Power influence in horizontal collaboration relationships

by

Juan David Suarez Moreno
MSc. Industrial Engineering
Universidad Nacional de Colombia

SUBMITTED TO THE PROGRAM IN SUPPLY CHAIN MANAGEMENT
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ENGINEERING IN SUPPLY CHAIN MANAGEMENT
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

May 2021

Signature of Author: ____
Department of Supply Chain Management
May 14, 2021

Certified by:
____
Dr. Maria Jesus Saenz Gil De Gomez
Executive Director, Supply Chain Management Blended Program
Thesis Advisor

Accepted by:
____
Prof. Yossi Sheffi
Director, Center for Transportation and Logistics
Elisha Gray II Professor of Engineering Systems
Professor, Civil and Environmental Engineering

Power influence in horizontal collaboration relationships

by

Juan David Suarez Moreno

Submitted to the Program in Supply Chain Management
on May 14, 2021 in Partial Fulfillment of the
Requirements for the Degree of Master of Engineering in Supply Chain Management

ABSTRACT

Supply chain horizontal collaboration has captured the attention of many researchers and practitioners. Horizontal collaboration offers multiple benefits in creating competitive advantages for companies and leveraging their sustainability in the long term. Although collaboration creates value for the supply chain, there is no evidence of what makes companies adopt these schemes since many of these initiatives fail to deliver the expected outcomes. In the core of the collaboration process lies power as an enabler since collaboration relationships arise from the inter-dependency between companies.

This research explores the influence of power in the performance of horizontal collaboration. Using data from the Colombian Ministry of Transportation, a set of 3,276 dyads and 1,095 single companies were identified as performing consolidation during the year 2020. Three different power asymmetries were built to characterize power among these dyads: income, cargo, and network asymmetries.

The effect of power asymmetries was evaluated on two outcome variables: the number of consolidated shipments and the shipping cost per kg. To do this, the augmented inverse propensity weight estimator method (AIPW) is used to analyze the average treatment effects empirically. A set of 16 experiments were conducted to understand the influence of the different asymmetries in the horizontal collaboration performance.

The statistically significant results show that power asymmetries have a negative effect on the number of consolidated shipments, reducing them. However, different effects are account for the shipping cost per kg. Income and Network asymmetries have a positive effect, reducing the shipment cost. Cargo asymmetry has an opposite effect regarding the shipment cost as it is increased when asymmetry is increased.

Significant results are found for network and cargo asymmetry on reducing the number of consolidated shipments. No significant effect is observable on the shipment cost when looking at the asymmetry in isolation. However several moderator effects were also tested under the different treatments.

Better performance was achieved for those dyads with low network asymmetry, a greater shipped volume, a broader collaborative network, and industry compatibility. The different experimental settings demonstrate that power effect on the performance depends on the dyad's relationship-specific features.

Thesis Advisor: Dr. Maria Jesus Saenz Gil De Gomez
Title: Executive Director, Supply Chain Management Blended Program

ACKNOWLEDGMENTS

First, I would like to thank to my thesis advisor Dr. Maria Jesus Saenz Gil de Gomez, for her encouragement and valuable advice during all this journey that finally made this accomplishment possible. Thank you for your support, patience and guidance.

Thanks to my thesis committee members, Dr. Josué Velázquez Mártinez and Dr. Christopher Mejia Argueta, for their periodic feedback and suggestions to improve the output of my research. In addition, I would like to thank Toby Gooley for reviewing this paper time and time again providing incredible feedback and improving my writing skills.

I would like to thank my family, my parents Samuel and Stella, and my sister Laura for their full support and love. Without them I would not be able to join and continue the program and I will be forever grateful to them. Also, my deepest appreciation to Andrea Padilla for her care and love to our son Manuel, with hopes that this will inspire him to give his best in the future.

To friends in MIT, I take with me valuable experiences and memories. We made it together. Finally, to myself for the hard work and the courage to never give up.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Logistics has been related to nations' competitiveness because of the high correlation between freight movement and economic growth. Just in the United States, 48 million tons of freight valued more than $46 billion are moved every day, according to the U.S. Department of Transportation (Ferrell et al., 2020).

For developed countries, the comprehensive logistics cost is around 10% of the GNP (Groos National Product) and is even more significant for less-advanced countries (Savy, 2016); logistics plays a crucial role in determining the efficiency of the whole production and exchange process. Although logistics plays an important role, many inefficiencies can burden its performance: vehicle utilization, empty trips, congestion, and CO2 emissions are among the most representative.

Continuous demand growth for goods and services poses an enormous pressure in logistics challenges related to efficiency and sustainability that will continue to grow without any significant changes, limiting the competitiveness of a region (Arvis et al., 2016).

There are many ways to leverage logistics performance, improving physical infrastructure, information systems integration, and objectives alignment (Cao & Zhang, 2011; Chen et al., 2017; Singh et al., 2018).

Similarly, supply chain collaboration has been stated as a way to improve firms' competitiveness and performance. Many are the pieces of evidence about the benefits of collaboration in logistics, it reduces costs, enhances equipment utilization, minimizes environmental impact, and in the end, generates a competitive advantage (Li & Chan, 2012; Nasab, 2019; Serrano-Hernández et al., 2017; Tyan et al., 2003; Wang & Kopfer, 2014).

Collaboration in the supply chain is defined as a mutually beneficial relationship based on trust, information sharing, joint decisions, and supply chain integration, ultimately outperforming the supply chain from the scenario where firms work alone (Barratt, 2004; Soosay & Hyland, 2015).

Supply chain collaboration may be found in literature in two principal schemes: vertical and horizontal collaboration. Vertical collaboration refers to when two firms working together are in different supply chain levels. On the other hand, we have horizontal collaboration, which relates to companies operating at the same supply chain level and performing comparable logistics functions (Barratt, 2004).

An example of horizontal collaboration employed to make more efficient goods transportation can be seen in the Collaboration Concepts for Co-modality (CO3) project[1]. This initiative's principal objective is to motivate shippers to rethink logistics through horizontal collaboration, ending in economic, social, and environmental benefits. This case study involves bundling road transport flows between two independent shippers (manufacturing companies). More examples of horizontal collaboration can be found in Saenz et al. (2015).

Even though the reported benefits of collaboration, this is not an extended practice. Lack of shared information, trust, flexibility, and commitment impede the application of collaboration schemes. It is even more problematic when it comes to horizontal collaboration; since non-cooperating companies tend to underestimate the opportunities and overestimate the impediments (Cruijssen et al., 2007)

[1] http://www.co3-project.eu/about-co3/

Among the benefits of horizontal collaboration, it improves product flow consolidation, better response to demand variations, and increased market power; however, how firms create a successful long-term horizontal collaboration needs to be further explored (Sheffi et al., 2019).

Horizontal collaboration is more than a technical problem. Mathematical models have been developed to optimize goods flow, maximizing utilization, and minimizing costs. Information systems ease the process for finding collaboration opportunities, but in the end, these decisions rely on decision-makers that are influenced by the relationships on their supply chains.

Understanding what drives companies to bet for horizontal collaboration in the supply chain in a would help determine guidelines to improve logistics in developing countries since it has been recognized as a facilitator for competitiveness.

Many authors state that research on supply chain collaboration tends to stem from a one-sided organization-focused approach (Soosay & Hyland, 2015). In this respect, it is also essential to explore the reciprocity in collaborative efforts; trust, dependency, and power must be included in the discussion for building successful collaboration.

Power and interdependence are crucial elements in a relationship and might influence governance and how transactions are decided. Power has been defined as the ability that one party has to influence the actions of a second party. This ability enables supply chain members to contribute to the success of collaboration by generating synergistic outcomes capitalizing on their power asymmetry (Sridharan & Simatupang, 2013).

However, power may not be considered as the unique prerequisite for effective collaboration. It should also be considered a basis for capabilities and productive behaviors that enhance collaboration relationships (Sridharan & Simatupang, 2013). Identifying power types on collaborative relationships may help to explain how to achieve successful horizontal collaboration.

One specific question arises from the previous background:

"What is the effect of power in developing successful collaboration relationships?"

For solving this research question, the causal effect of power needs to be assessed. Causal effects are defined as the difference in the same individual's potential outcomes who receive two different treatments (Robins, 1986; Rubin, 1978). However, since the causal effects are defined as a contrast of counterfactual outcomes in general individual causal effects cannot be identified because of missing data. Because of this, the potential outcomes must be estimated. Literature has focused on the average treatment effects methodology for solving this missing data problem.

Two different models are estimated using regressions: an outcome and a treatment model to estimate the propensity score, i.e., the conditional probability of receiving treatment given covariates. The interesting feature of adjusting for differences in the propensity score is that all biases are removed (Hirano et al., 2003).

Data from the Colombian Ministry of Transportation is used to identify and assess power's influence in collaborative relationships. These relationships are observed for pair of companies, dyads. Two main data sets are used. First, cargo manifests give information about a particular trucking company serving a shipment.

The second relates to the companies that compose a specific shipment. Both databases are crossed to understand how companies develop their transportation, find collaborative relationships, and assess information regarding their shipments. Secondary data is also used to characterize the firms' size, revenue, and industry sectors.

The remaining document is presented as follows. Chapter 2 presents the framework that builds up the research project, delving into supply chain collaboration and power influence. Chapter 3 presents the research methods underwent and the conceptual model. Chapter 4 presents results and discussion. Chapter 5 discuss the statistical results providing empirical explanations. Finally, Chapter 6 presents the conclusions, summarizing the study and highlighting the principal findings, managerial implications are discussed and future research is proposed.

2 LITERATURE REVIEW

This chapter establishes the building blocks for the project. The review is presented in four sections. Section 2.1 introduces the concept of supply chain collaboration, the different types of collaborations and their benefits, and the different factors that make adoption difficult. In section 2.2, collaboration in supply chain is regarded more profoundly by looking for underlying factors such as power and trust and how they mold the supply chain relationships, also governance mechanisms for managing this relationship are considered in this section. Section 2.3 discusses the different sources of power and how literature has operationalized this construct. Two principal kinds of power—mediated and non-mediated—are identified, and various studies that relate power's influence in collaboration are introduced. Section 2.4 describes the conceptual model developed; it provides the framework for the different experiments. Finally, section 2.5 explains how this thesis contributes to the body of literature in supply chain collaboration and presents general remarks for the review.

2.1 Supply chain collaboration

Supply chain collaboration has its foundations in the opportunity to increase a company's competitive advantage. In a collaborative supply chain, sharing knowledge and experience aids in advancing the mutual understanding of circumstances affecting companies and developing capabilities to address common challenges, resulting in a collaborative advantage. Collaboration among companies' interfaces may increase efficiency and provide access to more extensive capabilities, ideas, experiences, know-how, and capital

Supply chain collaboration may occur in two general approaches: vertical and horizontal collaboration (Barratt, 2004). Vertical collaboration refers to when two firms working together are in different supply chain levels; this kind of relationship is the most studied among researchers. On the other hand, we have horizontal collaboration, which refers to companies working in the same supply chain level and performing a comparable logistics function (Barratt, 2004).

Literature has identified different factors that drive horizontal collaboration in the supply chain. Cruijssen (2006) spots five objectives that partners pursue: cost reduction, growth, innovation, quick response, and social relevance. Even though all of these are factors that influence partners in a supply chain to collaborate, more importantly, these are the elements that make these relationships sustainable.

Although there are multiple elements characterizing collaboration, many types of research have focused on collaboration drivers. Some studies have focused on information technology capabilities and inter-organizational systems (IOS); other studies introduce collaborative culture and trust (Cao & Zhang, 2010).

Among many other factors that boost collaboration success, literature identifies partner selection, negotiations, determining and dividing the gains, coordination, and information and communication technology (Nasab, 2019).

When characterizing supply chain collaboration, it is also vital to take into account the collaboration structure. Schmoltzi & Wallenburg (2011) aggregate several factors in a six-dimension framework model. Each of these structural dimensions shapes partners' behavior in collaboration relationships and their outcomes. Understanding the cooperation structure adds substance to the interpretations of collaboration performance.

The following describes the six dimensions: Contractual scope focuses on the formality of the relationship. Organizational scope reflects the number of companies involved in the collaboration. Functional scope focuses on the value creation from the collaboration. Service scope accounts for the type of logistics services provided. Geographical scope and resource scope relate to structural factors, such as complementarity, the importance of the region, company size, and social structure.

2.1.1 Horizontal supply chain collaboration

Horizontal collaboration in supply chain describes the relationship between companies that performs similar functions, providing the same products, even more the collaborating firms may be direct competitors (Simatupang, Togar M & Sridharan, 2002). In a horizontal collaboration scheme share information, resources, opportunities and risks improving efficiency and profits and, in the end, creating collaborating advantages (Ferrell et al., 2020)..

Benefits from horizontal collaboration include reducing costs, improving customer experience, increases responsiveness in the supply chain, improve innovation and value creation, reduce supply chain network, and achieve a better resource management (Tafuri et al., 2013).

Although supply chain collaboration reports to provide multiple benefits few are the successful cases reported in the literature, this is explained because collaboration venture fails in meeting expectations of the parties involved (Cao et al., 2010; Fawcett et al., 2012). Few detailed theories or models capture the impact of successful collaboration so no meaningful correlations can be confidently identified (Ferrell et al., 2020).

Horizontal supply chain collaboration is characterized depending on the extend of it application, in a broad view it goes from a short-term scenario to long-term agreement, what is called a strategic alliance (Cruijssen, 2006, 2012). Collaboration may be performed for an operational, tactical, or strategic approach, each of them will need different levels of integration by the parties involved.

2.2 Collaboration process

Managing supply chain relationships has become crucial in maintaining a competitive advantage; power becomes a central point of discussion. Power might be defined as the capability that allows a firm to influence other firms' behavior or have the potential to affect the status of the supply chain (Borgström & Hertz, 2007). Different kinds of powers might be identified through literature: coercive power, reward power, expert power, informational power, legitimate power, and referent power (Belaya & Hanf, 2016).

Power has different impacts on supply chain relationships. Many authors see power as a way in which the partner that holds a higher level of it exploits the other party leading to opportunistic behaviors, undermining trust in the relationship, and threatening the relationship's sustainability. Others see power as a valuable tool for coordinating and promoting relationships, resulting in better performance for the whole supply chain, positively impacting coordination (Belaya & Hanf, 2016).

Two principal categories for power can be identified: mediated and non-mediated Non-mediated power can be defined as a power exercised by the member unintentionally. On the other hand, mediated power is exercised by the member intentionally for their advantage (French & Raven, 1959).

With the correct application of these, the supply chain can be balanced among partners. Even more, how power is balanced among supply chain partners leads to a sustainable collaboration relationship (Ibishukcu & Datar, 2016). Different studies have shown that non-mediated power can strengthen relationships among firms, whereas mediated power is detrimental to the relationship (Ketchen, 2017).

