. The primary focus of this study is to determine if there a significant relationship between source dependence, contract volume, and supplier performance. In this case, supplier performance is captured by the following graded categories accomplished through CPARS: timeliness, cost control, quality, business relations, and regulatory compliance. In this chapter, each of these categories were used as the dependent variables of interest. Each performance metric was modeled through linear regression to determine how they are influenced by source dependence and contract volume.

Analysis and Results

Correlation Matrix

Before the conduction of linear regression models, it is imperative to ensure that variables of interest are not too closely related. The correlation matrix below (see Figure 2) provides the correlations between all the supplier performance metrics, source dependence, and contract volume. As each of the CPARS performance metrics were being considered in separate models, it needed to be confirmed that each of these graded areas of performance were not scored similarly. While there are certainly some correlations between the performance metrics, the majority are lower than .5. However, the business relations metric did have an above average correlation with both timeliness (.6687) and quality (.6308.) The two independent variables, source dependence and contract volume, yielded much weaker correlations with all other variables of interest. Overall, it was concluded that there were not any performance variables that were too closely related and that they could be considered as dependent variables in separate regression models. In the following sections of this chapter, each performance metric will be assessed and modeled to explain their relationships with source dependence and contract volume.

Table 2: Correlation Matrix for Variables

	Timeliness	Cost Control	Quality	Business Relations	Regulatory Compliance	Source Dependence	Contract Volume
Timeliness	1.0000						
Cost Control	0.3513	1.0000					
Quality	0.5813	0.4001	1.0000				
Business Relations	0.6687	0.3915	0.6308	1.0000			
Regulatory Compliance	0.3913	0.4287	0.4953	0.5236	1.0000		
Source Dependence	-0.2777	- 0.1762	-0.2433	-0.2006	-0.1469	1.0000	
Contract Volume	0.1261	0.0734	0.1562	0.1649	0.1503	-0.0686	1.0000

Schedule/Timeliness

As previously mentioned, the schedule or timeliness metric in CPARS refers to the supplier's ability to ensure contract requirements are fulfilled in a timely manner. A simple linear regression was formulated to determine the relationship between source dependence supplier timeliness. The calculated regression formula was found to be statistically significant ($p = .0001$), with an R^2 of .077. Meaning that 7.7% of variance in supplier timeliness scores can be explained by the source dependence variable. While the model is statistically significant, high levels of variance around the slope suggests that source dependence alone would not generate accurate predictions of supplier timeliness. Furthermore, the scatterplot displayed in Figure 2 below indicates that source dependence has a negative influence (β = -.086) on supplier timeliness. This negative relationship differs from the transaction cost economics literature which suggest that higher levels of dependence lead to improved performance (Williamson, 2008.) This could potentially be attributed to a lack of interdependence within the buyer-seller relationship. Additionally, a separate linear regression model was calculated to measure the influence of supplier contract volume on the timeliness performance metric. This model also yielded a small but statistically significant result (p = .0234.) and an R^2 of .0159. Which indicates that only 1.6% of variance in timeliness is attributed to contract volume of suppliers.

