LUND UNIVERSITY

SCHOOL OF ECONOMICS AND MANAGEMENT

The Relationship Between Vertical Integration and Risk

A Statistical Analysis of Changes in Vertical Integration within Industries Affected by the Global Semiconductor Shortage

by

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May 2022

Bachelor's Programme in International Business

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Abstract

Succeeding a brief discussion of what vertical integration (VI) is, its interaction with risk and uncertainty, and the context of this study, namely the COVID-19 pandemic and its simultaneous semiconductor shortages, the purpose of this paper is outlined to fill a research gap regarding an empirically supported relationship between vertical integration and systemic risk. The aim and contribution here is subsequently twofold: to examine whether one can predict strategic trends and behavior among multinational companies when it comes to value chain ownership and control decisions in response to abnormal levels of systemic risk, and, to more generally statistically prove or disprove the seeming theoretical consensus that vertical integration can be a key risk-reduction strategy for various reasons, something that will be detailed and explored more closely in an extensive literature review. The literature review is guided principally by Transaction Cost Theory, otherwise referred to as Transaction Cost Economics and commonly abbreviated to TCE, in order to provide a theoretical background, connection, and support to both the purpose and expected and actual results of this study. To answer the research question of whether or not there is a statistically significant and verifiable relationship between vertical integration and systemic risk, this paper uses a quantitative approach to measure the change in vertical integration level and systemic risk between two specified years of interest, one representative of the semiconductor shortage effects and the other a base year, for 101 multinational companies, or MNCs, operating in semiconductor-reliant industries. Simple linear regression is used to test for a relationship between the independent variable, the change in systemic risk, and the dependent variable, the change in vertical integration level. Finally, the resulting finding of a positive and statistically significant relationship between the two is then critically analyzed with a connection to relevant theoretical assertions, whereafter the limitations of this study and their potential to segue into future studies are discussed.

Keywords: vertical integration, systemic risk, MNCs, semiconductor-reliant industries, semiconductor shortage, TCE

Word Count: 21,072

Acknowledgements

As our three years at the Lund School of Economics and Management culminate in an opportunity to apply and reflect upon the knowledge gained throughout our collegiate careers in the form of this paper, we would like to acknowledge and extend our sincere appreciation and gratitude to those that have helped to guide and enable its completion. The process of writing this thesis ironically seemed to reflect the years we have spent at LUSEM so far, at times quite challenging but nonetheless incredibly rewarding and engaging. Thus, various sources of support received from the student body, professors and administrators not only while writing this paper but also throughout the duration of our time pursuing an undergraduate degree, all deserve recognition.

That being said, we would first and foremost like to recognize and express our gratitude for our supervisor, Magnus Johansson, whose insightful and critical lens was integral in ensuring that this study was adequately supported and structured in the most comprehensive and successful way. His ongoing support and commitment to offering an analytical and grounded perspective throughout all stages of writing this paper undoubtedly worked to its success, and we are incredibly grateful to have received his guidance and expertise.

We would also like to acknowledge those involved with providing the Academic Skills and Services at LUSEM, specifically Garo Harwood, whose lectures and other written resources were incredibly valuable, particularly when it came to detailing referencing standards and offering tips for refining the flow and structure of this thesis.

Last but certainly not least, we would like to express our appreciation for the friendship and support of our fellow students who have offered solidarity, kindness, and light-heartedness for the duration of the degree project and our cumulative time together, subsequently inspiring us to celebrate our collective growth and resilience through the difficult and isolative time presented us by the COVID-19 pandemic. This time was also marked by the constant support of not only our immediate families but also our academic family at LUSEM, both of whom we would therefore like to recognize and appreciate. We could not have done this without these various avenues of support and are grateful for each and every one.

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1 Introduction

1.1 Background

There is a plethora of research indicating a close relationship between firm strategy and structure, some maintaining that strategy shapes structure and others the reverse, but a consensus lies within their interconnectedness regardless of which affects and which is affected (Kim & Mauborgne, 2009). As well, while there are many both internal and external factors that dynamically shape a firm's strategy, risk and uncertainty are arguably two of the key driving factors and thus also impact firm structure (Kaplan & Mikes, 2012). One of the most recent major events affecting numerous industries is the 2020 semiconductor shortage, which would have presumably caused a multitude of firms to change their strategy, at least to some extent, to respond to exogenous factors heightening risk and uncertainty across global value chains (Vakil & Linton, 2021). One of the key strategic options would be establishing a greater degree of control over the value chain and production. Thus, the increased risk of supplier default at the hands of supply shortages could incentivize a "structural" or strategic change within the context of the value chain, namely vertically integrating the process and/or production of the component affected by the shortage, instead of outsourcing.

1.1.1 Defining Vertical Integration

To keep its relevance and description for this paper dichotomous, structure is denoted in terms of control over the value chain and can be split into two categories: vertically integrated or not vertically integrated (i.e. high control over the value chain vs limited control and outsourcing heavy, respectively). Vertical integration can therefore best be understood as the degree to which a company owns parts of its value chain both upstream and downstream (Buzzell, 1983). Thus, it can be considered both a structural type and a strategy since vertical integration refers to how a firm structures its control and involvement in its value chain but is also a strategic approach to maximizing profitability and gaining competitive advantage. Vertical integration goes far beyond a simplistic view of all activities being either collected in-house or outsourced. Within the organization, it can be described by several characteristics such as the breadth of integrated activities, the number of stages of activities, the degree of internal transfers, and the ownership form of activities (Harrigan, 1984). Nowadays, there is hardly any multi-business or multinational company that would be completely integrated, as most of these companies are enjoying the benefits of integrating separate stages of value creation or pursuing alternative integration strategies (Harrigan, 1984). Thus, there is a wide range of combinations of integration strategies a company might pursue. For the purpose of adequate quantification, this study treats vertical integration as a "make or buy" decision over the whole production process of goods sold by every company, as technology-reliant firms, which are focused on in this paper, have core operations with a fairly large number of production processes of complex technology-heavy products.