In their research, Zhao et al. (2008) found that non-mediated power positively impacts a mutual, ongoing relationship over an extended period, based on mutual commitment and sharing.

While the research presented by Zhao et al. (2008) digs into integration in the supply chain, the study considers an application for vertical integration (manufacturer-consumer). Horizontal collaboration is expected to experience a higher potential for opportunism and dysfunctional conflicts, as partners involved in this relationship may compete for the same customers (Tidström, 2009). In this sense, horizontal collaboration's conflict-oriented governance may foster its success (Wallenburg & Raue, 2011).

Literature has advanced the understanding of mechanisms that allow a successful horizontal collaboration. Governance deals with the question of how to manage and maintain horizontal collaboration. Two principal mechanisms are identified: corporate and cooperative. Corporate relations relate to partners acting as a single company, while cooperative relations relate to independent partners collaborating based on alliance agreements (Pan et al., 2019).

Sheffi et al. (2019) establish four different governance mechanisms for supply chain horizontal collaboration: joint value propositions, informal governance, formal governance, and information exchange. Governance mechanisms enhance coordination and reduce behavioral uncertainty among partners.

Among several projects related to horizontal collaboration, including CO3, Smart Rail Project, AEOLIX, and SELIS project, a fair gainsharing mechanism, and a trusted party are considered the most critical factors for a successful horizontal collaboration. Furthermore, an information-sharing platform is a must for an active connection between them (Abolfazl et al., 2020).

Governance mechanisms proposed in Sheffi et al. (2019) have an essential effect in creating fair gainsharing and improving trust. Joint ventures establish a proposition for how collaboration will be approached, setting a collaborative relationship baseline. Informal mechanisms improve trust and “soft” aspects, while formal mechanisms define bounds and avoid the appearance of opportunistic behaviors among partners. Finally, the information exchange contributes to a collaborative relationship as a building block for the alliance.

The above elements define several issues to consider in achieving a robust horizontal collaboration relationship; however, as explained before, power as an underlying factor influences how these mechanisms interact. Understanding how power is generated in horizontal collaboration would generate insights into creating long-lasting relationships among partners.

Power originates in the dependencies between actors. One partner’s reliance on the other leads to power imbalance and advantages, to the extent that a party may constrain the other party's behavior (Essabbar et al., 2016). Resource dependence theory (RDT) establishes companies' need to get involved in collaborative relationships as dependence on resources rises. RDT can be usefully applied to horizontal collaboration initiatives to understand how power is influenced by variables exogenous to the relationship itself.

Resource dependency emerges as the key antecedent that motivates collaborative relationships. Dependence identification encourages the supply chain members' willingness to break down norms of isolation and sacrifice some of their autonomy so they can get the potential benefits of greater collaboration (Sridharan & Simatupang, 2013).

Trust and power are essential in building on collaborative relationships and improving value creation among supply chain partners; however, power may not be considered the unique prerequisite for effective collaboration. It should also be considered a basis for capabilities and productive behaviors that enhance long-term collaboration relationships (Sridharan & Simatupang, 2013).

Exogenous variables may determine dependency among partners, creating the need for collaborative relationships. These dependencies generate power asymmetry that ends up molding the relationship between partners. The use of mediated and non-mediated power may determine behaviors that enhance collaboration relationships framed by governance mechanisms.

Building trust promotes successful collaboration. However, parties involved should have a common understanding of how trust is built through power and governance mechanisms that mold their relationship. Identifying power types in collaborative relationships may help to explain how to achieve successful horizontal collaboration.

2.3 Power sources

As explained by resource dependency theory, for firms to operate and compete successfully, they need to access a resource base that is not under their complete control; instead, they must acquire it in the market (Reimann & Ketchen, 2017). So, the amount of power a firm might have depends on the control it has over the resources another firm might need, which results in a power asymmetry.

The ability to influence firms' behavior enables supply chain members to contribute to the success of collaboration by generating synergistic outcomes capitalizing on their power asymmetry (Sridharan & Simatupang, 2013).

Different sources may determine this power asymmetry. As discussed in section 2.2, power may be classified as mediated and not mediated. However, multiple classifications are dependent on the power source. There are coercive, reward, expert, informational, legitimate, and referent power (Belaya & Hanf, 2016; Kähkönen, 2014; Reimann & Ketchen, 2017; Sridharan & Simatupang, 2013).

Reward and coercive power are classified as mediated power, while the remaining belong to the non-mediated power classification. When identifying the power sources, there are two parties: the power source and the target, over whom the power is exerted. In reward power, the source can mediate rewards to the target. Coercive power occurs when the source holds the ability to punish the target. In expert power, the source has access to knowledge and skills desired by the target. For informational power, the source possesses needed or wanted information, while in legitimate power, the target believes that the source has a natural right to exercise influence.

2.4 Conceptual model

Horizontal collaboration is the main topic of this research, particularly the influence of power in determining a long-lasting (sustainable) relationship. Two different kinds of power are identified, mediated and non-mediated. Non-mediated power will be analyzed since this can strengthen relationships among firms (Ketchen, 2017).

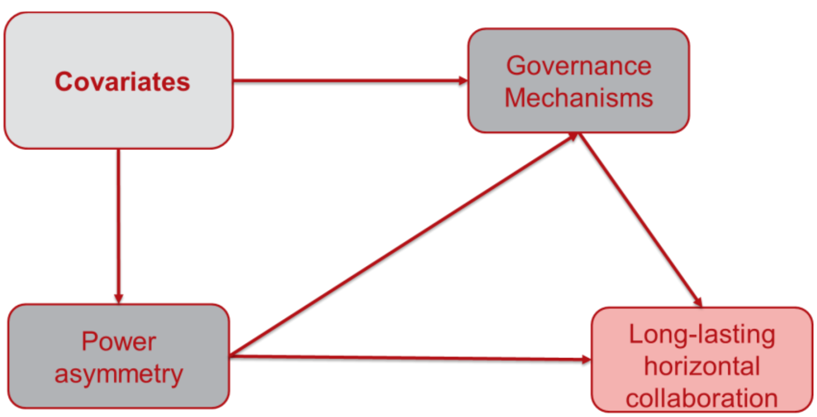
Horizontal collaboration arises from the possibility of partners creating a competitive advantage that cannot be reached independently. This condition supposes a resource dependency among firms; resource dependency triggers horizontal collaboration, but how this dependency is managed determines a horizontal collaboration's success.

The specific relationship to be proven is the causality between power and successful horizontal collaboration. Causality can be defined as the following: X variable causes Y if in any way Y depends on X for its value. X is a cause for Y if Y listens to X and decides its value to respond to what it hears (Pearl et al., 2016).

Figure 1 depicts the causality model we want to explore. Here nodes represent the different variables, and arrows represent the causality. For instance, X → Y, tells that X has a causal link with Y. These causal links can only have one direction. The presence and absence of nodes and arrows present our theory and the causal philosophy.

Conducting this research is essential to determine which companies are making horizontal collaboration and the power relationship. As collaboration might be defined as a mutually beneficial relationship, non-mediated power is seen as the kind of power present in these partnerships. The following section shows how horizontal collaboration and power were evaluated.

Figure 1. Conceptual modeling for causality in horizontal collaboration.



Here power asymmetry among supply chain partners is influenced by several covariates represented by different variables that define the relationship behavior. Both the power asymmetry and the covariates influence the governance mechanisms. Finally, power asymmetry and governance mechanisms influence the collaboration between supply chain partners. This research is focused on the causal link between power asymmetry and long-lasting horizontal collaboration.

2.5 Conclusions

Supply chain collaboration has been recognized as a way to gain competitive advantages and many reported benefits. Supply chain collaboration taxonomy characterizes two principal kinds: vertical and horizontal collaboration. While the first one studies the relationships among partners in different echelons, horizontal collaboration looks into relationships among firms in the same supply chain echelon or rival companies.

Regarding horizontal collaboration, research has focused on determining its benefits, exploring the reasons for participating in horizontal schemes and identifying factors that make horizontal collaboration feasible. Even though much research has been conducted on all of these topics, few research studies make horizontal collaboration a long-lasting relationship.

Several authors have researched factors underlying horizontal collaboration relationships. Among these factors, literature has paid attention mainly to trust. Evidence shows that mistrust in collaborative relationships undermines these alliances. On the other hand, power is less studied, but it has a strong relationship with trust. Depending on the author, power might have a positive or negative effect on collaborative relationships.

Special attention has been paid to power in vertical collaboration—identifying effects of mediated and non-mediated impact on the sustainability of collaborative relationships. Several authors have shown evidence of the positive effects of non-mediated power. Nonetheless, horizontal collaboration presents a challenge since it is expected to experience a higher potential for opportunism and dysfunctional conflicts since partners involved in this relationship may compete for the same customers and resources. Thus, they need governance mechanisms that allow partners to solve disputes and make the collaborative relationship successful.

Literature has advanced on identifying governance mechanisms for horizontal collaboration: joint value propositions, formal governances, informal governances, and information exchange have been proposed. However, as experienced in multiple practical implementations, a fair gainsharing mechanism and a trusted party are considered the most critical factors for a successful horizontal collaboration.

3 DATA AND METHODOLOGY

The following section describes the proposed methods that will be conducted to answer the research question. This research's principal objective is to understand if power influences long-lasting horizontal collaboration relationships. First, the research scope is defined, then the data and its analysis are explained. Finally, the proposed research methods are described.

3.1 Scope

This research is focused on determining the influence of power in horizontal collaboration. The project analyzes Colombia's national cargo system using information from the Transportation Ministry for 2020 in two different data sets. This project is limited to analyzing data for collaborating companies, so an important assumption was made. Companies that use the exact vehicle for transporting their goods are said to collaborate, this is a fundamental assumption, since no validation process was available. Some other information sources are considered to explain the relationships among partners, such as firms' economic activities, size, and the number of companies with which they have a relationship.

Because of the exploratory and explanatory nature of this research, the use of mixed methods is required. Mixed methods represent a set of systematic, empirical, and critical research processes and involve collecting and analyzing quantitative and qualitative data and their integration and joint discussion.

With the information collected, it is possible to make inferences due to all the data collected and achieve a greater understanding of the phenomenon under study (Hernández et al., 2014).

The mixed design selected for this research is sequential. The qualitative approach is needed as a base for determining firms and their relationship characteristics, while quantitative methods are required for hypothesis testing. This study is empirical research, as it would use existing data.

This research aims to estimate the causal effect of different power asymmetries in the collaboration process. In order to measure this effect, treatment effects models are built, where treatments are the different levels of power asymmetries, and the outcome is the number of collaborating trips and the cost of the shipments.

For conducting this research, different levels of the treatment were considered. The results presented use a multivalued treatment since it allows better explanatory power. Potential outcomes are estimated for each collaborating relationship under its specific features.

3.2 Data

For this research, data from the National Cargo Registry (RNDC) was collected. Two different data sets are considered. The first one is known as "Cargo Manifest," which gathers all the trucking companies' trips. Information such as origin, destination, kind of cargo, volume or weight, type of vehicle, dates is related to a unique identifier, the manifest ID.

The second database is known as “Consignments.” In addition to the information gathered in the Manifest, the Consignment database allows identifying the specific cargo generator. Each trip is related to a manifest ID so that several consignments may be related to a unique manifest ID.

The information collected allows identifying when two or more companies use the same vehicle to transport their cargo. A first step for building a theoretical model that relates horizontal collaboration and power is identifying the companies engaged in collaboration. This process is done by placing consignments that are related to the same manifest ID. The following table presents the key fields contained in the datasets. These data sets are recorded monthly.

Table 1. Key fields for involved data sets

Manifests	Consignments
• Date	• Date
• Transportation company	• Consignment ID
• Manifest ID	• Transportation company
• Origin	• Shipper
• Destination	• Destination
• Shipping cost	• Origin
• Weight	• Destination
• Product description	• Product description
	• Manifest ID

- Date relates to the day on which the shipment is made.
- Transportation company specifies the freighter performing the shipment; in Colombia, only registered transport companies can perform this operation.
- Manifest_ID is the unique identifier that the system gives to each shipment, and multiple shippers can be linked to the same ID.
- Origin and Destination fields specify the cities where the shipment is generated and where it is delivered.
- Shipping cost relates agreed fare between the shipper and the freighter.
- Weight specifies the total kilograms of the transported load.

- Product description specifies the cargo nature according to the harmonized global tariff system.
- Shipper, in the consignments database, identifies the companies that are linked to the same manifest ID.

3.2.1 Data gathering

The following is the process by which the above data sets are collected. First, the shipper should choose a trucking company, followed by notifying both the freighter and receiver. The freighter selects a driver and a vehicle and then registers the preliminary information in the national system. Finally, complete information is recorded, and shipping order is created.

Then, the vehicle is loaded and recorded in the system, followed by the manifest creation. Once this is done, the shipment begins. A tracking system allows the remitter to know if the shipment was completed, the remittance is completed, and the manifest is closed; finally, the payment and invoice process is done. This information is recorded in the data sets described above.

3.3 Data processing

Since the research question is focused on understanding what drives a horizontal collaboration, a specific measure for the intensity of this relationship must be built. For creating this dependent variable, the frequency in which two different companies (a dyad) perform a consolidated shipment is computed. The other dependent variable that describes the successful collaboration is the shipment cost.

Horizontal collaboration in a supply chain may be affected by several factors; notably, this research seeks to explore the effect that power has in long-term horizontal collaboration relationships. The principal hypothesis regarding the effect of power on horizontal supply chain collaboration is that power asymmetry among partners undermines these relationships.

H1: Power asymmetries undermines the horizontal collaboration performance

While a variable for the success of the collaborative relationship may be created from the data, the construct of power should also be extracted from the related data sets and external information for characterizing the power relationship among collaborative partners.

3.3.1 Performance in horizontal collaboration

Firms in recent years have changed how they relate with others. For instance, firms look for more long-term relationships, building strategic relationships representing an integral part of the firm's operation. One aspect of strategic partnerships is longevity, as it allows for significant investments, including information technologies and information sharing, which ultimately translate to more sustainable collaboration (Prajogo & Olhager, 2012).

Supply chain collaboration sustainability depends on the benefits derived from collaboration. The success of collaboration partnership motivates businesses to engage in future projects; hence supply chain collaboration relationship probes to be sustainable as it extends in time (Ramanathan & Gunasekaran, 2012).