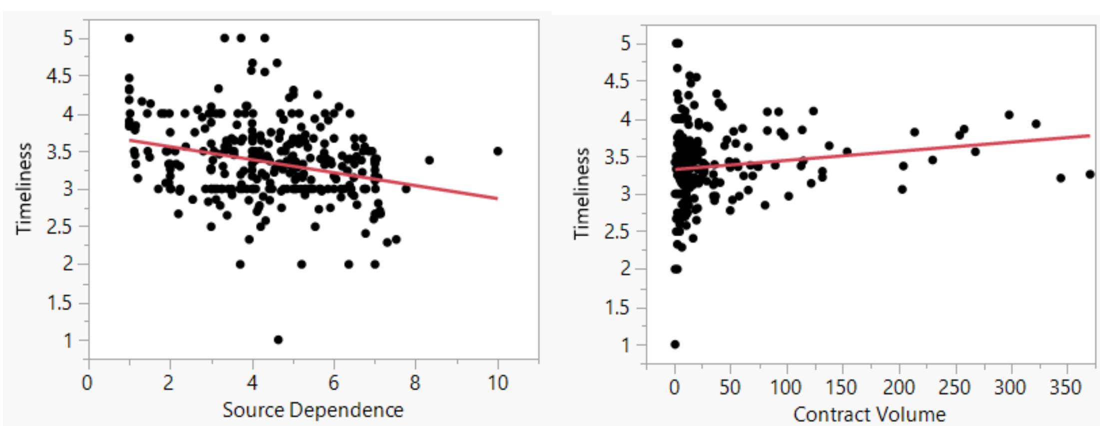


Figure 2: Scatterplots for Timeliness

Cost Control

The cost control performance metric in CPARS refers to the supplier's ability to exhibit cost responsibility through forecasting and order cost control. First, a simple linear regression model was formulated to measure the relationship between the cost control performance of suppliers and the USAF's level of dependence toward those suppliers. The calculated regression formula was found to have a statistically small significance (p = .0015), with an R^2 of .031. Meaning that 3.1% of variance in supplier's cost control performance scores can be explained by source dependence. The scatterplot in Figure 3 below displays a negative relationship (β = -.041.) However, with high variance around the slope, it could not solely be used as a predicting variable.

Additionally, a simple linear regression model was calculated to measure the influence of supplier's contract volume on the cost control performance metric. This calculation was not found to be statistically significant (p = .1884) and resulted in an R^2 of .0054. This indicates that only .54% of variance in cost control is attributed to supplier size in terms of contract volume.

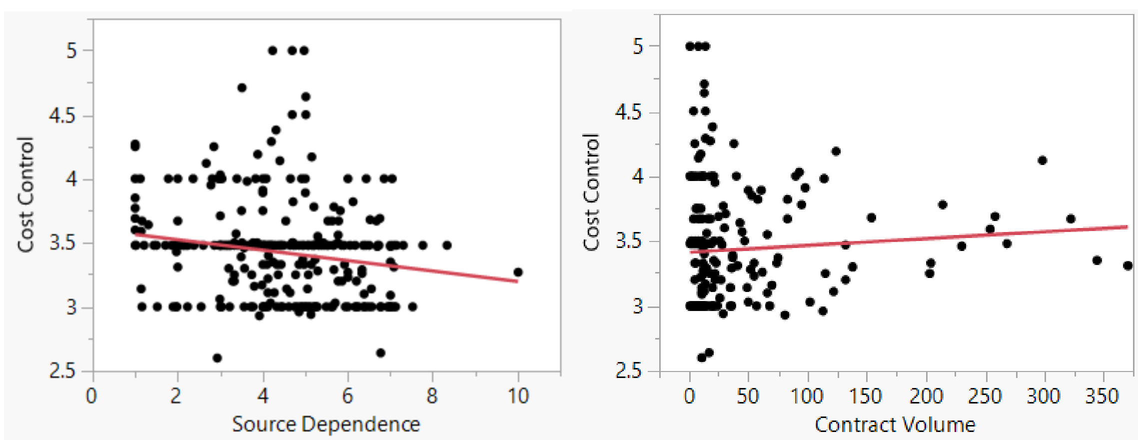
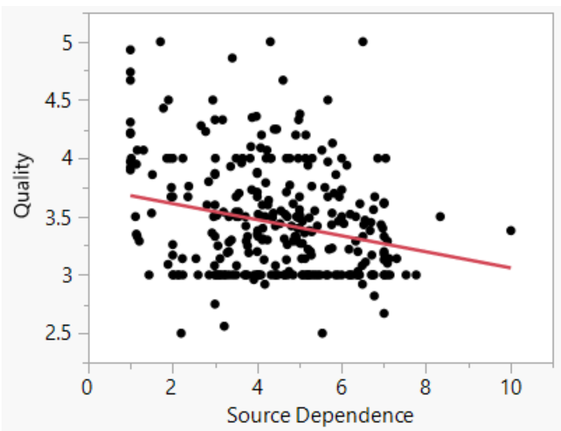