That being said, there are many arguments both for and against the success of vertical integration, with the benefits being largely explicable through transaction cost theory and the potential for economies of scale or scope, as well as swift coordination of production processes, while the drawbacks center around the rise in administrative costs, incentive challenges, and potentially negative competitive effects (Grant, 2015). According to Stuckey and White (1993), uncertainty and risk, particularly relating to contract creation and enforcement with suppliers and customers, as well as potential supply shortages, have an impact on the choice of a firm to become more or less vertically integrated. This is the case since integrating parts of a value chain can reduce risk, in the sense that a firm will be independent of others in its responses and coordination of production and processes along the value chain, therefore enjoying more control and agility when addressing supply chain disruptions while also avoiding market failure costs and opportunism (Stuckey & White, 1993). The semiconductor shortage is an example of such a systemic supply chain risk and disruption in which a firm may benefit from integrating processes, specifically when it comes to chip manufacturing. Integration can allow the firm to gain more oversight or control of its operations during a volatile time and, to some extent, avoid the risks of incomplete contracts with suppliers under strain and potentially opportunistic behavior of competitors. However, these benefits do not come without costs that a firm can likely also not want to incur regardless of the previously detailed, potential advantages. For example, vertical integration raises administrative costs since it is likely that expensive adjustments like bringing in new employees who have the skill and know-how to steer a newly integrated function, among others, are necessary (Grant, 2015). In addition, if integrating a function is a reactive strategy to address the issue of the semiconductor shortage short-term, the costs may very well outweigh the benefits.

1.1.2 Global Semiconductor Shortage

This trade-off between control and incurring potentially high administrative and direct costs is also affected by which aspect of the value-adding process could benefit from, or requires, integration. As semiconductors are the heart of most consumer electronics, cars, advanced medical devices, communication equipment, clean energy solutions, and many more, they are inherently a core component for many electronics-focused firms' products and services. This makes it potentially beneficial to have control, to some extent, over their production and supply to avoid having to halt production due to overextended suppliers and production delays, as reflected in the current chip shortage (Vakil & Linton, 2021). Simply put, semiconductors are irreplaceable elements of all advanced electronic divides, disruption in the supply of which is traceable in numerous industries (Vakil & Linton, 2021). Thus, the chipsets required for the production of a wide range of electronic equipment are a major cost driver for manufacturers as well.

The semiconductor shortage is one of the key examples of supply chain disruptions following the COVID-19 pandemic and the growing demand for microchips in multiple industries (Vakil & Linton, 2021). With advancements in the technologies used in consumer electronics, cars, medical devices, IT, communication, and more, the demand for semiconductors has grown substantially over the past couple of years (Burkacky, Dragon, & Lehmann, 2022). In addition, with the beginning of the pandemic, demand for consumer electronics and cars decreased initially but then proceeded to increase significantly due to the rapid change in consumer behavior instigated by COVID-19 (Schewe, 2021). However, due to the subsequent supply chain disruptions, specifically the mismatch of supply and demand for semiconductors, as well as complex geopolitics and poor management practices, companies have failed to get ahold of the semiconductors needed in order to secure flawless production and meet production plans (Schewe, 2021). Reportedly, 169 industries globally that spend more than one percent of their industry GDP's on microchips have been affected by the semiconductor shortage (Howley, 2021). This led to a hard hit on the economies of many countries, especially the USA and those in the EU, and motivated a trend towards the deglobalization of semiconductor manufacturing. One percent of America's GDP is expected to be affected by the semiconductor shortage which has led to increased investments in domestic production of chips and, presumably, insourcing by dependent companies (Howley, 2021). This is particularly in line with the emerging de-globalization trend, whose existence is partially due to the change in geopolitics and disruptions in global supply chains (Witt, 2019).

1.2 Aim and Objectives

This research paper aims to explore whether or not there is any statistically verifiable relationship between vertical integration and systemic risk, in this case, represented by COVID-19, and more specifically, the parallel semiconductor shortages. Taking theoretical conclusions into consideration, there seems to be a correlation between the two; however, the relationship has yet to be definitively statistically grounded or rebuked and thus benefits from empirical analysis. The objective of this study is therefore to develop and implement an accurate and robust method to quantify systemic risk and vertical integration, in order to statistically assess the presence of a correlation between the two, or lack thereof. Secondarily, the approval or disapproval of such a relationship can likely be extrapolated to estimate or predict the reactive behaviors or strategies of multinational firms to various environmental stimuli, specifically changes in systemic risk.

1.3 Research Purpose

The purpose of this paper is thus to reach a statistically supported, preliminary conclusion on whether in the face of substantial systemic risk multinational firms would lean towards a vertical integration strategy or not. This question is addressed with quite a bit of depth theoretically; however, there are relatively few statistical studies that, especially definitively, prove or disprove theoretical conclusions, which seem to be quite aligned regarding the correlation or relationship between risk and vertical integration, making the quantitative analysis performed in this paper particularly valuable. The previously contextualized semiconductor shortage during the COVID-19 pandemic is a great example of substantial uncertainty and systemic risk affecting global production in multiple semiconductor-reliant industries. Thus, it has been chosen as a testable time period, specifically the focal year 2021, representative of substantial systemic risk, to be compared with the contrasting base year 2015, a year of relative stability on the financial markets and semiconductor market, in order to analyze the reactive strategies of multinational firms as they relate to make or buy decisions (McKinsey, 2015).

In this way, the statistical analysis presented in this paper contributes to verifying or rejecting the theoretically supported conclusion of a relationship between systemic risk and vertical integration. This allows for the ability to predict a multinational firm's behavior as it relates to make-or-buy strategies in the face of abnormal levels of systemic risk, and as a by-product, to some extent predict structural changes within global value chains. As well, vertical integration levels of a wide range of firms are quantified as part of the required calculations which is not something that is publicly available. Usually, firms are quite subjectively and loosely identified as either vertically integrated or not which gives no benchmark or scale of the cutoffs for what is considered "integrated". This reveals an additional contribution of this paper, namely the quantification of vertical integration levels of many large, well-known, multinational firms using a percentage scale (i.e. 0-1).

Considering the purpose, aims, and objectives of this thesis, the research question is expressed as follows:

RQ: *What is the relationship between changes in the vertical integration level of semiconductor-reliant, multinational companies and changes in systemic risk in the form of the global semiconductor shortage?*

1.4 Delimitations

This study is specifically tracking the semiconductor shortage-driven systemic risk within chosen industries that are considered to have been affected. Thus, this analysis aims at uncovering an overarching trend by considering a limited number of industries that have shared characteristics, meaning that the findings of this study stay relevant to the industries considered, and the connection to other industries is not discussed in an empirical sense. Another important reservation needing to be addressed is that the vertical integration on stages of the production process of sellable goods is considered only, while the integration of other functions e.g. R&D and marketing are not considered due to methodological considerations. One theoretical limitation arises from the fact that vertical integration is treated as a strategy in this paper; however, some argue for a consideration of its structural nature. Other limitations of this study might originate from methodological and data discussion choices which are detailed later in the paper.