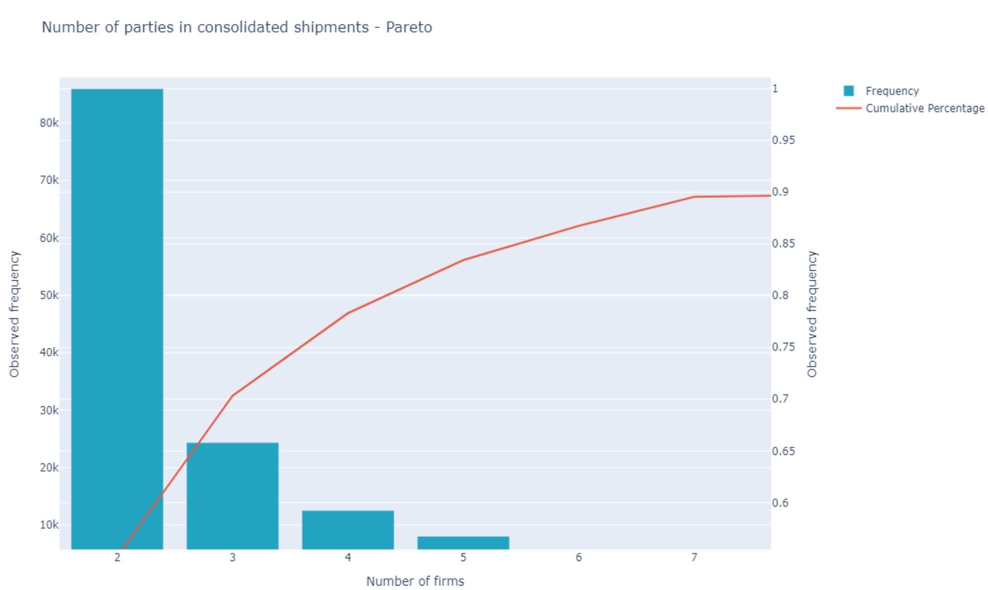
The data sets previously presented allow us to determine when two companies are undergoing collaboration utilizing consolidating cargo. However, for assessing this practice's sustainability, the frequency with which this behavior occurs is used as the primary outcome variable in this research.

The greater the frequency with which a particular dyad consolidates its shipments, the more significant is the collaboration success for this dyad. The higher frequency for consolidating shipments indicates that the collaboration relationship has been successful and has shown benefits for both firms as they continue this practice.

The data were analyzed to determine the number of parties involved in a consolidated shipment. This process was done to filter the companies that are assumed to be collaborating since it is not an extended practice; collaboration is more probably to be found among few parties. Figure 2 shows the distribution for the number of firms in a consolidated shipment. As can be seen, the most significant number of consolidated shipments occurs between two firms, and more than 86% of the consolidated shipments occur among six companies.

For determining the frequency for dyad making, any consolidation queries were performed to identify the companies using the same shipments. This query was limited to 6 companies in the same Manifest_ID.

Figure 2. Pareto for the number of parties in consolidated shipments.



3.3.2 Power

Because power is not a factor that may be controlled in an experimental design but rather emerges from the relationship among partners, it is crucial to understand the context in which a collaborative relationship is formed.

Determining power is a more challenging activity. Power relies on resource dependency and might be a latent construct among supply chain partners. However, this may be determined by isolating the dyad's shipment activities.

As explained in the literature review, power emerges from the dependencies between actors and multiple power sources, generating power asymmetry. The nature of power in supply chain relationships presupposes an asymmetrical distribution of power among partners. These asymmetries may be caused by differences in expertise, size, switching costs, dependence, contract structure, etc. (Nyaga et al., 2013)

Kähkönen (2014) proposes other sources for these asymmetries: market power, the volume of purchases, the number of alternatives and substitutes, the type of product, and the resources, capabilities, and competencies.

When characterizing the dyad, the following information was collected:

- The amount of cargo that each of the firms has shipped is recorded in kg.
- Companies' revenue informed in the monthly minimum wage for each firm
- Collaborative network for each firm, i.e., the number of companies they collaborate with.
- The business sector for single companies was also recorded.
- Origin and destination for the consolidated shipment

- Shipment cost
- Cargo nature for the shipment
- Shipment status

With these variables, the asymmetries were calculated for each dyad by normalizing each recorded variable's difference by the maximum value for the observed dyad, such that asymmetries for the cargo, revenue, and network size were calculated. For instance, each calculated asymmetry is measured from 0 to 1, where 0 represents a perfectly balanced relationship, while 1 represents a complete dominance by one firm over the other.

Information regarding the total shipment cargo and the number of companies linked to companies in the dyad, and the income were also normalized to avoid conflicts with the measurement units.

3.4 Proposed methods

Once both crucial measures are built and identified, the causal effect testing comes in place. Since the presence and the degree of power cannot be randomized, a quasi-experimental research design is performed. For the deployment of the research project, a multivalued treatment is run.

These treatments regard the amount of power asymmetry that can be found for the different experimental units. Once the power asymmetry is measured, the dyads of collaborating companies are classified into treatments, end then the effect of the treatment is evaluated.

What will be measured is the expected value of the outcome (Y) in the presence of X, i.e., E(Y/X). To calculate the treatment effect, we need to compare the expected value of the outcome when the different treatments are applied.

The presence or absence of the treatment is recorded as a dichotomic variable. However, the treatment's effect would be the difference of the conditional expected values due to the data sets' observation-based nature. The individual causal effects cannot be measured because counterfactual effects cannot be observed individually. Rather than measure the individual effects, the aggregated treatment effect (ATE) would be evaluated, as proposed in (Morgan & Winship, 2014),

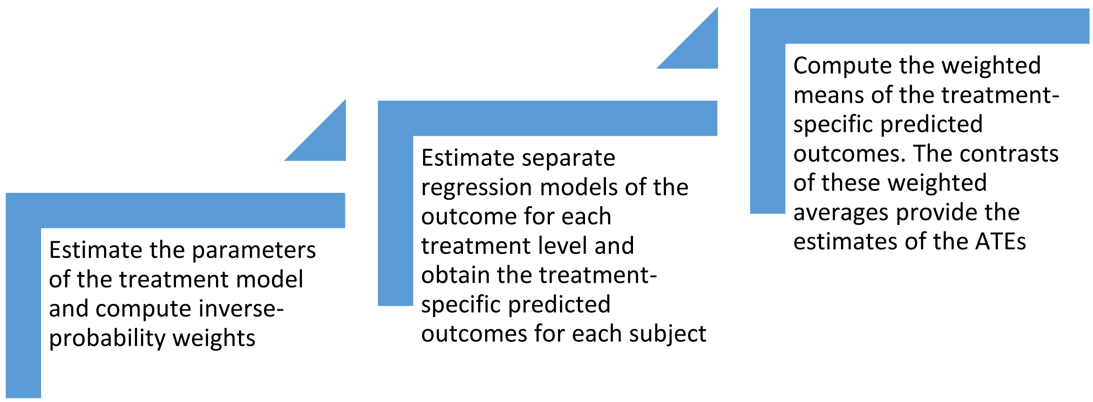
$$\boldsymbol{ATE} = \mathbb{E}[\boldsymbol{Y}(\mathbf{1}) - \boldsymbol{Y}(\mathbf{0})] \qquad \textbf{(1)}$$

$$\boldsymbol{ATE} = \mathbb{E}\big[\mathbb{E}[\boldsymbol{Y}/\boldsymbol{X} = \mathbf{1}, \boldsymbol{Z}] - \mathbb{E}[\boldsymbol{Y}/\boldsymbol{X} = \mathbf{0}, \boldsymbol{Z}]\big] \qquad \textbf{(2)}$$

Equation 1 represents the effect that occurs when the experimental unit receives one treatment instead of another. Equation 2 takes the outer expectation with respect to the distribution of Z, where Z is the set of covariates that influences X and Y's behavior.

For measuring the ATE, the augmented inverse probability weighted (AIPW) estimator is proposed. For applying AIPW, two simple procedures must be done: First, specify a binary regression model for the propensity score, and second, specify a regression model for the outcome variable. AIPW is said to be double robust. It will be consistent for the ATE whether the propensity score model is correctly specified or the outcome regression is correctly specified (Scharfstein et al., 1999). The process depicted in Figure 2, based on the STATA reference manual, is followed when applying AIPW.

Figure 3. Augmented Inverse Probability Weighted process



Source: (StataCorp, 2019)

3.4.1 Treatments

Companies' relationships are classified according to the power asymmetry among them. As explained before, power asymmetry is mainly measured by the difference in resources and capabilities between them. However, there are control variables that might be involved. In that sense, the treatment is specified as the level of asymmetry in a particular relationship.

Power asymmetry has implications in the distribution of created value in a relationship. Thus, it is impossible to expect collaborative relationships to provide balance gains to all participants ending up in the perception of unfairness; moreover, power asymmetry is expected to define the governance mechanisms (Brito & Miguel, 2017).

For determining the different asymmetries that will be used for establishing the treatments, the concept of asymmetry is regarded from the standpoint of interdependence, a relationship that has been studied in (Caniëls & Roeleveld, 2009; Crook & Combs, 2007).

As depicted in the conceptual modeling, three different sources of power are analyzed. The firms' income represents the size of the companies in the dyad. The volume of operations is represented by the number of shipped kilograms for each company in the dyad. Finally, the number of alternatives is characterized by measuring the size of the network for each company.

To calculate the different asymmetries to be considered, the dominance over variables considered is measured. This dominance is measured as the relative difference regarding the maximum amount of a specific variable, as shown in Equation 3. This measure allows the normalization of the different asymmetries, such that a value of 0 for this measure indicates a completely balanced relation. In contrast, a value of 1 represents a complete dominance over the variable of interest.

$$\Delta = \frac{|x_1 - x_2|}{\max\{x_1, x_2\}} \tag{3}$$

Three different asymmetries are considered: income asymmetry, cargo asymmetry, and network asymmetry. In order to build a multivalued treatment, a cluster analysis was performed for each of the asymmetries used as treatments; this allows to define thresholds for each one. Three different clusters were determined through the k-means algorithm. The features of each cluster are defined in Table 2. Figure 4 shows the spatial distribution for the formed clusters. The different treatments for the multivalued treatment are considered as follows:

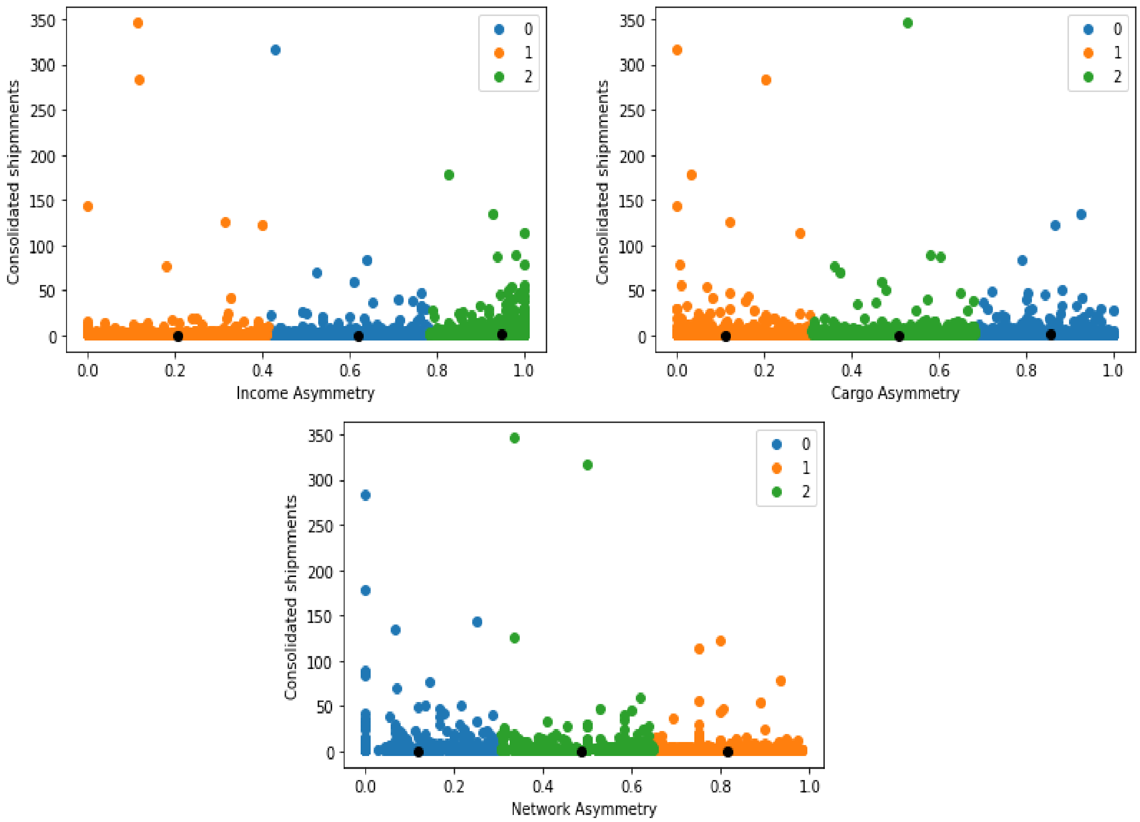
- Value 0 represents a low asymmetric relationship for the considered variable.
- Value 1 represents a medium asymmetric relationship for the considered variable.
- Value 2 represents a high asymmetric relationship for the considered variable.

Table 2. Cluster analysis for different asymmetries.

	CLUSTER 0		CLUSTER 1		CLUSTER 2	
THRESHOLD	MIN	MAX	MIN	MAX	MIN	MAX
INCOME	0	0.411	0.411	0.783	0.783	1

CARGO	0	0.307	0.309	0.683	0.685	1
NETWORK	0	0.296	0.3	0.647	0.65	1

Figure 4. Spatial distribution for cluster analysis.



As this is a multi-valued treatment experiment, any treatment could be the control group to be compared with any of the other groups. However, in this case, we will not have a control group since it represents the absence of a treatment, which is impossible.

3.4.2 Outcome variables

Two different variables are analyzed as the effect measurements for the different treatments. First is the number of consolidated shipments that involves the two companies in a dyad, which shows the frequency with a specific dyad performs a consolidated shipment. This measure is observed for the whole year 2020.

The number of consolidated shipments indicates the success of the collaborative relationships since the more consolidated trips, the stronger this relationship is.

The second outcome variable is the value of the shipment normalized regarding the total cargo. This measure is related to the success of the collaborative relationship since it allows companies to acquire economies of scale.

3.4.3 Pretreatments

The proposed methodology requires that both a treatment and output model be defined. To ensure the selection-on-observables, several pretreatments' variables are selected, and in this way, control the impact of the power asymmetry on the outcome variables.

First, we used the total income for both companies in the dyad since bigger companies tend to build longer-term relationships. In the same way, the total amount of cargo and the network size for the dyad are used as pretreatments. All three variables are normalized, so their values hold between 0 and 1.

Because several treatments are deployed, depending on the model, the asymmetries are used as pretreatment variables. However, when using a specific asymmetry as treatment, this is not used as pretreatment to avoid possible collinearity effects.