Figure 3: Scatterplots for Cost Control

Technical/Quality

The technical or quality rating in CPARS refers to the supplier's ability to deliver products or services within contract specifications. In this model, the calculated regression formula was also found to be statistically significant (p = .0001), with an R^2 of

.0592. Meaning that 5.92% of variance in the supplier's quality performance scores can be explained by source dependence. The scatterplot in Figure 4 below indicates that source dependence also has negative relationship (β = -.069) with supplier quality scores. However, with large amounts of variance around the slope, it is unlikely to yield accurate results as a predicting variable. Additionally, a simple linear regression model was calculated to measure the influence of supplier contract volume on the quality performance metric. This calculation was also deemed to have a statistically small significance (p = .0049.) However, it resulted in a much lower R^2 of .0244, indicating that only about 2.44% of variance in supplier quality ratings can be attributed to contract volume.



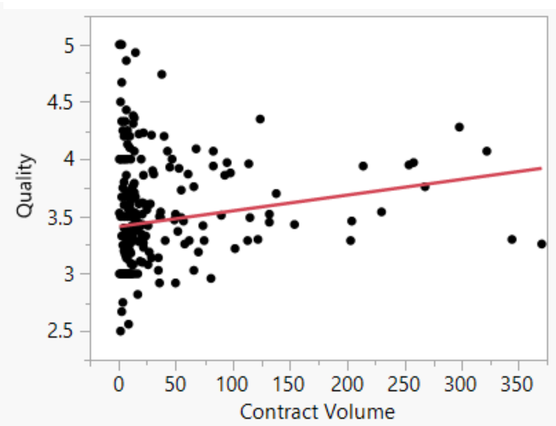


Figure 4: Scatterplots for Quality

Management/Business Relations

Management or business relations in CPARS measures a supplier's level of customer service and how they respond to problems or changes that may occur during the procurement process. A simple linear regression was formulated to relate the business relations of suppliers to the USAF's level of dependence toward those suppliers. The linear regression model was calculated and found to be statistically significant (p = .0003), with an R^2 of .0402. Meaning that 4.02% of variance in business relations performance scores can be explained by source dependence. Again, this performance metric was found to have a negative relationship (β = -.064) with source dependence, as seen below in Figure 5. Additionally, another linear regression model was calculated to measure the influence of supplier contract volume on the business relations metric. This calculation was also deemed to be statistically significant (p = .0029.) However, it resulted in a much lower R^2 of .0272, indicating that only about 2.72% of variance in business relations can be attributed to contract volume.

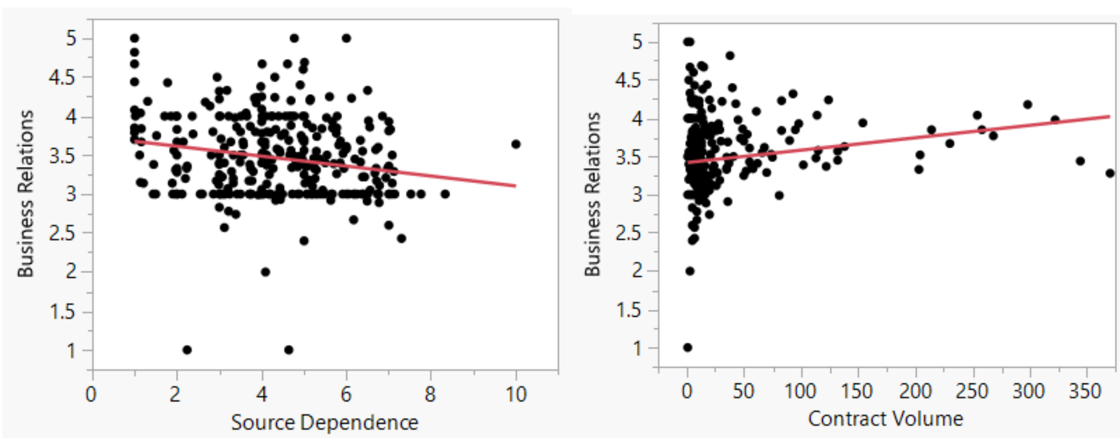


Figure 5: Scatterplots for Business Relations

Regulatory Compliance

Regulatory compliance is scored in CPARS to capture the supplier's ability to abide by miscellaneous contract terms such as environment, safety, or financial regulations. A simple linear regression was formulated to predict the regulatory compliance scores of suppliers based on the USAF's level of dependence toward those suppliers. The calculated regression formula was found to be statistically significant (p =