1.5 Outline of the Thesis

The introduction chapter, providing general context and relevant definitions, is followed by chapter two, the literature review, which focuses on relevant organizational theories to contextualize and support expectations for the study done in this paper. In particular, transaction cost economics, uncertainty and risk theories, agency theory, and property rights theory will be discussed. This chapter will also introduce existing research and empirical studies on quantifying vertical integration, as well as its relation to risk and uncertainty. Chapter two is concluded with the hypothesis statement for this study and is followed by chapter three which details the methodological process, as well as the reservations of performing the statistical analysis in this paper. In particular, it provides a methodological description of the approach to quantifying vertical integration, the use of beta **β** as a measurement of systemic risk, sampling and data collection methods, and data analysis. Chapter four consolidates and comments on the results of the study and presents their respective collected data, regression output, and interpretation. The following chapter provides an analysis of, and elaboration on, the data presented in the previous chapter and consists of results considerations, theoretical support, limitations, and other considerations. The concluding chapter of this paper refers back to the research aims and objectives and elaborates on the findings of this study. Finally, practical implications of the results are discussed, and suggestions for future research are made.

2 Literature Review

2.1 Organizational Theories Review

From a theoretical perspective, firms' motivation behind pursuing a vertical integration strategy can be explained by multiple organizational theories. While the best theoretical framework is arguably offered by transaction cost economics; incomplete contracts, property rights, and agency theories are essential for a broader and more accurate understanding of complex theoretical issues behind the topic.

2.1.1 Supplemental Organizational Theories

To begin with the issue of incomplete contracts, it is necessary to first define what characterizes a complete contract. A complete contract identifies and accounts for all future contingencies after the transaction occurs (Macneil, 1978). It would also include a remedy for any breach, offering predictability of outcomes (Williamson, 1979) However, all real-world contracts are incomplete as none, especially long-term contracts, can capture every contingency in the world of uncertainty (Kim, 2019). The main reasons for contracts being incomplete include bounded rationality of contracting parties, quality measurement problems, information asymmetry, and cultural aspects (Kim, 2019). These aspects of incomplete contracts are further linked to the organizational theories that are utilized for explaining why companies are pursuing vertical integration. However, incomplete contracts in the form of spot contracts, long-term contracts, etc. are one of the fundamental reasons for pursuing integration due to the monitoring cost they have the potential to create, resulting from their failure to account for all contingencies.

Continuing with two more of the key organizational theories required to understand the rationale behind vertical integration, property rights, and agency theories both offer distinct perspectives on the issue. Property rights theory complements transaction cost economics, which will be elaborated on further in this section, by stating that an asset can be most efficiently utilized by an owner due to deeper asset-specific knowledge (Kim, 2019). This is particularly relevant to vertical integration as it is a structure defined by the ownership of value-creation activities. Thus, incentives around the efficiency of vertical integration would change depending on the ownership structure.

Agency theory, on the other hand, describes a relationship between an agent, who acts in the interest of a principal, and a principal, who is affected by the agent's actions. Agency costs arise in this relationship when the principal is not able to control that the agent's actions are in line with the principal's interests (Kim, 2019). Since uncertainty and risks make it difficult to set control over an agent, contracts between an agent and a principal must include a certain level of trade-off between motivating an agent and decreasing risk for a principal. Informational asymmetry might exist in the agent-principal relationship as well, which increases the hazard of hidden actions and hidden information (Arrow, 1985). This theory has a direct link to vertical integration, as in a "make or buy" decision, where an external supplier would act as an agent while the buyer is the principal. In this setting, vertical integration is less likely to be implemented in the case of an agent's high willingness to be productive and low-risk aversion since the maximum efficiency of the agent can be secured by an increase in incentives and re-allocation of risks from principal to agent (Kim, 2019). However, in the case of high risk-aversion of an agent, higher incentivization would not secure higher productivity, thus, vertical integration would be more likely to be adopted (Kim, 2019).

2.1.2 Transaction Costs Economics

Though the aforementioned theories contribute to the understanding of what incentivizes the pursuit of a vertical integration strategy, to bring to light the complex theoretical background behind the interaction of uncertainty and strategic management decisions, transaction cost economics arguably deserves the most attention. Organizational economic theories set a basis for understanding the complex organizational structure of firms in general, while transaction cost economics and agency theory, as part of organizational economics, are dedicated to scrutinizing optimal governance mechanisms, specifically (Young, 2013).

Transaction cost theory is therefore a key theoretical framework for understanding trends behind integration, as one of the main advantages of vertical integration is the reduction of transaction costs (Buzzell, 1983). Transaction cost economics defines the conditions and factors that influence the cost of various organizational transactions and emphasizes the dependence of economic efficiency on the minimization of the cost of those transactions (Williamson, 1989). Consequently, organizations are expected to seek a reduction in transaction costs to reach higher operational efficiency and illuminate freeriding (Williamson, 1989). Importantly, Williamson (1989) defines transactions as any form of transfer of goods between separate entities during the value-creation process, wherein perfect conditions for such a transfer would allow it to occur flawlessly. Thus, transaction costs appear when a transaction is performed in two different governance systems, and naturally, imperfect conditions apply (Williamson, 1989). The complex transaction cost sources can be further broken down into the following causes: asset specificity, transaction frequency, environmental uncertainty, and behavioral uncertainty (Williamson, 1989).

Asset Specificity

Mahoney (1992) has emphasized, however, that in the perspective of transaction costs economics and choice of the organizational structure, transaction frequency is less relevant, while asset specificity and uncertainty are the main drivers of transaction costs. Asset specificity originates from asset-specific investments and is referred to as the degree to which an asset can be deployed for use in another setting than the original one. Williamson (1989) specifies the following contexts in which asset specificity might be discovered: human resources, physical assets, and locations. In turn, asset specificity affects the degree of integration a company pursues.