Finally, the industry compatibility is included as a pretreatment so that if both firms in a dyad are from the same industry sector, then a binary variable is equal to 1. Otherwise, it becomes 0. This classification is done by using the International Standard Industrial Classification. Here the assumption is that companies belonging to the same sector tend to build more collaborative relationships.

3.4.4 Moderator variables

In order to explain contextual factors, moderator variables are considered. This third variable might influence the relationship between the treatment and the outcome variable. When using one of the asymmetries as treatment, the remaining ones are considered as moderators. Also, the total cargo and the total network explain the relationship between treatments and outcome variables better. Table 3 presents the experimental setting conducted for this research. Three different experiments are proposed using power asymmetries as different treatments.

Table 3. The experimental setting for the research

	Treatments	Pretreatment	Moderators	Outcome
1	Low-income asymmetry Medium-income asymmetry High-income asymmetry	Cargo asymmetry Network asymmetry Total shipped cargo Total collaborative network Industry compatibility	Cargo asymmetry Network asymmetry Total shipped cargo Total collaborative network Industry compatibility	Consolidated shipments Shipments cost per kg
2	Low-cargo asymmetry Medium-cargo asymmetry High-cargo asymmetry	Income asymmetry Network asymmetry Total collaborative network Industry compatibility	Income asymmetry Network asymmetry Total collaborative network Industry compatibility	Consolidated shipments Shipments cost per kg
3	Low-network asymmetry	Cargo asymmetry	Cargo asymmetry	Consolidated shipments

Medium-network asymmetry	Income asymmetry	Income asymmetry	Shipments cost per kg
	Total shipped cargo	Total shipped cargo	
High-network asymmetry	Industry compatibility	Industry compatibility	

4 RESULTS AND ANALYSIS

In this chapter, the proposed methods covered in Chapter 3 are deployed to assess power's effect in long-lasting collaboration relationships. First, a general outlook is given to the treatments and outcomes variables distribution in the sample. Then the different models are formulated, and the average treatment effects are presented. Finally, the results are discussed.

4.1 General outlook

This section presents a general overview of the outcome variable, the frequency of consolidated shipments, and the covariates and treatments used to define the models. Once the data was filtered, as discussed in the methodology chapter, the sample shows 3,276 dyad relationships with 1,945 unique firms.

Using the International Standard Industrial Classification of All Economic Activities (ISIC), it was possible to determine that the largest group of the identified companies correspond to wholesale and retail firms (34.6%), followed by transportation and warehousing firms (8.7%) and mining (8%). Other important sectors are automotive and food manufacturing.

Regarding the variables of interest, both outcome and covariates, Table 3 presents summary statistics. Interestingly, there is significant variability for the outcome variable. For instance, while the mean for the number of consolidated shipments is around 3.33 per observed dyad, the standard deviation is 12.56. On the other hand, the most significant asymmetry is revenue; this might be explained by firms' size, while cargo asymmetry and network asymmetry seem to be more balanced.

Table 4. Summary statistics for variables of interest.

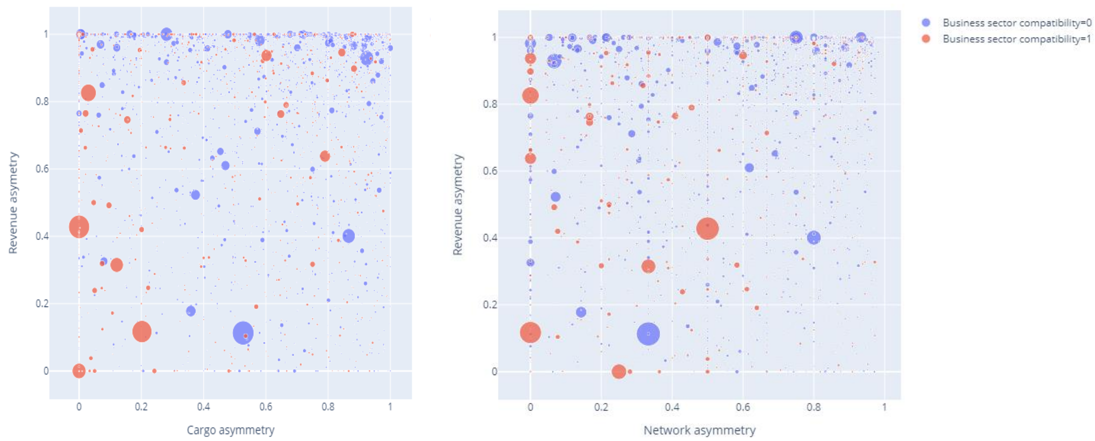
	CONSOLIDATED SHIPMENTS	SHIPMENT VALUE/KG	REVENUE SUM	CARGO SUM	NETWORK SUM	REVENUE ASYMMETRY	CARGO ASYMMETRY	NETWORK SIZE ASYMMETRY
MIN	1	2.55	0	3	2	0	0	0
MAX	346	492930	7.095E+06	55209	91	1	1	0.973
MEAN	3.33	2549.83	1.95E+05	4321.11	19.8	0.763	0.549	0.561
STD	12.56	14924.91	5.44E+04	7517.85	13.7	0.285	0.317	0.288

Figure 5 shows the relationships among the presented variables. Each axis displays one of the measured asymmetries in these charts, while the bubble's size represents the outcome variable. Additionally, if the dyad firms are from the same business sector, the bubble is colored red. Otherwise, they are blue.

From the chart on the left, it can be derived that the cargo asymmetry harms the outcome variable since bigger bubbles are located on the left side of the chart, particularly a cluster formed for high revenue and cargo asymmetry.

On the other hand, from the right-hand chart, it can be observed that most of the dyads are in the low network size asymmetry. However, the number of observations increases as the dyad has a higher revenue asymmetry.

Figure 5. Variables of interest relationships



The following section relates these conclusions employing the average treatment effects methodology. Each asymmetry will be used as the power source (treatment), while the remaining are proposed as covariates and moderators in the proposed models.

4.2 Income asymmetry as the source of power

First, the revenue asymmetry is used as the power source, using the cargo and the network size asymmetries as covariates and the business sector compatibility. Also, the normalized values for the total cargo and network are included. Three different levels are considered for allocating the dyads to treatments, as explained in chapter 3, using clusters. This process is performed for understanding these clusters regarding the asymmetry cluster 0 is assigned for low asymmetry treatment, cluster 1 for medium asymmetry, and cluster 2 for high asymmetry.

Table 5 shows the potential outcome means for both outcome variables. The ATEs among those treatment groups are the comparison results among samples-averaged treatment effects, which are the results under one treatment instead of another. The comparison of the potential outcome means between them.

Dyads with a higher income asymmetry have an expected value of 3.08 consolidated shipments, while dyads with low asymmetry have an expected value of 4.32 consolidated shipments. The average treatment effects as the difference among potential outcomes are adverse while comparing the different levels, meaning that lower-income asymmetry will lead to higher shipment consolidation. This difference is significant at 10% for the ATE of high asymmetry compared to low asymmetry.

Table 5. ATE for income asymmetry as power source

Average Treatment Effects Estimates by income asymmetry

	Outcome 1		**Outcome 2**	
	Consolidated shipments		**Shipment cost per kg**	
Income asymmetry	Potential Mean (%)	s.e	Potential Mean (%)	s. e
1 Low-income asymmetry	4.32	0.92	3089.96	661.42
2 Medium income asymmetries	3.08	0.40	1792.44	369.28
3 High income asymmetries	3.08	0.20	2786.35	393.30
Averages %	Average Treatment Effect	s. e	Average Treatment Effect	s. e
2 vs 1	-28.55%	0.18	-41.99 **	0.17
3 vs 1	-28.55% *	0.18	-9.82%	0.23
3 vs 2	-0.00	0.15	55.44%	0.39

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry and industry compatibility.
s. e: robust standard errors.
*Significant at 10% **Significant at 5% ***Significant at 1%

When analyzing the value for the shipment cost, the potential means for each level are 3,089, 1,792, and 2,786 Colombian pesos per kg, respectively. In this case, an increase in the revenue asymmetry decreases the price per shipment, a difference that is significant at 5%. However, larger revenue asymmetry increases the shipment cost compared to medium asymmetries.

4.2.1 Income asymmetry – moderator effects for consolidated shipments

The results discussed before can be further explored using moderators. For doing this, the average treatment effects methodology is run for two different levels of the moderator variable. The following section describes the moderator effect of the cargo and network asymmetries, industry compatibility, total cargo, and network while using the income asymmetry as treatment.

For the first outcome, the number of consolidated shipments, and considering two levels for the moderator variable, i.e., cargo asymmetry, network asymmetry, cargo compatibility, total cargo, total network. Table 6 shows the effect of cargo asymmetry level in the average treatment effect of the income asymmetry. Thus the impact of the treatment is significant at 10% when comparing low and medium revenue asymmetries for dyads that have high cargo asymmetry. When comparing both groups, low cargo asymmetry dyads end up with more consolidated shipments. This difference is significant at 10% for medium-income asymmetry.

For dyads with low cargo asymmetry, the treatment (income asymmetry) does not significantly affect the number of consolidated shipments; however, a practical difference can be observed. Higher-income asymmetries mean fewer consolidated shipments.

Table 6. ATE for income asymmetry as power source controlling with cargo asymmetry – Outcome: Number of consolidated shipments.

Average Treatment Effects Estimates by Cargo asymmetry

	Outcome 1 Consolidated shipments					
	High Cargo Asymmetry (>=0.5)				Low Cargo Asymmetry (<0.5)	
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean	s.e
1 Low-income asymmetry	4.03		1.34		4.61	1.07
2 Medium income asymmetries	2.46		0.22	*	4.07	0.91
3 High income asymmetries	2.90		0.21		3.34	0.40
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-39%	*	0.21		-12%		0.28

3 vs 1	-28%	0.25	-26%	0.18
3 vs 2	18%	0.14	-18%	0.21

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%

Table 7 shows the moderator effect of the network asymmetry in the average treatment effect when using income asymmetry as treatment. Here the number of consolidated shipments is greater for dyads with low network asymmetry. Significant differences are observed when contrasting both scenarios. Moreover, the average treatment effect is more sensitive when network asymmetry is low. Under this scenario, the difference is significant at 1% when comparing low income and medium asymmetry. The difference between low- and high-income asymmetry is significant at 5% under the same scenario.

Table 7. ATE for income asymmetry as power source controlling with network asymmetry – Outcome: Number of consolidated shipments.

Average Treatment Effects Estimates by Network asymmetry

	Outcome 1 Consolidated shipments					
	High Network Asymmetry (>=0.5)			Low Network Asymmetry (<0.5)		
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low-income asymmetry	2.52		0.49	**	7.43		2.37
2 Medium income asymmetries	2.70		0.52	*	3.90		0.49
3 High income asymmetries	2.40		0.14	***	4.33		0.48
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	7%		0.29		-48%	***	0.18
3 vs 1	-4%	*	0.20		-42%	**	0.20
3 vs 2	-11%	*	0.18		11%		0.19

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

The moderator effect of the industry compatibility can be observed in Table 8. Here more collaborative trips are performed for dyads with industry compatibility; however, these differences are not significant. Dyads with higher income asymmetries reduce the number of consolidated trips. This difference is significant at 5% when comparing low- and high-income asymmetries. Dyads with industry incompatibility do not present significant differences between the different treatments.

Table 8. ATE for income asymmetry as power source controlling with industry compatibility – Outcome: Number of consolidated shipments.

Average Treatment Effects Estimates by Industry Compatibility

	Outcome 1 Consolidated shipments						
	Industry compatibility (=1)				Industry incompatibility (=0)		
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low-income asymmetry	5.78		1.78		3.84		1.03
2 Medium income asymmetries	4.10		1.33		2.71		0.23
3 High income asymmetries	3.20		0.55		3.02		0.19
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-0.29		0.32		-0.29		0.20
3 vs 1	-0.45	**	0.20		-0.21		0.22
3 vs 2	-0.22		0.29		0.12		0.12

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

When controlling the effects with the total cargo moderator, dyads that transport lower volumes and with similar income perform more consolidated shipments than those that move higher volumes. This difference is significant at 1% and remains significant at 5% for dyads with medium income asymmetry. For dyads that ship bigger volumes, the effect of the income asymmetry is the opposite. As the income asymmetry increases, the number of consolidated shipments increases. This difference is significant at 5% comparing dyads whit low-income asymmetry and high-income asymmetry.

Table 9. ATE for income asymmetry as power source controlling with total cargo – Outcome: Number of consolidated shipments.

Average Treatment Effects Estimates by Total Cargo

	Outcome 1 Consolidated shipments						
	Total cargo >= 0.5				Total Cargo < 0.5		
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low-income asymmetry	1.62		0.22	***	4.44		0.95
2 Medium income asymmetries	1.79		0.34	**	3.14		0.42
3 High income asymmetries	3.50		0.79		3.06		0.21
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	0.11		0.27		-0.29		0.18
3 vs 1	1.16	**	0.58	**	-0.31	**	0.16
3 vs 2	0.95	*	0.58		-0.02		0.15

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Finally, the moderator effect of the total network (number of companies which with the dyad collaborates) is presented in Table 10. When companies have a bigger base for collaborating, more consolidated shipments are performed. This difference is significant at 1% for medium and high-income asymmetries. When the number of companies in the collaboration network is more extensive, income asymmetry has a positive impact on the number of consolidated shipments. The opposite occurs when the base for collaboration is narrowed.

Table 10. ATE for income asymmetry as power source controlling with total network – Outcome: Number of consolidated shipments.

Average Treatment Effects Estimates by Total Network

	Outcome 1 Consolidated shipments				
	Total Network (>=0.5)			Total Network (<0.5)	
Income asymmetry	Potential Mean	s.e	Sign	Potential Mean	s.e
1 Low-income asymmetry	4.52	1.87		4.30	0.96
2 Medium income asymmetries	10.43	2.69	***	2.94	0.42
3 High income asymmetries	6.28	1.09	***	2.89	0.19

	Average Treatment Effect	Sign	s. e	Average Treatment Effect	Sign	s. e
2 vs 1	1.30		1.13	-0.32	*	0.18
3 vs 1	0.39		0.63	-0.33	**	0.16
3 vs 2	-0.40	**	0.18	-0.02		0.16

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

4.2.2 Income asymmetry – moderator effects for shipment cost.

Table 11 shows the moderator effect of cargo asymmetry on the shipment cost per kg. Significant differences are found for dyads with high cargo asymmetry. On the other hand, no significant effects are displayed for income asymmetry for dyads with low cargo asymmetry.