.0082), with an R^2 of .0215. Meaning that 2.15% of variance in regulatory performance scores can be explained by source dependence. As found in the previous models, source dependence was found to negatively influence (β = -.031) the regulatory compliance of suppliers. Additionally, a simple linear regression model was calculated to measure the influence of supplier contract volume on the regulatory compliance performance metric. This calculation was also found to have a small but statistically significant result (p = .0068.) However, it resulted in a much lower R^2 of .0226, indicating that only 2.26% of variance in regulatory compliance is attributed to contract volume.

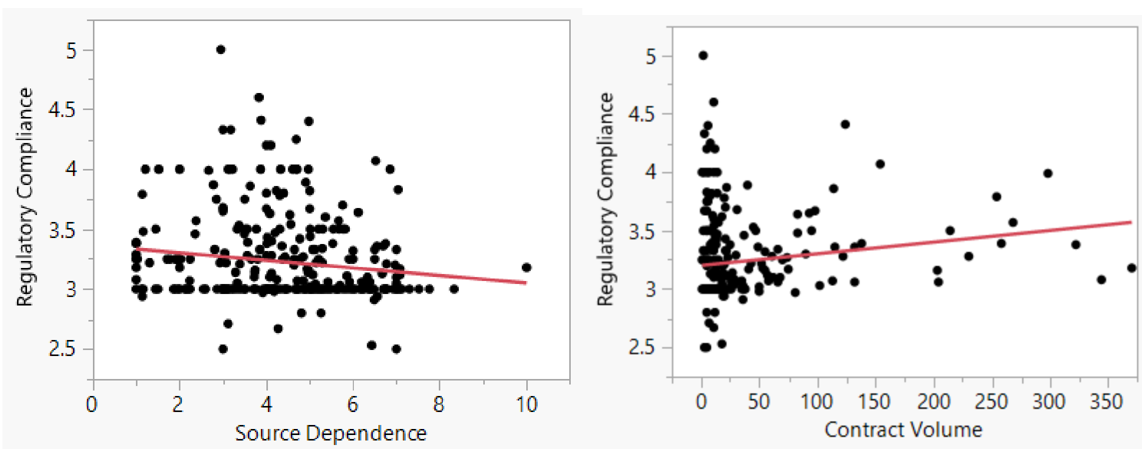


Figure 6: Scatterplots for Regulatory Compliance

Summary

The intent of this chapter was to statistically explain the influence of source dependence and contract volume on various aspects of supplier performance. As indicated in table 3 below, source dependence was found to have a small but statistically significant influence all CPARS performance metrics, with timeliness being the most influenced. Furthermore, it was discovered that source dependence had a negative relationship with the performance metrics. This negative relationship differs from the transaction cost economics literature which suggest that higher levels of dependence lead to improved performance (Williamson, 2008.) This could potentially be attributed to a lack of interdependence within the buyer-seller relationship, which relates to a limitation discussed in the previous chapter. Additionally, it was found that contract volume also had a significant but small influence (see Table 4) on all aspects of supplier performance, except for cost control.