There is also a strong link between asset specificity and innovation which indirectly affects the level of integration. Arguably, asset specificity affects the cost of innovation and therefore the R&D expenditure (Williamson, 1989). Buzzell (1983) argues that vertically integrated companies are delivering more new products and are more fit for innovation. There are a number of other studies also suggesting a positive relationship between innovation expenditures and the degrees of integration in various industries (Armour & Teece, 1980; Liu, 2016). Moreover, many of the innovative semiconductor-reliant industries considered in this study have extensive R&D budgets (OECD, 2017). Consequently, in the automotive industry particularly, this leads to the creation of new asset-specific developments that are kept in-house, while production of generic components is outsourced (Ciravegna and Pilkington, 2013; Cohen, 2021). Thus, depending on the proportion of innovative stages of production to total production, with heavy innovation, a firm's level of integration to deliver new developments would appear high.

Kvaløy (2007), offering a quantitative study, has identified that the relationship between asset specificity and vertical integration is rather ambiguous, yet high asset specificity could be a driver for companies to pursue integration, a claim that is further supported by Ruzzier (2009) in a study discovering factors that affect integration. Stuckey & White (1993) stress a positive relationship between asset specificity and vertical integration as well, emphasizing that in the case of low asset specificity, markets are able to function using standard contracts, while in the case of high asset specificity, contracts might become complex and difficult to execute which can be a driver for vertical integration strategy. Although empirical evidence for this relationship is quite inconclusive, theoretically speaking, there is a strong assertion that there is a positive relationship between asset specificity and vertical integration.

Transaction Frequency

Transaction frequency is a characteristic of the frequency of business transactions performed throughout the value creation process and arguably is another transaction cost driver that urges the pursuit of vertical integration strategy, alongside asset specificity and others. Mahoney (1992) has argued that asset specificity is of great importance in the determination of organizational form, while transaction frequency is irrelevant to the organizational form in general. On the contrary, Stuckey & White (1993) argue that in combination with high asset specificity, transaction frequency would be a promoter of vertical integration strategy. This is due to the increased cost of negotiation and execution of contracts given high asset specificity and increased risk of freeriding (Stuckey & White, 1993). Considering a mismatch in conclusions of theoretical assertions and quantitative studies on the relationship between asset specificity and vertical integration, the findings of this paper are particularly interesting, as theoretical conclusions regarding the relationship between risk and vertical integration are similar to those of asset specificity and vertical integration. However, empirical evidence is still to be discovered. This will be elaborated on in the upcoming sections.

Uncertainty in Transaction Cost Economics

A key focus of the studies on transaction cost economics and vertical integration is the role of uncertainty and its correlation with companies pursuing a strategy of vertical integration. Multiple studies (Gil, 2007; Woodruff, 2002; Monteverde & Teece, 1982; Masten, Meehan, & Snyder, 1991) have found a positive relationship between the level of uncertainty and vertical integration due to an increase in the cost of designing and executing contracts given a substantial increase in uncertainty. Uncertainty, however, can take many forms depending on the industry and aspect of the organizational structure studied (Kim, 2019). Williamson (1989) has proposed a more transaction cost-relevant form of uncertainty, taking the shape of comparative contracting behavior in differing organizational forms. He outlines two types of uncertainties: behavioral uncertainty of the opportunistic nature between contracting parties and market demand uncertainty (Williamson, 1989). However, from a transaction cost perspective, opportunistic behavior uncertainty is of more importance due to the direct link to the contracting cost (Kim, 2019). Arguably, in the case of environmental uncertainty such as a semiconductor shortage, there is a high probability of opportunistic behavior amongst competitors and suppliers, which would incentivize integration. Environmental uncertainty is one of the drivers of transaction costs as well, and while the chip shortage is characterized by an increase in systemic risk, unquantifiable environmental uncertainty is part of such disruption as well. The nature of uncertainty, its connection to risk, and its role in organizational theory will therefore be covered in the next section.

2.2 Uncertainty, Risk, and Vertical Integration in Organizational Theory

2.2.1 Uncertainty

In order to understand the relationship between uncertainty, systemic risk, and vertical integration, it is crucial to arrive at a clear definition of what uncertainty and risk are, and how to differentiate the two. Uncertainty is a term that has been analyzed and criticized by many theories and in varying contexts during the past decades, making its definition quite subjective (Krickx, 2000). Even though uncertainty is not quantifiable, it is a factor to be considered since it can be a methodological limitation and reason for certain unexpected outcomes, making it relevant to this study.

Uncertainty plays a large role in organizational theory and strategy and was first recognized in this context by Barnard in 1938 (Krickx, 2000). According to Downey, Hellriegel, & Sloccum (1975), uncertainty has both subjective, or external, and objective, or internal, characteristics with a weak but still existing interconnection (Krickx, 2000). It is thus crucial to consider uncertainty from both external and internal perspectives since this aids in gaining a complete understanding of how uncertainty interacts with vertical integration.

Milliken's study, discussed by Krickx (2000), continues to explore the different dimensions of the environmental objective factors that affect uncertainty, namely state uncertainty (i.e. unpredictable environment), effect uncertainty (i.e. connections between organizations and change), and response uncertainty (i.e. the options to the organizations i.e their outcomes and value), which are all closely connected.

In this case, what directly relates to the data analysis performed in this study is environmental uncertainty. Environmental uncertainty is characterized by the state of the environment and the difficulty of predicting future outcomes affected and created by environmental change. Environmental uncertainty can thus be considered directly tied to systemic risk in this case since the year that was chosen as a "risk year" for this analysis (2021) is a perfect example of substantial environmental uncertainty and systemic risk in action. Companies are widely theorized to become more vertically integrated in the wake of environmental uncertainty and systemic risk since integrating means having direct control over different parts of a firm's value chain (Dwirandra and Astika, 2020). This is likely because having more control over management, technology, and/or production is conducive to better reactive preparedness for a company in situations characterized by unusual levels of systemic risk (Dwirandra and Astika, 2020).

2.2.2 Risk

Business risk, on the other hand, refers to any threat level that can affect a company's generation of profits or financial and/or strategic targets in any way (Kenton, 2022). It is critical to note that there is a difference between risk and uncertainty, and it lies in the measurability of the two. Uncertainty is a set of intertwined, complex events that create an inability to predict future outcomes, whereas, with risk, one refers to a single quantifiable and/or predictable event.