Table 11. ATE for income asymmetry as power source controlling with Cargo asymmetry– Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Cargo asymmetry

	Outcome 2 Shipment cost per kg			
	High Cargo Asymmetry (>=0.5)		Low Cargo Asymmetry (<0.5)	
Income asymmetry	Potential Mean	s.e	Potential Mean	s.e
1 Low-income asymmetry	3613.11	933.72	2058.28	642.28
2 Medium income asymmetries	1475.47	252.7	2191.45	840.25

3 High income asymmetries	3182.4		591.39	2283.64		501.09
	Average Treatment Effect	Sign	s. e	Average Treatment Effect	Sign	s. e
2 vs 1	-59%	***	0.13	6%		0.52
3 vs 1	-12%		0.28	11%		0.42
3 vs 2	116%	**	0.54	4%		0.46

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Similar to what was described when using the network asymmetry as the moderator, dyads with lower network asymmetry result in lower shipment costs per kg when the income asymmetry is low. This difference is significant at 1%. When comparing the difference among treatments, the outcome variable shows significant differences for both scenarios. These can be observed in Table 12.

Table 12. ATE for income asymmetry as power source controlling with Network asymmetry– Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Network asymmetry

	Outcome 2 Shipment cost per kg						
	High Network Asymmetry (>=0.5)				Low Network Asymmetry (<0.5)		
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low-income asymmetry	4183		1032.63	***	1124.78		204.55
2 Medium income asymmetries	1652.45		456.37		1989.88		538.30
3 High income asymmetries	2733.95		499.91		2792.53		572.64
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-60%	***	0.15	**	77%		0.58
3 vs 1	-35%	*	0.20	**	148%	**	0.68
3 vs 2	65%		0.55		40%		0.48

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.

*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Next, the treatment effects are controlled using the total cargo moderator effect. Here dyads are compared according to the volume of their shipments. Dyads that transport bigger volumes have a cheaper cost per transported kg. This difference is significant at 1% for the different treatments. Collaboration effects are present in scale economies. These results can be observed in Table 13

Table 13. ATE for income asymmetry as power source controlling with Total Cargo - Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Total Cargo

	Outcome 2 Shipment cost per kg						
	Total Cargo >= 0.5				Total Cargo < 0.5		
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low-income asymmetry	139.04		5.03	***	3324.24		709.17
2 Medium income asymmetries	156.69		5.22	***	1892.43		393.64
3 High-income asymmetries	142.10		3.74	***	2879.97		404.35
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	0.13	**	0.05	***	-43%	**	0.17
3 vs 1	0.02		0.05		-13%		0.22
3 vs 2	-0.09	**	0.04		52%		0.38

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Finally, when using the total network as a moderator variable to explain better the effect of the income asymmetry, it is observed that companies with a more extensive base of collaborating companies incur lower transportation costs. This difference is significant at 1% for both low- and high-income asymmetry. There is no significant effect of the income asymmetry in the shipment cost for dyads with bigger collaborative networks. Otherwise, for dyads with a reduced network, the average treatment effect between low- and medium-income asymmetry is significant at 5%. Previous results can be observed in Table 14.

Table 14. TE for income asymmetry as power source controlling with Total Network- Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Total Network

	Outcome 2 Shipment cost per kg						
	Total Network (>=0.5)				Total Network (<0.5)		
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low-income asymmetry	951.69		346.59	***	3214.00		699.61
2 Medium income asymmetries	1190.95		441.47		1818.07		384.04
3 High income asymmetries	1275.72		297.39	***	2838.26		403.64
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	25%		0.65		-43%	**	0.17
3 vs 1	34%		0.57		-12%		0.23
3 vs 2	7%		0.46		56%		0.40

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

4.3 Cargo asymmetry as the source of power

Average treatment effect methodology is deployed for cargo asymmetry as the treatment. Similarly to what was done with the income asymmetry, three different treatments are selected, i.e., low, medium, and high

Table 15. presents the average treatment effect for both outcomes: number of consolidated shipments and shipment cost per kg. Significant differences at 10% are observed for the number of consolidated shipments for low and medium cargo asymmetry and at 5% for low and high cargo asymmetry.

Shipment cost per kg significant differences at 10% are identified for low and medium cargo asymmetry dyads, and at 5% for low and high cargo asymmetries. Cargo asymmetry increases the value of the shipment.

Table 15. ATE for cargo asymmetry as the power source

Average Treatment Effects Estimates.

	Outcome 1		**Outcome 2**	
	Consolidated shipments		**Shipment cost per kg**	
Cargo asymmetry	Potential Mean (%)	s.e	Potential Mean (%)	s. e
1 Low cargo asymmetry	4.26	0.56	1924.34	335.67
2 Medium cargo asymmetries	3.25	0.37	3410.53	671.79
3 High cargo asymmetries	2.69	0.18	2204.47	256.77
Averages %	Average Treatment Effect	s. e	Average Treatment Effect	s. e
2 vs 1	-0.236 *	0.13	0.772 *	0.46
3 vs 1	-0.368 ***	0.09	0.145	0.24
3 vs 2	-0.173	0.11	-0.353	0.15

AIPW estimators controlling for cargo asymmetries' difference in total income, total network, income asymmetry, network asymmetry, and industry compatibility.
s. e: robust standard errors.
*Significant at 10% **Significant at 5% ***Significant at 1%

4.3.1 Cargo asymmetry – moderator effects for consolidated shipments

Table 16 shows the average treatment effect for cargo asymmetry when using income as a moderator variable. Two levels for income asymmetry are used. The number of consolidated shipments is bigger under the scenario of low-income asymmetry. However, no significant difference among the groups is observed. Significant differences are kept for the average treatment effect comparing low and high cargo asymmetry regardless of the income asymmetry.

Table 16. ATE for cargo asymmetry as power source controlling with Income asymmetry– Outcome: Consolidated shipments

Average Treatment Effects Estimates by Income asymmetry

	Outcome 1 Consolidated shipments

Cargo asymmetry	High Income Asymmetry (>=0.5)				Low Income Asymmetry (<0.5)		
	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low cargo asymmetry	3.45		0.37		6.05		1.72
2 Medium cargo asymmetries	2.98		0.22		4.30		1.62
3 High cargo asymmetries	2.71		0.19		2.57		0.47
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-14%		0.11		-29%		0.33
3 vs 1	-21%	**	0.10	**	-58%	**	0.14
3 vs 2	-9%		0.09		-40%		0.25

AIPW estimators controlling for cargo asymmetries' difference in total income, total network, income asymmetry, network asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

The network asymmetry plays a moderator effect in the number of consolidated shipments. Dyads with lower network asymmetry performed more collaborative trips. However, as the cargo asymmetry increases, the number of consolidated shipments decreases for both network asymmetry scenarios. These differences are significant at 1% for the high and medium cargo asymmetry scenario. Cargo asymmetry harms the number of consolidated shipments. These differences are statistically significant at 1% for the high network asymmetry scenario. There is a statistically significant difference for the low network asymmetry for the comparison between low and high cargo asymmetry at 5%. These results can be observed in Table 17.

Table 17. ATE for cargo asymmetry as power source controlling with Network asymmetry– Outcome: Consolidated shipments

Average Treatment Effects Estimates by Network asymmetry

	Outcome 1 Consolidated shipments				
	High Network Asymmetry (>=0.5)			Low Network Asymmetry (<0.5)	
Cargo Asymmetry	Potential Mean	s.e	Sign	Potential Mean	s.e
1 Low cargo asymmetry	3.44	0.57	*	5.60	1.07
2 Medium cargo asymmetries	2.25	0.13	***	5.19	1.01

3 High cargo asymmetries	2.11		0.17	***	3.79		0.41
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-35%	***	0.12		-7%		0.25
3 vs 1	-39%	***	0.11		-32%	**	0.15
3 vs 2	-6%		0.09		-27%	*	0.16

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Table 18 shows the moderator effect of industry compatibility. First, for dyads with low cargo asymmetry, more consolidated shipments are performed when companies are compatible than when they are not. No significant difference can be observed for other treatments. As in many of the cases presented before, fewer consolidated shipments are performed as the cargo asymmetry increases. Particularly these differences are significant at 1% for the scenario of industry compatibility.

Table 18. ATE for cargo asymmetry as power source controlling with industry compatibility– Outcome: Consolidated shipments

Average Treatment Effects Estimates by Industry Compatibility

	Outcome 1 Consolidated shipments						
	Industry compatibility (=1)				Industry incompatibility (=0)		
Cargo Asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low cargo asymmetry	6.39		1.56	**	3.20		0.32
2 Medium cargo asymmetries	3.11		0.54		3.37		0.48
3 High cargo asymmetries	2.52		0.34		2.76		0.22
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-0.51	***	0.14	**	0.05		0.18
3 vs 1	-0.60	***	0.11	***	-0.14		0.11
3 vs 2	-0.19		0.17		-0.18		0.13

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Table 19 shows the results for the average treatment effect when using the total network as a moderator variable. A higher number of consolidated shipments are performed for dyads that have a broader base of collaborative firms. This difference is statistically significant for medium and high cargo asymmetries. The effect of cargo asymmetry is significant regardless of the total network of the dyad; however, this effect is more pronounced for dyads with a broader collaborative base.

Table 19. ATE for cargo asymmetry as power source controlling with total network – Outcome: Consolidated shipments

Average Treatment Effects Estimates by Total Network

	Outcome 1 Consolidated shipments						
	Total Network (>=0.5)				Total Network (<0.5)		
Cargo Asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low cargo asymmetry	5.02		0.94		4.17		0.59
2 Medium cargo asymmetries	10.26		2.17	***	2.91		0.36
3 High cargo asymmetries	4.07		0.86	*	2.60		0.19
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	104%	*	0.60	**	-30%	**	0.13
3 vs 1	-19%		0.23		-38%	***	0.10
3 vs 2	-60%	***	0.12	***	-11%		0.13

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

4.3.2 Cargo asymmetry – moderator effects for shipment cost

For cargo asymmetry, two moderator effects are presented, the effect of the industry compatibility and the effect of the total network. The remaining effects do not have any statistical significance. Moderator effects for the income and the network asymmetries can be reviewed in Appendix A.

First, regarding the moderator effect of the industry compatibility, no significant differences are observed between the two groups for the different treatments. However, the cargo asymmetry presents an effect on the outcome variable. For dyads with industry incompatibility, as the asymmetry increase, so does the shipment cost. However, these differences are not significant.

Dyads with industry compatibility present a different effect. First, there is a considerable increase (77%) when comparing low cargo asymmetry with medium cargo asymmetry. However, this difference is not significant because of the high variance found in the second treatment. High cargo asymmetry dyads show to have a cheaper shipment cost. This effect is significant at 5% compared to low cargo asymmetry dyads and significant at 1% versus medium cargo asymmetry dyads.

The effects are opposite for the different groups. At the same time, in the industry compatibility, the high cargo asymmetry reduces the shipment cost in the dyads with industry incompatibility the shipment cost increases. These results are shown in Table 20.

Table 20. ATE for cargo asymmetry as power source controlling with industry compatibility– Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Industry Compatibility

	Outcome 2 Shipment cost per kg				
	Industry compatibility (=1)			Industry incompatibility (=0)	
Cargo Asymmetry	Potential Mean	s.e	Sign	Potential Mean	s.e
1 Low cargo asymmetry	2857.72	792.21		1605.96	359.87
2 Medium cargo asymmetries	5039.75	1941.52		2776.87	571.89
3 High cargo asymmetries	1631.82	334.86	*	2417.36	328.08

	Average Treatment Effect	Sign	s. e	Average Treatment Effect	Sign	s. e
2 vs 1	77%		0.84	73%		0.52

3 vs 1	-43%	**	0.20	**	51%	0.39
3 vs 2	-68%	***	0.14	**	-13%	0.21

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

An interesting effect is observed for the total network as a moderator variable. Here when comparing both groups, the shipment cost is cheaper for companies with a higher total network, i.e., a broader collaborative network. These differences are significant at 1% for low and medium cargo asymmetry dyads and 5% for high cargo asymmetry dyads. On the other hand, increasing the cargo asymmetry increases the value for the shipment cost per kg. However, these increases are not statistically significant, except for the comparison between medium and high asymmetry for dyads with a narrowed collaborative network. Table 21 shows these results.

Table 21. ATE for cargo asymmetry as power source controlling with total network– Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Total Network

	Outcome 2 Shipment cost per kg					
	Total Network (>=0.5)				Total Network (<0.5)	
Cargo Asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low cargo asymmetry	748.86		114.59	***	1969.80		349.11
2 Medium cargo asymmetries	1328.07		419.75	***	3506.42		701.92
3 High cargo asymmetries	1242.34		308.05	**	2245.19		268.43
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	77%		0.62		78%		0.47
3 vs 1	66%		0.48		14%		0.24
3 vs 2	-6%		0.37		-36%	**	0.15

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.

*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

4.4 Network size asymmetry as the source of power

Finally, using network size asymmetry as the source power shows that the number of consolidated shipments decreases as the network asymmetry increases. Both differences regarding the low asymmetry are significant at 1%.

Table 22 shows the results. There is no clear trend regarding the shipment cost per kg since effects are opposite depending on medium and high asymmetries. For dyads with medium network asymmetry, this value increases. However, for dyads with higher network asymmetry, this value decreases. This last difference ends up being statistically significant at 5% when compared to medium network asymmetry dyads.

Table 22. ATE for network size asymmetry as the power source

Average Treatment Effects Estimates

	Outcome 1		**Outcome 2**	
	Consolidated shipments		**Shipment cost per kg**	
Network asymmetry	Potential Mean (%)	s.e	Potential Mean (%)	s. e
1 Low network asymmetry	5.40	0.62	2619.80	594.71
2 Medium network asymmetries	2.95	0.39	3003.96	503.96
3 High network asymmetries	2.55	0.16	2028.35	263.54
Averages %	Average Treatment Effect	s. e	Average Treatment Effect	s. e
2 vs 1	-45.32% ***	0.10	14.66%	0.32
3 vs 1	-52.7% ***	0.06	-22.57%	0.32
3 vs 2	-13.53%	0.12	-32.47% **	0.14

AIPW estimators controlling for network asymmetries' differences in total cargo, total income, cargo asymmetry, income asymmetry, and industry compatibility.
s. e: robust standard errors.
*Significant at 10%   **Significant at 5%   ***Significant at 1%

4.4.1 Network asymmetry – moderator effects for consolidated shipments

The moderator effect of income asymmetry is displayed in Table 23. A higher number of consolidated shipments occur for dyads with low-income asymmetry; however, this is statistically significant for medium network asymmetry dyads at 10%. The average treatment effects for the different network asymmetries are significant for both scenarios of income asymmetry. As the network asymmetry increases, the number of consolidated shipments decreases.