Table 3: Source Dependence Model Results

	Source Dependence				
Dependent Variables	α	β	$SE(\beta)$	R^2	p
Timeliness	3.732	-0.086	0.017	0.077	0.0001*
Cost Control	3.605	-0.041	0.013	0.031	0.0015*
Quality	3.749	-0.069	0.015	0.059	0.0001*
Business Relations	3.741	-0.064	0.017	0.0402	0.0001*
Regulatory Compliance	3.366	-0.031	0.012	0.022	0.0001*

* $p < .05$

Table 4: Contract Volume Model Results

	Contract Volume				
Dependent Variables	α	β	$SE(\beta)$	R^2	p
Timeliness	3.323	0.001	0.0005	0.016	0.0234*
Cost Control	3.413	0.001	0.0004	0.005	0.1884
Quality	3.412	0.001	0.00004	0.024	0.0049*
Business Relations	3.41	0.002	0.0001	0.027	0.0029*
Regulatory Compliance	3.202	0.001	0.0003	0.023	0.0068*

* $p < .05$

While both source dependence and contract volume were found to have statistically measurable influences on performance, it is unlikely they would yield in accurate predictions solely as prediction variables. The next and final chapter of this study will draw conclusions from these findings and recommendations will be made to inform sourcing decisions and future research.

V. Conclusions and Recommendations

Conclusions of Research

As many of the USAF's aircraft fleets are now decades old, the procurement of spare parts needed to sustain and prolong their life cycles is imperative. The diminishment of manufacturing sources experienced by many of these weapon systems has led the USAF to be highly dependent on sole sources of supply to furnish these critical spare parts (AF/A4, 2019.) While there is extensive research in the literature on source dependence and how they influence procurement outcomes, there has been little research conducted within the scope of federal procurement and USAF spare part logistics. The overall goal of this study was to investigate the USAF's dependence toward sole sources of supply and its impact on supplier performance outcomes. In this case, supplier performance was captured through CPARS records and the performance scores of timeliness, quality, cost control, business relations, and regulatory compliance were examined as outcome variables.

Using a series of linear regression models, it was found that source dependence had a negative influence on all performance categories. Among these models, the analysis indicated that the timeliness performance metric was impacted more adversely than the others. This suggests that suppliers with increased levels of dependence, achieved lower performance scores in terms of their ability to avoid delinquent deliveries and satisfy their order requirements in a timely manner. This finding of a negative relationship differs from the transaction cost economics literature which suggest that higher levels of dependence can lead to improved performance. This could be attributed a lack of interdependence within the buyer-seller relationship, which was a limiting factor of this research. Additionally, supplier size in terms of contract volume was also considered as a driver of performance. While, four of the five models were deemed statistically significant, it proved to be less significant than source dependence.

Recommendations for Action

The USAF has already made the growth of manufacturing and repair sources a priority in their sustainment strategic framework. With a high proportion of contracts being awarded to sole sources, they call for future investments in new sources of supply and the dual sourcing of critical workloads (AF/AF, 2019.) Additionally, the Strategic Alternative Sourcing Program Office (SASPO) within the 448th SCMW has long been the backbone of this initiative by recruiting alternative sources of supply that aim to reduce procurement costs and lead times. While this study did not focus on the effect of source dependence on costs and lead times, there was sufficient evidence found to support potential improvements in supplier performance through the reduction of source dependence. With that, it can be recommended that the USAF should continue their efforts toward alternative sourcing programs by investing in new sources of supply and repair.

Future Research

One of the major limitations of this study was the inability to measure interdependence between the USAF and its suppliers. Meaning that the source dependence metric provided by the 448th SCMW only captures the USAF's level of dependence toward suppliers, but it fails to capture dependence from the supplier's perspective. Being able to incorporate interdependence would be a natural extension to this study. Another limitation was the use of subjective performance reports that are subject to biases. Being that the dataset was aggregated by supplier, and the performance raters were unknown, it made it difficult to detect biases in the data. Future researchers should obtain unaggregated CPARS data to aid in the detection of these biases. The unaggregated data will also allow the use of source selection method and other contract specific characteristics as independent variables of interest. Additionally, future research could investigate other potential drivers of CPARS performance scores such as supplier age, length of business relationship with USAF, or perhaps the physical distance between supplier's and their servicing Air Logistics Complex (ALC.)