In the context of this paper, the type of risk being discussed and calculated is systemic risk, defined as a risk of interconnected, complex events that might lead to an overall economic and catastrophic downturn, in this study represented by COVID-19 and its parallel semiconductor shortages. Furthermore, systemic risk is unique in that it not only affects the risk of failure in individual parts but also the risk of failure or breakdown in an entire system (CFA Institute, 2022). It is important, however, to note the distinction between systematic and systemic risk. Systematic risk refers to the day-to-day risk that is inherent to the market as a whole, while systemic risk refers to an exogenous risk, like the pandemic or war, which is usually more specific to an individual company or industry and has the potential to trigger system collapse (Nguyen, 2021). Thus, systemic risk is of interest for this paper due to its more specific and relevant definition, as this analysis centers around an industry-specific risk, the semiconductor shortage, rather than general day-to-day risk.

The pandemic and its simultaneous chip shortage accurately demonstrate the nature of systemic risk in the way that both were able to destabilize multiple industries or economies as a whole which led to bankrupted businesses on an international level, something that can be largely attributed to supply chain shortages (UNDRR, 2021). Within a firm, systemic risk is considered to be the possibility of an event that can destabilize entire industries or even the global economy. It is most commonly represented by the beta of a company's stock prices, where beta measures the level of volatility of a firm's stock compared to the market as a whole (Kenton, 2021). The beta **β** will also be used in this paper to quantify levels of systemic risk and calculate respective differences between two years of interest, something that will be elaborated on in the methodological chapter. Often, companies that are highly interconnected with others are considered to be far more vulnerable to systemic risk since they are exposed to the effects of failure of the other firms that they are connected to. In this case, the word "connected" refers to a contractual relationship between firms that makes them a part of each other's value chains (Helfat & Teece, 1987). The takeaway here is that the more vertically integrated a company is, the lower the level of systemic risk it faces, since integration lessens the amount of outsourcing and, in turn, reliance on other firms (Helfat & Teece, 1987). This point is relevant to the empirical research done in this paper since it sets the expectation that higher systemic risk is likely to increase a firm's propensity to vertically integrate.

2.3 Vertical Integration & MNCs

2.3.1 Strategic Perspectives on Vertical Integration

To integrate or not is, in this way, a key strategic decision that a firm can take in light of developing its value chain and coordinating its operating activities. Simply put, vertical integration can be defined as a "make or buy", "outsource or insource" decision with regard to the production processes of a good or service (Kim, 2019). This decision, however, is not binary concerning the whole value creation process of the firm. There is a wide spectrum of integration combinations a company might pursue in terms of different governance forms, ownership forms, and a number of activities integrated (Kim, 2019). These complement a wide range of options a company might take on, for example, short and long-term contracts, joint ventures, franchising, and licensing (Kim, 2019). Shaped by Coase (1937), the neoclassical view of vertical integration comes from the perspective of market efficiencies and concludes that integration is a response to upstream and/or downstream market powers in an attempt to exploit them. For example, Mahoney (1992) argues that price discrimination is one of the reasons for a firm to vertically integrate or use vertical integration for increasing barriers to entry. Specifically, Mahoney (1992) suggests that an intermediate good monopolist would price discriminate depending on the price sensitivity of the buyer's industry. Thus, there is a risk of arbitrage between downstream companies with different price sensitivities which can be prevented through vertical integration by the upstream monopolist (Mahoney, 1992). Such a conclusion is a great example of the neoclassical view of vertical integration as a tool to tackle market efficiencies; however, a different, more strategically relevant view of, and approach to, vertical integration is introduced below.

2.3.2 Vertical Integration as a Strategy

Advantages and Disadvantages of Vertical Integration

Strategy literature perhaps provides a more study-relevant approach to explaining vertical integration, as it is treated therein as a complex strategy existing to address and fulfill various needs (Kim, 2019). The advantages and disadvantages of this strategy have been outlined by Harrigan (1984). In particular, advantages include the reduction of outsourcing costs, improved coordination of activities, increased efficiency due to the transparency of negotiations with contractors, improved intelligence, differentiation possibilities, a higher degree of control over the economic environment and product quality, and synergy creation possibilities (Harrigan, 1984). Disadvantages include higher vertical structure coordination cost, higher risk of supply mismanagement, costs of exceeding capacity due to the minimum running output, higher exit barriers, loss of information exchange with suppliers, and default use of vertical integration even when it is not the optimal strategy (Harrigan, 1984).

Dimensions of Vertical Integration

In her study, Harrigan (1984) states that when making decisions to pursue any of the vertical integration strategies, there are 4 dimensions that those decisions are based on: the number of integrated activities within the firm, the different levels of integrated activities, each vertical linkage and the number of internal transfers that occur, as well as ownership forms used in controlling the vertical relationships. The first dimension described refers to the number of tasks that are performed within the firm, meaning that performing many upstream and downstream activities "in-house" characterizes the firm as broadly integrated, whereas if there are few tasks that are performed "in house", the firm is characterized as narrowly integrated (Harrigan, 1984).

In turn, the second dimension refers to the number of different levels that are handled within vertically integrated firms. In this study, Harrigan (1984) shows how it is acceptable to skip a stage of production within the chain if doing so makes the end goal easier to reach or makes the production flow in an improved way. Furthermore, in the third dimension, she delves into the different proportions of goods produced, and what percentage of that same good is produced "in-house" (Harrigan, 1984). The larger the portion of goods being produced within the firm, the more vertically integrated it is. Finally, in the last dimension, Harrigan claims that the different forms of vertically integrated ownerships within firms dictate the amount of a firm's equity invested in vertically-linked ventures (Harrigan 1984). She continues to describe the different ways that a firm can choose to integrate when investing equity. For example, franchises, joint ventures, and other quasi-integration forms can be considered a great substitute for wholly-owned ventures (Harrigan, 1984).

Alternatives to Vertical Integration

Harrigan (1984) has thus discarded a simplistic view of integration and instead introduced a concept of multi-dimensionality. Thus, the pursuit of a vertical integration strategy has several alternatives. These include non-integration, quasi-integration, taper integration, and full integration (Harrigan, 1984). Non-integration is a strategy solely using contracts and markets and is especially attractive when investment into highly specific assets is unattractive and the industry faces a lot of uncertainty. Quasi-integration, by contrast, displays the ownership of activities as the use of joint ventures, equity agreements, and non-equity agreements which still bring a high degree of flexibility but are associated with a higher degree of risk (Harrigan, 1984). When a company is partly reliant upon supply from another business, the company is taper integrated, which allows it to balance between higher control over the supply chain, while also keeping a high level of flexibility. The final form then is full integration which is characterized as full control over internal transfers and the value creation process (Harrigan, 1984). These different forms of integration are particularly important for understanding the findings of this paper, particularly in interpreting the calculated integration levels of the sample firms. Methodological reservations which are outlined in the methodology chapter of this paper set limits in identifying quasi-integration due to the non-equity contracts used. Thus, this paper will quantify and distinguish between non-integration, taper integration, and full integration.