Table 23. ATE for network asymmetry as power source controlling with income asymmetry– Outcome: Consolidated shipments

Average Treatment Effects Estimates by Income asymmetry

	Outcome 1 Consolidated shipments						
	High Income Asymmetry (>=0.5)				Low Income Asymmetry (<0.5)		
Network asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low network asymmetry	5.13		0.59		5.65		1.48
2 Medium network asymmetries	2.37		0.153	*	5.27		1.83
3 High network asymmetries	2.55		0.161		2.59		0.51
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-54%	***	0.06		-7%	*	0.40
3 vs 1	-50%	***	0.07		-54%	***	0.15
3 vs 2	7.4%		0.09	***	-51%	***	0.20

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Moderator effect of cargo asymmetry is similar to the effect of income asymmetry. Again, low cargo asymmetry allows more consolidated shipments to occur. However, increasing the network asymmetry among dyads tends to decrease the output. The average treatment effects are significant when compared to the low network asymmetry, as shown in Table 24

Table 24. ATE for network asymmetry as power source controlling with cargo asymmetry– Outcome: Consolidated shipments

Average Treatment Effects Estimates by Cargo asymmetry

	Outcome 1 Consolidated shipments						
	High Cargo Asymmetry (>=0.5)				Low Cargo Asymmetry (<0.5)		
Network asymmetry	Potential Mean		s.e		Potential Mean		s.e
1 Low network asymmetry	5.07		0.68		5.67		1.05
2 Medium network asymmetries	2.57		0.43		3.46		0.67
3 High network asymmetries	2.24		0.18	**	3.00		0.29
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-49%	***	0.11		-39%	**	0.16
3 vs 1	-56%	***	0.07		-47%	***	0.11
3 vs 2	-13%		0.16		-13%		0.19

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Similar effects can be observed when using industry compatibility as a moderator. Again, dyads with lower network asymmetries performed more collaborative trips. However, more trips are conducted when companies in the dyad are compatible with low and medium network asymmetries.

For compatible dyads, the average treatment effects are significant at 1% when comparing low and high network asymmetries and comparing medium and high network asymmetries. The higher the network asymmetry fewer collaborative trips are performed.

For dyads with industry incompatibility, the average treatment effects are significant at 1%, comparing low and medium and low and high network symmetry. Statistical significance of the effect of the network asymmetry for dyads with industry compatibility is found at 10, 5, and 1%, respectively, can be observed in Table 25

Table 25. ATE for network asymmetry as power source controlling with industry compatibility– Outcome: Consolidated shipments

Average Treatment Effects Estimates by Industry Compatibility

	Outcome 1 Consolidated shipments						
	Industry compatibility (=1)				Industry incompatibility (=0)		
Network asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low network asymmetry	5.76		1.12		4.86		0.57
2 Medium network asymmetries	3.49		0.96		2.78		0.38
3 High network asymmetries	2.35		0.23		2.61		0.20
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-39%	**	0.20		-43%	***	0.10
3 vs 1	-59%	***	0.08		-46%	***	0.08
3 vs 2	-33%	*	0.19		-0.06%		0.15

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Finally, the network asymmetry is controlled by the total cargo transported by the dyad. For dyads with a low network asymmetry, i.e., their collaborative networks are similar in size, the shipped volume moderates over the outcome consolidated shipments. Dyads with lower shipped volume perform a greater number of collaborative trips; this difference is statistically significant at 1%. As the network asymmetry increases, there is no significant difference between both groups. However, the effect of the network asymmetry is significant only for those dyads that have a lower shipped volume. These differences are significant at 1%. Table 26 present these results.

Table 26. ATE for network asymmetry as power source controlling with total cargo – Outcome: Consolidated shipments

Average Treatment Effects Estimates by Total Cargo

	Outcome 1 Consolidated shipments					
	Total cargo >= 0.5			Total cargo < 0.5		
Network asymmetry	Potential Mean	s.e	Sign	Potential Mean		s.e
1 Low network asymmetry	3.09	0.48	***	5.50		0.65
2 Medium network asymmetries	2.39	0.53		2.98		0.41
3 High network asymmetries	2.93	0.87		2.52		0.16
	Average Treatment Effect	Sign	s. e	Average Treatment Effect	Sign	s. e
2 vs 1	-0.23		0.21	-0.46	***	0.09
3 vs 1	-0.05		0.32	-0.54	***	0.06
3 vs 2	0.23		0.45	-0.15		0.13

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

4.4.2 Network asymmetry – moderator effects for shipment cost

Using network asymmetry as treatment and using the different moderator variables do not show any significant results except for the income asymmetry. Two opposite effects can be observed for dyads with high- and low-income asymmetry. For the first ones, the value of the shipment cost is reduced as the network asymmetry is increased. Conversely, for dyads with low-income asymmetry, the shipment cost increases while the network asymmetry increases. Mainly the effect is significant for those dyads that have a low-income asymmetry. The previous insights can be observed in Table 27. The remaining moderator effects that do not present any significant results are shown in Appendix A.

Table 27. ATE for network asymmetry as power source controlling with income asymmetry – Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Income asymmetry

	Outcome 2 Shipment cost per kg						
	High Income Asymmetry (>=0.5)				Low Income Asymmetry (<0.5)		
Network asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low network asymmetry	3082.55		731.25	***	845.54		163.87
2 Medium network asymmetries	2745.64		556.81		3967.23		1062.52
3 High network asymmetries	1957.63		291.67		2169.38		506.26
	Average Treatment Effect	Sign	s. e		Average Treatment Effect	Sign	s. e
2 vs 1	-30%		0.20	**	369%	**	1.54
3 vs 1	-11%		0.29	**	157%	**	0.77
3 vs 2	27%		0.35	*	-45%	**	0.19

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s. e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

For all of the previous models, it can be shown that power, regardless of its source, negatively affects collaboration. For the three models described before, as power asymmetry increases, the outcome for collaboration decreases for the number of consolidated shipments, while it increases the shipment cost per kg. For all three proved power sources, the average treatment effect regarding the consolidated shipments shows to be significant. The shipment cost per kg showed only significant differences when using the income asymmetry as the treatment.

Table 28 and Table 29 show a summary of the causal effect for the different asymmetries when using total cargo and total network as moderator variables, respectively.

Table 28. Causal effect of asymmetries using Total Cargo as moderator variable (High-Low)

	Outcome 1: Consolidated Shipments					
High vs Low	Individual effect	Sig	M. Total Cargo High	Sig	M. Total Cargo Low	Sig
Income asymmetry	-36.80%	***	116%	**	-31%	**
Cargo asymmetry	-28.50%	*	-		-	
Network asymmetry	-52.70%	***	-5%		-54%	***
	Outcome 2: Shipment cost per kg					
High vs Low	Individual effect	Sig	M. Total Cargo High	Sig	M. Total Cargo Low	Sig
Income asymmetry	24.00%		2%		-13%	
Cargo asymmetry	-9.82%	*	-		-	
Network asymmetry	-22.57%		2%		-22%	

AIPW estimators controlling for asymmetries' difference in total cargo
*Significant at 10% **Significant at 5% ***Significant at 1%

Table 29. Causal effect of asymmetries using Total network as moderator variable (High-Low)

	Outcome 1: Consolidated Shipments					
High vs Low	Individual effect	Sig	M. Total Network High	Sig	M. Total Network Low	Sig
Income asymmetry	-36.80%	***	39%	**	-33%	**
Cargo asymmetry	-28.50%	*	-19%		-38%	***
Network asymmetry	-52.70%	***	-		-	
	Outcome 2: Shipment cost per kg					
High vs Low	Individual effect	Sig	M. Total Network High	Sig	M. Total Network Low	Sig
Income asymmetry	24.00%		34%		-12%	
Cargo asymmetry	-9.82%	*	66%		14%	
Network asymmetry	-22.57%		-		-	

AIPW estimators controlling for asymmetries' difference in total network
*Significant at 10% **Significant at 5% ***Significant at 1%

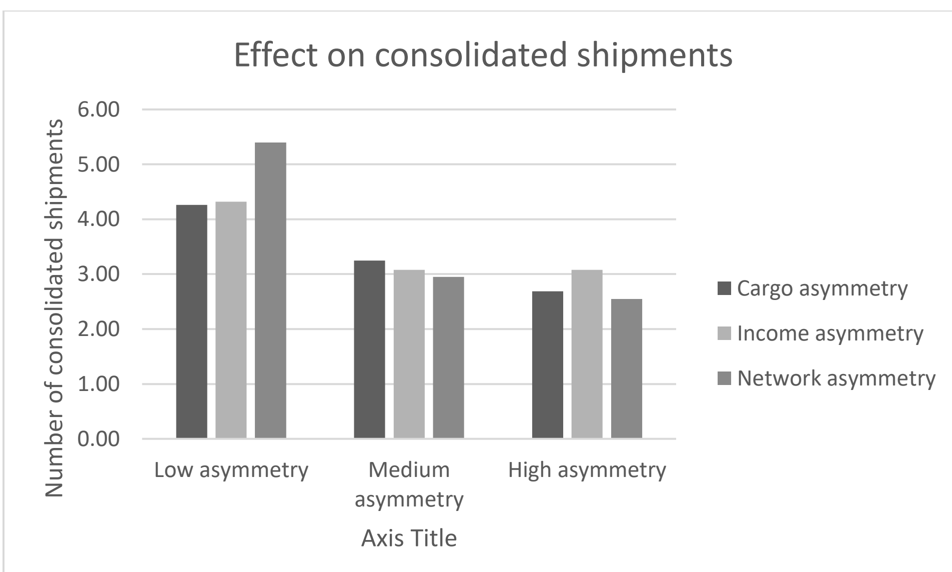
5 DISCUSSION

In this section, the results presented in Chapter 4 are further discussed, introducing practical implications for collaborative relationships and how to make them successful. This discussion is made or each of the three models presented according to the source of power income, cargo, and network asymmetry.

5.1 Income asymmetry as the source of power

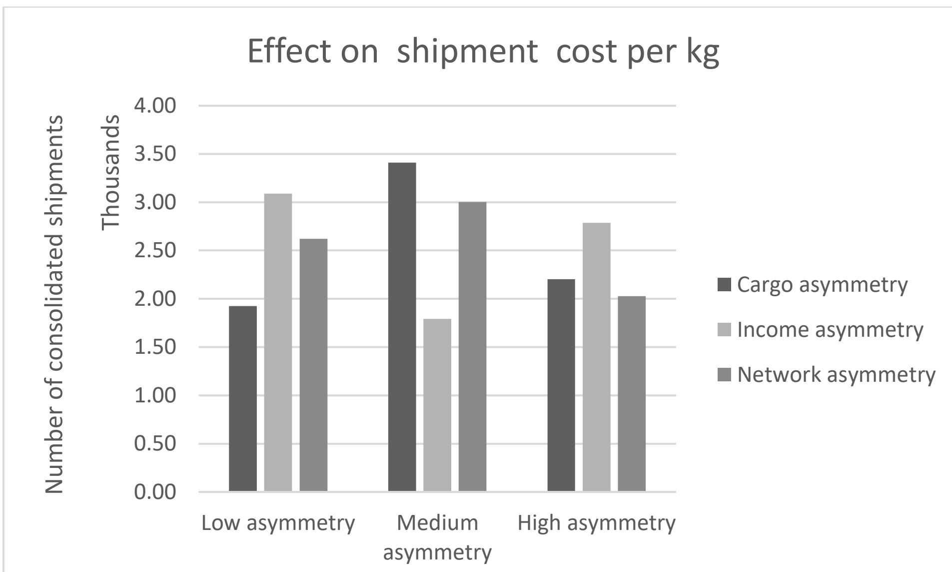
When having the income asymmetry as the source of power, i.e., treatment, an adverse effect is observed regarding outcome 1; the number of consolidated shipments. A statistical significance is shown when comparing low versus high-income asymmetry. Figure 6 presents the potential outcome means for the different asymmetries in each level for the number of consolidated shipments.

Figure 6. Potential outcome means for different asymmetries – consolidated shipments.



A positive effect (decreased shipment cost) is found for outcome 2: shipment cost per kg. A significant difference exists between low- and medium-income asymmetries. Figure 7 shows the potential outcome mean for the shipment cost for the different asymmetries in each level. When talking about income asymmetry, we should consider low-income asymmetry as the companies in the dyad have a similar volume of sales. In contrast, a high-income asymmetry means that one company has way more sales than the other.

Figure 7. Potential outcome means for different asymmetries – shipment cost per kg.



Taking this into account, when companies in the dyad have a significant difference regarding their sales, the number of consolidated shipments is reduced. This result suggests that companies that are similar in size are more willing to collaborate between them. On the other hand, when looking at outcome two, companies similar in size (low-income asymmetry) incur higher shipping costs. This cost is reduced when the companies participating in the collaborative dyad have a medium asymmetry. Although this difference is significant, there is not an apparent reason why this is happening.

The cargo asymmetry as moderator variable shows that dyads in which each of the companies provide the same amount of cargo (low cargo asymmetry) perform a more significant number of consolidated shipments. Practical differences regarding dyads with high cargo asymmetry suggest this result. However, this is only significant at 10% when comparing low versus medium-income asymmetry. When companies have a similar share in the transported cargo, more consolidated shipments are performed regardless of their income asymmetry.

The moderator effect of network asymmetry behaves similarly to cargo asymmetry. Hence, companies with a lower network asymmetry, regardless of the differences in income, perform a greater number of consolidated shipments. This result is significant for all the different income asymmetries. However, the effect reduces when the income asymmetry increases. Even with a similar collaborative network, companies with a bigger difference in their sales volume are more challenging to collaborate with. Hence, a smaller number of consolidated shipments are performed.

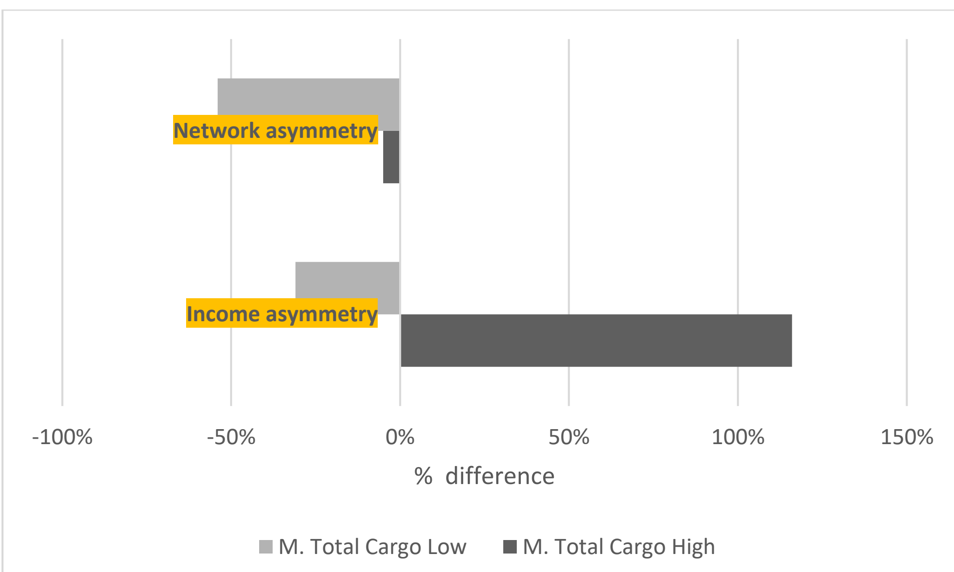
Dyads belonging to the same industry sector perform a significant number of consolidated shipments. However, this difference did not result statistically significant. Practical differences can be observed for all the different income asymmetry treatments. Companies belonging to the same sector seem more willing to collaborate; however, as the income asymmetry increases, the number of consolidated shipments is reduced. Dyads with companies similar in size that belong to the same industry sector perform more collaborative trips than those dyads where a company is much more significant.