Appendicies

Appendix A: Model Outputs for Timeliness

Linear Regression Model for Timeliness and Source Dependence

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	217	58.541866	0.269778	1.3125
Pure Error	104	21.376895	0.205547	Prob > F
Total Error	321	79.918761		0.0591
				Max RSq
				0.7531

Summary of Fit

RSquare	0.077107
RSquare Adj	0.074232
Root Mean Square Error	0.498967
Mean of Response	3.354892
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	6.677110	6.67711	26.8191
Error	321	79.918761	0.24897	Prob > F
C. Total	322	86.595871		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.7316916	0.077876	47.92	<.0001*
Source Dependence	-0.086042	0.016615	-5.18	<.0001*

Linear Regression Model for Timeliness and Contract Volume

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	78	15.494903	0.198653	0.6923
Pure Error	243	69.723285	0.286927	Prob > F
Total Error	321	85.218188		0.9712
				Max RSq
				0.1948

Summary of Fit

RSquare	0.015909
RSquare Adj	0.012844
Root Mean Square Error	0.515245
Mean of Response	3.354892
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.377683	1.37768	5.1895
Error	321	85.218188	0.26548	Prob > F
C. Total	322	86.595871		0.0234*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.3232267	0.031861	104.30	<.0001*
Contract Volume	0.0012134	0.000533	2.28	0.0234*

Appendix B: Model Outputs for Cost Control

Linear Regression Model for Cost Control and Source Dependence

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	217	32.807050	0.151185	1.1205
Pure Error	104	14.032896	0.134932	**Prob > F**
Total Error	321	46.839945		0.2582
				Max RSq
				0.7097

Summary of Fit

RSquare	0.03104
RSquare Adj	0.028021
Root Mean Square Error	0.381993
Mean of Response	3.426811
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.500470	1.50047	10.2829
Error	321	46.839945	0.14592	**Prob > F**
C. Total	322	48.340415		0.0015*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.6054312	0.05962	60.47	<.0001*
Source Dependence	-0.040788	0.01272	-3.21	0.0015*

Linear Regression Model for Cost Control and Contract Volume

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	78	12.466713	0.159830	1.0906
Pure Error	243	35.613491	0.146558	**Prob > F**
Total Error	321	48.080204		0.3067
				Max RSq
				0.2633

Summary of Fit

RSquare	0.005383
RSquare Adj	0.002284
Root Mean Square Error	0.387018
Mean of Response	3.426811
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.260212	0.260212	1.7373
Error	321	48.080204	0.149783	**Prob > F**
C. Total	322	48.340415		0.1884

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.4130496	0.023932	142.62	<.0001*
Contract Volume	0.0005273	0.0004	1.32	0.1884

Appendix C: Model Outputs for Quality

Linear Regression Model for Quality and Source Dependence

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	217	52.998504	0.244233	1.6821
Pure Error	104	15.100013	0.145192	Prob > F
Total Error	321	68.098517		0.0016*
				Max RSq
				0.7914

Summary of Fit

RSquare	0.059202
RSquare Adj	0.056272
Root Mean Square Error	0.460592
Mean of Response	3.447523
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4.285302	4.28530	20.1999
Error	321	68.098517	0.21214	Prob > F
C. Total	322	72.383819		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.7493844	0.071887	52.16	<.0001*
Source Dependence	-0.06893	0.015337	-4.49	<.0001*

Linear Regression Model for Quality and Contract Volume

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	78	13.546645	0.173675	0.7395
Pure Error	243	57.070329	0.234857	Prob > F
Total Error	321	70.616973		0.9409
				Max RSq
				0.2116

Summary of Fit

RSquare	0.024409
RSquare Adj	0.02137
Root Mean Square Error	0.469032
Mean of Response	3.447523
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.766845	1.76685	8.0315
Error	321	70.616973	0.21999	Prob > F
C. Total	322	72.383819		0.0049*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.4116638	0.029003	117.63	<.0001*
Contract Volume	0.0013741	0.000485	2.83	0.0049*

Appendix D: Model Outputs for Business Relations

Linear Regression Model for Business Relations and Source Dependence

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	217	59.653438	0.274901	1.0249
Pure Error	104	27.896396	0.268235	**Prob > F**
Total Error	321	87.549835		0.4502
				Max RSq
				0.6942