Factors Affecting Integration

Furthermore, quite a few other factors affect the way that firms adapt to the dimensions mentioned previously. Firms adapt their strategies to pursue vertical integration in accordance with the following forces: sales, growth change, the volatility of the specific industry, the bargaining power of customers, consumers, suppliers and distributors, and the company's objectives (Harrigan, 1984). In this case, the number of integrated activities within the firm, the different levels of integrated activities, each vertical linkage, and the number of internal transfers that occur, as well as ownership forms used in controlling vertical relationships are affected by these different levels of development within the industry (Harrigan, 1984). Thus, one can deduce that the MNC's that have been taken into consideration are highly affected by the volatility in the semiconductor industry due to the supply shortage, meaning the levels of vertical integration that these companies will incorporate depends on the volatility of the specific industry.

Sales, growth, and demand changes affect the way that the MNC's react in terms of integrating vertically (Harrigan, 1984). The semiconductor shortage is again a good example, as it has caused many changes in various companies' strategies and has been constantly worsening as demand continues to rise, a contributing factor to why some of the biggest MNC's in the automotive and consumer electronics industry have been stocking up on semiconductors to avoid the negative effects of this shortage (Vakil & Linton 2021). Before the pandemic, the demand for products containing semiconductors was known to be constantly rising, whereas in 2021, during COVID-19, there has been a significant decrease in demand among end consumers which subsequently caused the production demand for semiconductors to decrease (Vakil & Linton 2021). So, considering the volatility of many key forces in semiconductor-reliant industries, one might expect that MNCs might like to gain some level of ownership and control over the factors of production needed to produce semiconductors, in order to gain a competitive advantage in both stable and uncertain phases.

2.3.3 Vertical Integration of MNCs

The trend of vertical integration is arguably more interesting within MNCs than in domestic firms, as it would seem that MNCs have more of an ability and propensity to benefit from arbitrage-based outsourcing strategies in production, especially if they span countries of varying economic and industrial development which is often the case. However, Alfaro (2016) states that multinational firms with stronger vertical production were more resilient and performed much better during a crisis period compared to firms that had a more outsource-reliant production. In her study, she analyzes the global patterns of MNCs, where she discusses their determinants. She concludes that a firm's tendency for upstream integration depends to a great extent on the elasticity of demand for the final product and the elasticity of substitution within the production stages. This can be an explanation as to why when MNCs are facing substantial levels of risk, they tend to adjust accordingly to the change in demand, as contextualized in Vakil and Linton's (2020) article. In cases of uncertainty and risk, the demand is highly dynamic and unpredictable, making it difficult to quantify; however, it affects the different stages of vertical integration and is thus important to keep in mind during this analysis. Alfaro (2016) also references the role of demand in the consideration of vertical integration strategies. She states that when demand is elastic, input investments are considered to be consecutive complements; however, when demand is inelastic, input investments are consecutive substitutes, meaning that in situations where demand is inelastic, firms choose to integrate upstream and outsource the downstream suppliers (Alfaro, 2016).

Since demand volatility is tightly linked to times of uncertainty, another reason for MNCs to pursue an integration strategy in an uncertain environment is the advantage of developing a faster response to changes in such an environment. Buzzell (1983) argues that the benefits of integration include better supply chain coordination, supply assurance, and innovation capabilities, which implies that a vertically integrated company is able to respond to a rapid change in the environment by promptly delivering innovation to the market. According to this study and the others introduced previously, one can conclude that MNCs would likely tend to follow a trend of vertical integration when facing unusual risk levels or uncertainty.

2.4 Vertical Integration & According Empirical Studies

2.4.1 Empirical Studies: Vertical Integration & Uncertainty

Empirical studies that have been done so far have centered around the relationship specifically between uncertainty, rather than risk, and vertical integration, something complex to study since the term uncertainty can be interpreted rather broadly (Krickx, 2000). In Krickx's (2000) article, uncertainty can be split into three categories: environmental and external uncertainty, relating to random occurrences in the global environment which often affect consumer preferences, organizational and internal uncertainty, relating to lack of coordination and ineffective decision-making stemming from partially informed decision-makers, and strategic uncertainty, indicating the combined effect of opportunism and uncertainty as it relates to a firm's customers, suppliers, and competitors (Williamson, 1989). When taking the aforementioned reasonings of transaction cost theory into consideration, it is hypothesized based on the preliminary findings of previous studies, that uncertainty, besides technological, has a positive relationship or correlation with vertical integration (Krickx, 2000). Krickx (2000) sought to find a generalizable outcome of fifteen previous empirical studies that indicates either support or rejection for this hypothesis; however, this outcome could have a quite large margin of error, seeing as most of these studies had different sample sizes, something addressed by using a weighted average, and chosen variables, both in types of uncertainty used (e.g. unpredictability, performance ambiguity, technological, demand, volatility, competitive, sales growth, dynamism, environmental diversity) and dependent variables (e.g. vertical integration, intra-firm transfers, channel integration, use of direct sales force, R&D intensity), although most used vertical integration (Krickx, 2000).

The overall conclusion was that a relationship between uncertainty and vertical integration depends greatly upon the type of uncertainty being considered, and the use of weighted versus unweighted samples yielded different results, with unweighted indicating a stronger likelihood for a positive correlation and weighted indicating a stronger likelihood for a negative correlation (Krickx, 2000). Support for the idea that the relationship between uncertainty and vertical integration depends on the type of uncertainty considered was found using the same sample in a chi-square test, with a focus on results of different types of uncertainty (Krickx, 2000). This test also showed varied results with regard to a positive or negative relation for each type of uncertainty (Krickx, 2000).