The moderator effect of the amount of shipped cargo shows that dyads that transport lower volumes tend to perform more consolidated shipments. Particularly, these differences are statistically significant for dyads with low- and medium-income asymmetry. Dyads with low volume shipments with similar sales end up collaborating more than those with high-income asymmetry. This difference means that companies identical in size have more consolidated shipments for low volume cargo, suggesting that companies that do not move a lot of cargo will look for other companies of the same characteristics (size) to achieve a competitive advantage.

On the other hand, shipments with high cargo volume are more likely to be collaboratively performed when the dyad has a high-income asymmetry. In this scenario, the small company can use the non-used capacity of the bigger one, improving the utilization factor.

Figure 8 shows the effect that asymmetry plays on the outcome number of consolidated shipments comparing low and high asymmetries as the percentual difference using total cargo as the moderator. A considerable difference is observed for income asymmetry. Consolidated shipments for high-income asymmetry dyads are more than two times compared to low-income asymmetry dyads.

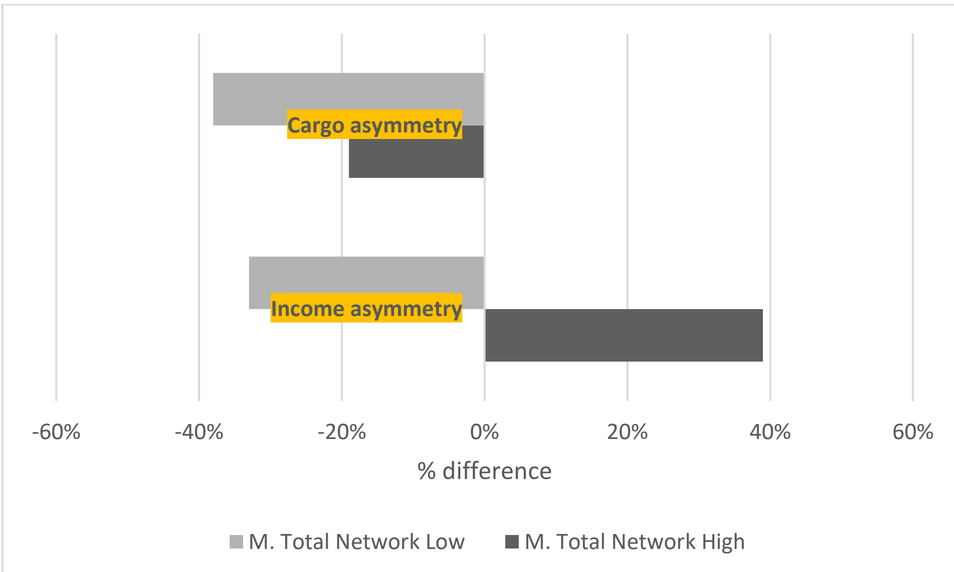
Figure 8. Total cargo effect on the number of consolidated shipments (High - Low) – Total cargo as moderator.



Regarding the total network, i.e., the number of companies linked to the dyad. Dyads with a broader base of collaborative firms perform a greater number of consolidated shipments. This result is statistically significant for both medium and high-income asymmetry. Since companies belonging to a collaborative environment will continue to collaborate regardless of the income asymmetry. However, it will be limited by the number of resources that the dyad can share

Figure 9 shows the positive effect, almost 39% more shipments are performed in the high asymmetry scenario when the total network is high.

Figure 9. Total cargo effect on the number of consolidated shipments (High - Low) – Total network as moderator.



5.2 Cargo asymmetry as the source of power

For the second model, cargo asymmetry was used as the source of power. The effect of the cargo asymmetry on the number of consolidated shipments is negative, as it reduces the shipments as cargo asymmetry increases. These differences in the potential outcomes are significant.

Companies that move a similar amount of cargo are more willing to collaborate. This might be explained because the transportation costs can be equally distributed between the two parties. As the cargo asymmetry increases, i.e., one firm provides more cargo than another, the number of consolidated shipments reduces. Similarly, this might be explained by the fact that the company that provides the most freight in the dyad occupies most of the truck, leaving little space available for other companies to take advantage of the trip, as they will have to break the cargo into different shipments.

On the other hand, cargo asymmetry also has a negative impact on the shipment cost per kg. However, these increases in the shipment cost end up not being statistically significant. Practical differences are observed. As the cargo asymmetry increases in the dyad, sharing costs in an equal manner is reduced.

The moderator effect of the income asymmetry over the cargo asymmetry treatments reflects in a practical view that as the income asymmetry remains low, more consolidated shipments are performed. However, these differences do not hold in a statistical point of view. A similar conclusion was drawn when using the income asymmetry as treatment and controlling with the cargo asymmetry. Regardless of the income asymmetry, the effect of the cargo asymmetry on outcome 1 is a negative one reducing the amount of consolidated shipment as the cargo asymmetry increases.

Network asymmetry provides a moderator effect when using cargo asymmetry as treatment. Dyads with low network asymmetry performed a significant number of consolidated shipments. This behavior holds for all cargo asymmetries. This result is statistically significant. As dyads have a more similar size for their collaborative network, they can perform more consolidated shipments companies belonging to similar ecosystems have more opportunities for collaboration. Nonetheless, the effect of the cargo asymmetry is identical for both scenarios. As the cargo asymmetry increases, the number of consolidated shipments is reduced.

Similar to what was discussed before the industry compatibility is has a moderator effect in enabling collaboration. When comparing dyads with industry incompatibility and those with compatibility, these last perform more consolidated shipments, particularly for dyads with low cargo asymmetry. So, companies that move similar cargo volumes will collaborate more if they belong to the same industry. For higher cargo asymmetries, this conclusion does not holds, as not significant difference exists. Although the cargo asymmetry effect is negative for the number of consolidated shipments, this effect is only statistically significant for dyads with industry compatibility.

The last moderator effect is the total network, dyads with bigger collaborative networks performed a greater number of consolidated shipments for all the different cargo asymmetries. While the effect of cargo asymmetry is more evident in dyads with a more narrowed collaborative network, it reduces the number of consolidated shipments. The effect for dyads with a broader collaborative network is not clear as it first increases and then decreases, so there is no coherent pattern.

For outcome number two: shipment cost per kg, only two moderator effects showed significant effects. These are the industry compatibility and the total network. Regarding the industry compatibility, the cargo asymmetry has a significant effect on the outcome, so dyads with higher cargo asymmetry are reduced. An opposite effect occurs for dyads with industry incompatibility; however, these effects are not significant.

5.3 Network asymmetry as the source of power

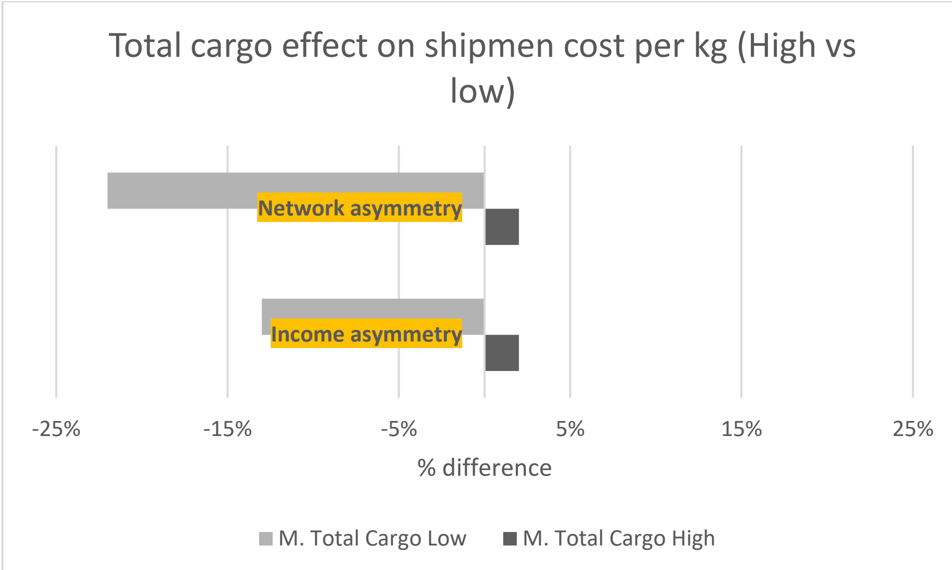
Like the previous models, the network asymmetry has a significant effect on the number of consolidated shipments. When this asymmetry increases, the number of consolidated shipments decrease. For companies that have similar collaborative network sizes, the collaboration is more considerable. Conversely, when two companies in a dyad have a different size for their collaborative networks, then they are less likely to collaborate. Regarding the second outcome, the shipment cost per kg, there are no significant effects.

The cargo asymmetry as a moderator effect does not affect the number of consolidated shipments, except for the scenario where the firms in the dyad have a high network asymmetry. In this particular scenario, dyads with lower cargo asymmetry perform a more significant number of consolidated shipments. Nevertheless, the effect of the treatment: network asymmetry, is consistent for both groups. As the asymmetry increases, the number of consolidated shipments is reduced. A similar effect is observed for the compatibility. No significant effects are observed when comparing dyads with industry incompatibility versus those with industry compatibility. However, the treatment effect is the same as it has been explained before. While the network asymmetry increases, the number of consolidated shipments is decreased.

Regarding the shipment cost per kg output, a single moderator effect showed to have significant results. The Income asymmetry presents opposite effects on this output. First, for dyads that have a high-income asymmetry, the shipment cost is reduced. This effect can be observed in Figure 10, comparing low and high network asymmetry shows a 22% reduction in average for the shipment cost.

This last occurs because firms with a considerable difference in their sales volume achieve reduced shipment costs as network asymmetry increases. However, this effect is not statistically significant.

Figure 10. Total cargo effect on the shipment cost (High - Low) – Total cargo as moderator.



Conversely, for dyads with a low-income asymmetry, i.e., firms with similar sales volumes, the shipment cost increases as network asymmetry increases. This result is statistically significant at 5%. Companies with collaborative networks similar in size and similar in income (sales volume) achieve a reduced shipment cost. One possible explanation for this is that companies more alike in size will collaborate more with a closed circle of partners. Collaboration is more established in the dyad because of partnership development. Also, a greater number of consolidated shipments may be performed, achieving economies of scale. This is not possible when the network asymmetry is high.

For the different developed models' significant effects could be observed regarding outcome 1 number of consolidated shipments. Especially as the asymmetries are low, more collaborative effort is evident. However, the model that provides major insights is model one using income asymmetry as the treatment. Outcome number two is more controversial as no pattern is clear regarding the effect of the several asymmetries. Here is essential to consider that this information is entered manually in the system, so a quality data problem may arise here that does not allow us to make conclusions on the treatment's effects.

6 CONCLUSIONS

Power has been explored in literature as an essential element in defining collaborative relationships. Two different points of view exist regarding power. First, power can be seen as a source of opportunistic behaviors that threaten collaborative relationships. Conversely, some authors see power as an enabling factor since it allows coordination through the supply chain, improving performance.

Two different kinds of power are identified: mediated and non-mediated. While mediated power is exercised intentionally for their advantage, non-mediated power arises from the nature of the relationship. Non-mediated power has been proved to have a positive impact in shaping collaborative relationships. However, this has been observed for vertical integrations. This study is a first approximation of the effect of power in supply chain horizontal collaboration.

This research showed how different non-mediated power sources impact collaboration among dyads by observing two outcome variables: the number of consolidated shipments and shipment cost per kg. The power sources are explained from three different power asymmetries: income, cargo, and network asymmetry.

Results show that higher power asymmetries reduce the number of consolidated shipments. However, no conclusive effect can be observed on the second outcome. When using the income asymmetry as a treatment, the shipment cost per kg is reduced as asymmetry increases. A similar effect is observed with network asymmetry as the treatment. Cargo asymmetry's effect on the shipment cost per kg is an increased cost.

From the previous description, we conclude that the different power asimmetries negatively impacts the number of consolidated shipments. However, the shipment cost per kg may have two different effects depending on the source of power. When the cargo asymmetry explains the power source, the shipment cost per kg increases. But when the power is attributed by the network or income asymmetry, this cost is reduced.

Regarding the shipment cost per kg, the following conclusion is drawn. In high-income and network asymmetries, one of the companies is much bigger than the other. This relationship is evident in the income asymmetry, as one company has bigger sales. For network asymmetry, the correct assumption is that the bigger party has a more extended collaborative network. For both asymmetries, the shipment cost is reduced because of the efficiencies of the bigger company.

For income asymmetry, different moderator effects were proved. For outcome 1 a more significant number of consolidated shipments is achieved for dyads under the following conditions:

- Low network asymmetry
- Greater shipped volume
- Broader collaborative network
- Industry compatibility, however, this didn't show significant evidence

Regarding outcome 2, shipment cost per kg, a cheaper cost is achieved for dyads under the following conditions:

- Low network asymmetry for dyads with low-income asymmetry
- Greater shipped volume
- Broader collaborative network

Under cargo asymmetry, better results for outcome 1, consolidated shipments, were observed for dyads under the following conditions:

- Low network asymmetry
- Industry compatibility for dyads with low cargo asymmetry

For outcome 2, shipment cost per kg, dyads achieved lower for:

- Broader collaborative network
- Industry compatibility

Finally, when network asymmetry was used as a treatment, the dyads achieved a better performance regarding the number of consolidated shipments under the following scenarios:

- Low cargo asymmetry, comparing for high network asymmetry.
- Low shipped volume, comparing for low network asymmetry.

On the other hand, for the shipment cost per kg, better performance is achieved for dyads that share the following features:

- High income asymmetry, comparing for low network asymmetry
- High shipped volume

6.1 Insights and Management Recommendations

Three different models were deployed to understand how power and its sources shape horizontal collaboration. The model that shows insights with greatest significance is the one that uses income asymmetry as the treatment. In a broad view, the different power sources negatively impact the number of consolidated shipments; however, they can have a positive impact on the shipment cost.