Summary of Fit

RSquare	0.040242
RSquare Adj	0.037252
Root Mean Square Error	0.522246
Mean of Response	3.462105
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	3.670934	3.67093	13.4594
Error	321	87.549835	0.27274	**Prob > F**
C. Total	322	91.220768		0.0003*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.7414914	0.08151	45.90	<.0001*
Source Dependence	-0.063798	0.01739	-3.67	0.0003*

Linear Regression Model for Business Relations and Contract Volume

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	78	15.444984	0.198013	0.6565
Pure Error	243	73.293931	0.301621	**Prob > F**
Total Error	321	88.738915		0.9849
				Max RSq
				0.1965

Summary of Fit

RSquare	0.027207
RSquare Adj	0.024177
Root Mean Square Error	0.525781
Mean of Response	3.462105
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2.481854	2.48185	8.9777
Error	321	88.738915	0.27645	**Prob > F**
C. Total	322	91.220768		0.0029*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.419605	0.032512	105.18	<.0001*
Contract Volume	0.0016286	0.000544	3.00	0.0029*

Appendix E: Model Outputs for Regulatory Compliance

Linear Regression Model for Regulatory Compliance and Source Dependence

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	217	28.325806	0.130534	1.1160
Pure Error	104	12.164127	0.116963	Prob > F
Total Error	321	40.489933		0.2658
				Max RSq
				0.7061

Summary of Fit

RSquare	0.021594
RSquare Adj	0.018546
Root Mean Square Error	0.355158
Mean of Response	3.227678
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.893626	0.893626	7.0846
Error	321	40.489933	0.126137	Prob > F
C. Total	322	41.383559		0.0082*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.3655241	0.055431	60.72	<.0001*
Source Dependence	-0.031477	0.011826	-2.66	0.0082*

Linear Regression Model for Regulatory Compliance and Contract Volume

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	78	6.499192	0.083323	0.5964
Pure Error	243	33.949409	0.139710	Prob > F
Total Error	321	40.448600		0.9959
				Max RSq
				0.1796

Summary of Fit

RSquare	0.022593
RSquare Adj	0.019548
Root Mean Square Error	0.354976
Mean of Response	3.227678
Observations (or Sum Wgts)	323

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.934958	0.934958	7.4198
Error	321	40.448600	0.126008	Prob > F
C. Total	322	41.383559		0.0068*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.2015925	0.021951	145.85	<.0001*
Contract Volume	0.0009996	0.000367	2.72	0.0068*

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
17-06-2021

2. REPORT TYPE
Master's Thesis

3. DATES COVERED *(From - To)*
Aug 2019 - Jun 2021

4. TITLE AND SUBTITLE
Examining the Influence of Source Dependence on Supplier Performance in the USAF Organic Supply Chain

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Counter, Thomas, A., Technical Sergeant

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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2950 Hobson Way, Building 640
WPAFB OH 45433-8865

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT-ENS-MS-21-J-040

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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10. SPONSOR/MONITOR'S ACRONYM(S)
420 SCMS

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A. Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
This material is declared a work of the U.S. Government and is not subject to copyright protection in the United States.

14. ABSTRACT
The purpose of this study is to examine the U.S. Air Force's dependence toward sole sourcing and how that influences procurement outcomes in terms of supplier performance. This research used linear regression to explain the effect of source dependence and supplier size on performance categories for 326 suppliers. The five supplier performance categories in the study included timeliness, cost control, quality, business relations, and regulatory compliance. The research found that the USAF's dependence on sole sourcing had a small but statistically significant influence on all five aspects of supplier performance, with timeliness being the most adversely impacted.

15. SUBJECT TERMS
Supplier Performance, Source Dependence, Strategic Sourcing, Linear Regression

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
U	U	U	UU	51

19a. NAME OF RESPONSIBLE PERSON
Lt Col Aaron Glassburner, AFIT/ENS

19b. TELEPHONE NUMBER *(Include area code)*
937-255-6565