2.4.2 Empirical Studies: Vertical Integration and Risk

One prior empirical study can be found which is quite similar to the one that will be used within this paper in terms of choices in variables, so it offers somewhat of a benchmark. Helfat and Teece (1987) performed a Wilcoxon Signed Rank Test on fourteen sample firms that were involved in vertical mergers between 1948 and 1979 and their fourteen acquiring counterparts to see if there was a significant relationship between a firm engaging in a vertical merger and a reduction in the firm's respective systemic risk, denoted by beta **β**. This was done by using each chosen merging firm's pre-merger estimated beta to predict a respective post-merger estimated asset beta or unlevered beta, and subsequently calculating the actual post-merger weighted asset beta, with the same process used to find values for the respective firms in the control group i.e. those that did the acquiring (Helfat & Teece, 1987).

The Wilcoxon test results showed that when one specifies vertical integration as a vertical merger, there is an observable tie between vertical integration and a reduction in **β** which in this case denotes systemic risk (Helfat & Teece, 1987). It is important to note that there was no adjustment for profitability and firm size, so larger firms could have impacted the index beta in a disproportionate way to smaller firms which the authors admitted made it biased against the finding of risk reduction (Helfat & Teece, 1987). Despite this, the results seemed to show a reduction in risk for merging firms when vertical mergers were performed (Helfat & Teece, 1987). Since this paper will aim to test a relationship between somewhat of the inverse of the variables used in this study, namely the potential correlation between changes in the unadjusted **β** of a firm and its respective calculated level of vertical integration, the results in the aforementioned study are valuable in hypothesizing an outcome. Thus, it seems one can cautiously expect a positive correlation between changes in risk and changes in vertical integration if one is to interpret and extrapolate Helfat and Teece's (1987) results.

2.5 Chapter Summary and Hypothesis Formulation

The literature review chapter of this report has introduced a diverse view on vertical integration, uncertainty, and risk, by introducing relevant theories, studies, and empirical evidence. First, the study starts by introducing organizational theories that attempt to explain vertical integration from the perspective of sociological behavior within organizations. These included property rights theory, agency theory, and transaction cost economics, the last of which offered the broadest and most comprehensive view of vertical integration and its driving factors by breaking transaction costs down to asset specificity, transaction frequency, environmental, and behavioral uncertainties. While multiple relevant theories have been discussed, the main focus is on transaction cost theory which was directly linked to vertical integration by Williamsson (1986), where components such as asset specificity, transaction frequency, and uncertainty were affecting the extent to which a firm might pursue integration.

Second, by relating to environmental uncertainty in transaction cost economics, the role of uncertainty in the organizational theory and its relevance to vertical integration was scrutinized. This was followed by the introduction of risk, where the relationship between uncertainty and vertical integration was discussed. More specifically, Krickx (2000) has discovered a positive relationship between uncertainty and vertical integration by presenting empirical evidence of such a relationship. This study is of significance as it served as a reference point for this paper, as it is one of the very few studies successfully quantifying vertical integration and the factors affecting it.

Third, the subjective and thus complex term vertical integration was introduced from two different perspectives. A neoclassical view of vertical integration as a tool for exploitation of market efficiencies was followed by a take on vertical integration as a strategy by Harrigan (1984). Vertical integration as a strategy was further broken down into dimensions, characteristics, alternatives, and factors affecting it. This framework of assessing vertical integration is adopted in this research to further assess the relationship between integration and systemic risk.

Finally, after further exploring vertical integration in MNCs specifically, theories on the measurement of vertical integration have been introduced together with empirical evidence from previous studies of relationships between risk, uncertainty, and vertical integration to set expectations and support choices in quantification methodology. In this way, theoretical and empirical evidence of a positive relationship between vertical integration is introduced. The largest contribution to this research, however, was made by Buzzell (1983) in his study developing and using a formula for the accurate quantification of the vertical integration level of a firm's activities, which was adopted to quantify vertical integration levels of sample companies included in this study.

Altogether, these theories and studies have created a broad yet detailed background for researching, analyzing, and testing for a relationship between systemic risk and vertical integration within this study. The null and alternative hypotheses are expressed as follows:

H_0: There is no relationship between systemic risk and vertical integration amongst MNCs.

H_1: There is a relationship between systemic risk and vertical integration amongst MNCs.

3 Methodology

3.1 Research Approach

This paper will implement a quantitative analysis of the relationship between systemic risk and vertical integration, specifically in multinational firms. In order to better isolate the relationship between these two variables, the scope of the analysis is narrowed to focus on multinational firms, specifically those belonging to industries most affected by the semiconductor shortage during the COVID-19 pandemic, including consumer electronics, electronic components, automotive, healthcare and pharmaceuticals, information communication technology, and energy (Howley, 2021). This approach is beneficial since it standardizes the source of, in this case, systemic risk so that its measured magnitude varies to a greater extent due to firm-specific internal factors rather than in combination with other external factors. In addition, it allows for an observation of changes in vertical integration and risk for a firm from a year with relatively normal levels of risk to a year during the COVID-19 pandemic which is widely accepted as a time period posing a substantial systematic risk in the global business environment (OECD, 2021). Thus, 2021 was chosen as a test year for examining the relationship between risk and vertical integration since it allows for an observation of firm behavior after a full year of semiconductor shortages, and it is reasonable to expect that risk levels increased as a result of this in semiconductor-reliant industries from the base year of 2015 which was chosen to represent a relatively stable year for the global business environment risk-wise (McKinsey, 2015). From the aforementioned industries, one hundred and one multinational firms were selected to be included in the analyzed sample since this sample size is statistically accepted to yield trustworthy results through its small margin of error and limitation for the influence of outliers (Martínez-Mesa, 2014).

3.1.1 Sampling Method

Since vertical integration theory is so multifaceted, as can be seen from the breadth of relevant literature in the previous chapter, there appear to be quite a few different components that are in some way connected to or affect the choice of this strategy like asset specificity, incomplete contracts, uncertainty, risk, etc., the only one of which able to be quantified with ease being risk. In addition to these components, there are also other, less obvious underlying potential explanatory factors to why a firm becomes more or less vertically integrated besides systemic risk including firm size, profitability and elasticity of demand to reiterate a few pinpointed in the theoretical review. For the statistical analysis done in this paper, one is able to control for firm size and profitability specifically since these are quantifiable terms and thus easily comparable. To control for firm size, the scope of the analysis is limited to multinational firms which are not owned by any other firm. This approach not only leads to a sample of firms that are very similar in terms of size but also makes sure that there are no accounting discrepancies caused due to some firms' financial reports being affected by their parent or acquiring company. In terms of profitability, to some extent this factor is inherently controlled for when controlling for size; however, the formula used in this paper (refer to Figure 3) to quantify vertical integration includes a component that adjusts for differences in profitability, namely through the use of an average return on investment (ROI) for the sample which is multiplied by the net profit for each firm to control for varying levels of profitability amongst sampled companies.