The effect of income asymmetry showed to be moderated by different variables. Better results were observed for dyads with lower network asymmetry. This result may be explained by the observatiion that companies with lower network asymmetry are likely to belong to a specific cluster. This effect can be amplified if the firms in the collaborative network belong to the same industry sector. However, as income asymmetry increases, the size of collaboration is reduced. Even though companies with similar network sizes tend to improve collaboration, the more significant the difference in size is detrimental to collaboration. Power explained from the difference in size ends up harming collaboration even for dyads with similar network sizes.

There are hints that collaboration occurs more frequently when economies of scale have been achieved. Bigger shipment volumes bring a greater number of consolidated shipments. As firms observed a positive result for collaboration, they will continue to collaborate, generating a virtuous circle. As shipped volume increases, more collaboration is needed, and as collaboration increases, more volume is transported by the dyad.

Finally, as the collaborative network increases, i.e., more companies are linked to parties in the dyad, better performance is achieved regarding the number of consolidated shipments. This result may suggest that better results could be drawn from these relationships as the companies became more experienced in collaborating.

6.2 Future Research and limitations

This research has looked into the influence of power in determining successful horizontal collaboration. Several insights were drawn from the developed models. However, these insights are hints about what is happening inside of the dyads. Dyads were observed from an outsider's perspective so that effects might be aggregated. Several variables could explain the relationships found.

A closer look from an internal perspective would allow researchers to determine what drives companies to participate in scenarios that will enable better collaborative results, and how their practices explain them. The several conclusions drawn in this study need to be further discussed in order to explain the observed behavior and the why behind them. Moderator effects for the total distance traveled, reach of the companies in the dyad, and identifying if the load constitutes a full truck load or less than a truck load can be included to understand the collaboration relationships better.

Collaboration deployment might determine logistics efficiency for countries, hence more research must be conducted to understand how to enable horizontal collaboration and make it a long-term relationship. Getting to know how to manage horizontal collaboration through power management can enable companies to acquire major capabilities in collaboration, gaining competitive advantages and, in the end, making them more sustainable.

REFERENCES

Abolfazl, S., Ag, M. P. T. V, Ag, F. P. T. V, & Bv, F. A. (2020). *Collaboration Methodology in Between Logistics Clusters*.

Arvis, J., Mustra, M., Panzer, J., Ojala, L., & Naula, T. (2016). Connecting to Compete: Trade Logistics in the Global Economy. *World Bank*, 1–76. http://lpi.worldbank.org/international/global

Barratt, M. (2004). Understanding the meaning of collaboration in the supply chain. *Supply Chain Management: An International Journal*, *9*(1), 30–42. https://doi.org/10.1108/13598540410517566

Belaya, V., & Hanf, J. H. (2016). *The dark and the bright side of power: implications for the management of business-to-business relationships*. https://doi.org/10.1186/s40100-016-0062-9

Borgström, B., & Hertz, S. (2007). Power issues when integrating supply chain. *Financial, Marketing and Production.*, *25*(1), 78–100.

Brito, R. P., & Miguel, P. L. S. (2017). Power, Governance, and Value in Collaboration: Differences between Buyer and Supplier Perspectives. *Journal of Supply Chain Management*, *53*(2), 61–87. https://doi.org/10.1111/jscm.12134

Caniëls, M. C. J., & Roeleveld, A. (2009). Power and dependence perspectives on outsourcing decisions. *European Management Journal*, *27*(6), 402–417. https://doi.org/10.1016/j.emj.2009.01.001

Cao, M., & Zhang, Q. (2010). Supply chain collaborative advantage: A firm's perspective. *International Journal of Production Economics*, *128*(1), 358–367. https://doi.org/10.1016/j.ijpe.2010.07.037

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, *29*(3), 163–180. https://doi.org/10.1016/j.jom.2010.12.008

Cao, Mei, Mark A. Vonderembse, Q. Z., & Ragu-Nathan, T. S. (2010). Supply Chain Collaboration: Conceptualisation and Instrument Development. *International Journal of Production Research*, *48*(22), 6613–6635.

Chen, L., Zhao, X., Tang, O., Price, L., Zhang, S., & Zhu, W. (2017). Supply chain collaboration for sustainability: A literature review and future research agenda. *International Journal of Production Economics*, *194*(April), 73–87. https://doi.org/10.1016/j.ijpe.2017.04.005

Crook, T. R., & Combs, J. G. (2007). Sources and consequences of bargaining power in supply chains. *Journal of Operations Management*, *25*(2), 546–555. https://doi.org/10.1016/j.jom.2006.05.008

Cruijssen, F. (2006). *Horizontal cooperation in transport and logistics*. Universiteit van Tilburg.

Cruijssen, F. (2012). Operational and Legal Framework for Collaboration. Position Paper. *CO3 Project. EU FP7 Funded Project*.

Cruijssen, F., Cools, M., & Dullaert, W. (2007). Horizontal cooperation in logistics: opportunities and impediments. *Transportation Research Part E: Logistics and Transportation Review*, *43*(2), 129–142.

Essabbar, D., Zrikem, M., & Zolghadri, M. (2016). Power imbalance in collaboration relationships. *International Journal of Supply and Operations Management*, *2*(4), 1021–1034.

Fawcett, S. E., Fawcett, A. M., Watson, B. J., & Magnan, G. M. (2012). Peeking inside the black box: toward an understanding of supply chain collaboration dynamics. *Journal of Supply Chain Management*, *48*(1), 44–72.

Ferrell, W., Ellis, K., Kaminsky, P., & Rainwater, C. (2020). Horizontal collaboration: opportunities for improved logistics planning. *International Journal of Production Research*, *58*(14), 4267–4284. https://doi.org/10.1080/00207543.2019.1651457

Hernández, R., Fernández, C., & Baptista, P. (2014). *Metodología de la investigación*. McGraw-Hill.

Hirano, K., Imbens, G. W., & Ridder, G. (2003). Efficient estimation of average treatment effects using the estimated propensity score. *Econometrica*, *71*(4), 1161–1189. https://doi.org/10.1111/1468-0262.00442

Ibishukcu, O., & Datar, A. (2016). *Maintaining Power Relations in Supply Chain*. Jönköping University.

Kähkönen, A.-K. (2014). The influence of power position on the depth of collaboration. *Supply Chain Management: An International Journal*, *10*(1), 17–30. https://doi.org/10.1108/SCM-03-2013-0079

Ketchen, D. J. (2017). *POWER IN SUPPLY CHAIN MANAGEMENT WHU – Otto Beisheim School of*

Management. *53*(April), 3–9. https://doi.org/10.1111/jscm.12140

Morgan, S. L., & Winship, C. (2014). Counterfactuals and causal inference: Methods and principles for social research. In C. U. Press. (Ed.), *Counterfactuals and Causal Inference: Methods and Principles for Social Research*. https://doi.org/10.1017/CBO9781107587991

Nasab, S. A. (2019). *Horizontal Collaboration between Logistics Service Providers (LSPs) in Australia : Examining the Structure , Opportunities and Impediments* (Issue July).

Nyaga, G. N., Lynch, D. F., Marshall, D., & Ambrose, E. (2013). Power asymmetry, adaptation and collaboration in dyadic relationships involving a powerful partner. *Journal of Supply Chain Management*, *49*(3), 42–65. https://doi.org/10.1111/jscm.12011

Pan, S., Trentesaux, D., Ballot, E., & Huang, G. Q. (2019). Horizontal collaborative transport: survey of solutions and practical implementation issues. *International Journal of Production Research*, *57*(15–16), 5340–5361. https://doi.org/10.1080/00207543.2019.1574040

Pearl, J., Glymour, M., & Jewell, N. P. (2016). *Causal inference in statistics: A primer.* (J. W. & Sons. (ed.)).

Prajogo, D., & Olhager, J. (2012). Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. *International Journal of Production Economics*, *135*(1), 514–522. https://doi.org/10.1016/j.ijpe.2011.09.001

Ramanathan, U., & Gunasekaran, A. (2012). Supply chain collaboration: Impact of success in long-term partnerships. *International Journal of Production Economics*, *0*. https://doi.org/10.1016/j.ijpe.2012.06.002

Saenz, M. J., Ubaghs, E., & Cuevas, A. I. (2015). *Enabling Horizontal Collaboration Through Continuous Relational Learning*.

Savy, M. (2016). Logistics as a political issue. *Transport Reviews*, *36*(4), 413–417. https://doi.org/10.1080/01441647.2016.1182793

Scharfstein, D. O., Rotnitzky, A., & Robins, J. M. (1999). Adjusting for nonignorable drop-out using semiparametric nonresponse models. *Journal of the American Statistical Association*, *94*(448), 1096–1120.

Schmoltzi, C., & Wallenburg, C. M. (2011). Horizontal cooperations between logistics service providers: motives, structure, performance. *International Journal of Physical Distribution and Logistics Management*, *41*(6), 552–576. https://doi.org/10.1108/09600031111147817

Sheffi, Y., Saenz, M. J., Rivera, L., & Gligor, D. (2019). New forms of partnership: the role of logistics clusters in facilitating horizontal collaboration mechanisms. *European Planning Studies*, *27*(5), 905–931. https://doi.org/10.1080/09654313.2019.1575797

Simatupang, Togar M, & Sridharan, R. (2002). The collaborative supply chain. *The International Journal of Logistics Management*, *13*(1), 15–30.

Singh, H., Garg, R. K., & Sachdeva, A. (2018). Supply chain collaboration: A state-of-the-art literature review. *Uncertain Supply Chain Management*, *6*(2), 149–180. https://doi.org/10.5267/j.uscm.2017.8.002

Soosay, C. A., & Hyland, P. (2015). A decade of supply chain collaboration and directions for future research. *Supply Chain Management: An International Journal*, *20*(6), 613–630. https://doi.org/10.1108/SCM-06-2015-0217

Sridharan, R., & Simatupang, T. M. (2013). Power and trust in supply chain collaboration. *International Journal of Value Chain Management*, *7*(1), 76–96. https://doi.org/10.1504/IJVCM.2013.057344

StataCorp. (2019). *Stata treatment-effects reference manual: potential outcomes/counterfactual outcomes.*

Tafuri, S., Pomponi, F., Palumbo, M., & Fratocchi, L. (2013). Horizontal collaboration in logistics: a comprehensive framework. *Research in Logistics & Production*, *3*(4), 243–254.

Tidström, A. (2009). Causes of conflict in intercompetitor cooperation. *Journal of Business & Industrial Marketing Marketing*, *24*(7), 506–518.

Wallenburg, C. M., & Raue, J. S. (2011). Conflict and its governance in horizontal cooperations of logistics service providers. *International Journal of Physical Distribution and Logistics Management*, *41*(4), 385–400. https://doi.org/10.1108/09600031111131940

Zhao, X., Huo, B., Flynn, B. B., & Yeung, J. H. Y. (2008). The impact of power and relationship commitment on the integration between manufacturers and customers in a supply chain. *Journal of Operations Management*, *26*(3), 368–388. https://doi.org/10.1016/j.jom.2007.08.002

APPENDIX A

Table 30. ATE for income asymmetry as power source controlling with cargo compatibility– Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Industry Compatibility

	Outcome 2 Shipment cost per kg						
	Industry compatibility (=1)				Industry incompatibility (=0)		
Income asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low income asymmetry	2483.55		957.04		3421.17		977.44
2 Medium income asymmetry	1868.49		732.38		2108.11		641.21
3 High income asymmetry	3760.30		1016.87		2242.60		280.78
	Average Treatment Effect	SIgn	s.e		Average Treatment Effect	Sign	s.e
2 vs 1	-0.25		0.41		-0.38		0.26
3 vs 1	0.51		0.71		-0.34	*	0.20
3 vs 2	1.01		0.96		0.06		0.35

AIPW estimators controlling for income asymmetries' difference in total cargo, total network, cargo asymmetry, network asymmetry, industry compatibility.
s.e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Table 31. ATE for cargo asymmetry as power source controlling with income asymmetry – Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Income asymmetry

	Outcome 2 Shipment cost per kg						
	High Income Asymmetry (>=0.5)				Low Income Asymmetry (<0.5)		
Cargo asymmetry	Potential Mean		s.e	Sign	Potential Mean		s.e
1 Low cargo asymmetry	2067.22		411.17		1499.91		413.22
2 Medium cargo asymmetry	3239.24		776.01		4044.64		1226.36
3 High cargo asymmetry	2207.26		291.9		2165.28		509.20
	Average Treatment Effect	Sign	s.e		Average Treatment Effect	Sign	s.e
2 vs 1	57%		0.49		169%		1.10
3 vs 1	7%		0.26		44%		0.52

3 vs 2	-32%	*	0.19	-46%	**	0.20

AIPW estimators controlling for cargo asymmetries' difference in total income, total network, income asymmetry, network asymmetry, industry compatibility.
s.e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Table 32. ATE for cargo asymmetry as power source controlling with network asymmetry – Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Network asymmetry

	Outcome 2 Shipment cost per kg					
	High Network Asymmetry (>=0.5)			Low Network Asymmetry (<0.5)		
Cargo Asymmetry	Potential Mean	s.e	Sign	Potential Mean		s.e
1 Low cargo asymmetry	1901.26	439.32		1935.33		462.46
2 Medium cargo asymmetry	3681.06	900.87		2951.82		964.42
3 High cargo asymmetry	2297.19	323.16		2010.50		412.76
	Average Treatment Effect	Sign	s.e	Average Treatment Effect	Sign	s.e
2 vs 1	94%		0.65	53%		0.62
3 vs 1	21%		0.33	4%		0.33
3 vs 2	-38%	**	0.18	-32%		0.26

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s.e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Table 33. ATE for network asymmetry as power source controlling with cargo asymemtry – Outcome: Shipment cost per kg

Average Treatment Effects Estimates by Cargo asymmetry

	Outcome 2 Shipment cost per kg				
	High Income Asymmetry (>=0.5)			Low Income Asymmetry (<0.5)	
Network asymmetry	Potential Mean	s.e	Sign	Potential Mean	s.e
1 Low network asymmetry	2490.56	548.41		2711.85	1173.94
2 Medium network asymmetry	3463.54	778.74		2257.84	444.84
3 High network asymmetry	2163.34	306.83		1869.06	466.92

	Average Treatment Effect	Sign	s.e	Average Treatment Effect	Sign	s.e
2 vs 1	39%		0.43	-17%		0.39
3 vs 1	-13%		0.23	-31%		0.34
3 vs 2	-38%	**	0.17	-17%		0.26

AIPW estimators controlling for network asymmetries' difference in total income, total cargo, income asymmetry, cargo asymmetry, industry compatibility.
s.e: robust standard errors.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.