In addition, to control for, at least to some extent, the level and source of systemic risk, it was decided to select firms belonging to industries most heavily affected by the semiconductor shortage which was a parallel by-product of the COVID-19 pandemic. This is important since for some firms COVID was an opportunity rather than a risk, and thus the assumption that the pandemic posed a substantial systemic risk for any given multinational firm is inaccurate and would lead to untrustworthy results regarding a potential relationship between vertical integration and systemic risk. The semiconductor shortage undoubtedly posed a clear systemic risk rather than an opportunity for semiconductor-reliant industries since it disrupted their production of goods and services due to pandemic-driven amplifications of pre-existing bottlenecks (Gwennap, 2022). Thus, it is a robust control for the level and source of systemic risk experienced by the sampled firms.

3.1.2 Beta as a Measure of Systemic Risk

Because the statistical endeavor of this paper is to test for a correlation between vertical integration and risk, the level of, and change in, vertical integration is considered to be dependent upon the level of, and change in, risk, meaning vertical integration will be the dependent variable and risk will be the independent variable. Both of these variables require quantification. Systemic risk was decided to be quantified by beta **β** which is a measure of systematic risk and denotes the volatility of a firm's stock compared to the market

(Harrington, 2014). Although this study is focused on the semiconductor shortage, which is characterized as a systemic risk as it affects specific industries, the exposure to this risk is uneven amongst the companies. Therefore, the extent to which a single company is affected by the semiconductor shortage can be measured by beta **β**. This is because although systematic risk is ongoing, it is amplified or dampened by exogenous factors like systemic risk, meaning the measure of systematic risk, beta **β**, accurately takes into account and reflects the systemic risk faced by an individual company during a time frame of interest (Nguyen, 2021). This is reflected in the noticeable market volatility changes and deviations across industries when systemic risks like wars, inflation, and pandemics, to name a few, occur. Company-specific betas, therefore, seem to accurately represent the systemic risk level and thus can also be used to calculate the change in risk level that COVID and its parallel semiconductor shortages pose for firms since they are classified as systemic risks (Rizwan, Ahamd, Ashraf, 2020). In addition, beta values are readily available for publicly listed firms not only in terms of current values but also historical, in select, accessible financial databases like Bloomberg.

3.1.3 Methodology for the Quantification of Vertical Integration

Unfortunately, finding a relationship between vertical integration and risk is quite difficult due to the information required to quantify a firm's level of integration. Broadly speaking, the term vertical integration seems to be used quite loosely as one could argue that any company internalizing any aspect of their value chain is vertically integrated at least to a small degree. Thus, based on experiences searching for internet sources evaluating the level of vertical integration of different companies, it seems that most assessments of degrees of integration are quite subjective and thus require quantification and an according scale to be accurately and uniformly evaluated. Previous peer-reviewed articles and studies provide a logical and widely-accepted yet preliminary formula for measuring vertical integration. The basic idea is to find the value-added of a company and divide it by its sales revenue, in order to obtain a percentage indicating the proportion of integrated value-adding activities to the total value created by way of the value chain (Buzzell, 1983).

One academic text, centering around finding a measurement for vertical integration, explains various methods developed for this purpose as well as their strengths and weaknesses, to finally arrive at the two most developed and accurate measures, one of which will be used in this study (Nugent & Hamblin, 1996). The first measure (Figure 1), created by

Morris Adelman, reflects a very simplistic way of measuring and interpreting vertical integration by simply taking value-added as a proportion of a firm's total sales, as alluded to previously. Although this method makes logical sense in that it uses the percentage of how much a firm spends adding value to its product or service itself, rather than outsourcing, to the total value of its sales to show the level of integration, it does have some key drawbacks. For one, the measure seems to be affected by the point of the value chain a firm finds itself in which is important to note since the potential to add value is generally highest for firms in the upstream stages (Nugent & Hamblin, 1996). The second drawback is that it does not adjust for the profit level of a firm which is problematic since this is something that can sway the level of vertical integration and thus make the comparison of integration levels between firms with varying profitability levels inaccurate (Nugent & Hamblin, 1996). Thus, the measure was then developed and adjusted for profitability by Joseph Vessey (Figure 2) to overcome the disadvantage of Adelman's inclusion of profits for a firm that had the potential to influence the vertical integration value (Nugent & Hamblin, 1996). Unfortunately, this measure still suffers from dependence on the value-added chain stage, but this is something quite difficult to adjust for. Bowman and Buzzell went on to adjust Vessey's measure by factoring in the average ROI of each firm used in a statistical sample to standardize profitability levels, which works to enable a more accurate study of integration levels of unlike firms earnings-wise (Nugent & Hamblin, 1996).

Since this development, a few different researchers like Werner Sichel, Ruth Maddigan, and Arthur Burgess have come up with different methods of calculating the level of vertical integration by interpreting it as a measure of divergence from industry norms, developing a vertical industry connections index (VIC) to measure linkages between inputs and outputs to a production process with a view of vertical integration as a strategy of ownership and control of the production of goods and services, and suggesting two indices for vertical integration, one for the length of the value chain and one for linkages between business units, respectively (Nugent & Hamblin, 1996). Sichel, Maddigan, and Burgess' methods (Appendix B), though being more elaborate, are difficult to use since much of the necessary input values to the formulas are not public information, such as values for total internal transfers (Nugent & Hamblin, 1996). Therefore, Bowman and Buzzell's measure (Figure 3) will be used in this paper since its components are publicly available or able to be calculated with public information, and it has been implemented in previous, credible empirical studies where vertical integration was a factor requiring quantification (Nugent & Hamblin, 1996).

Figure 1: Adelman's VI Measure (1955)

$$V = \frac{\text{Value added}}{\text{Sales}}$$

Figure 2: Vessey's VI Measure (1978)

$$V = \frac{\text{Value added} - \text{Profit}}{\text{Sales} - \text{Profit}}$$

Figure 3: Bowman & Buzzell's Measure (1978 & 1983)

$$V = \frac{\text{Value added} - \text{Profits} + 20\% \text{ of investment}}{\text{Sales} - \text{Profits} + 20\% \text{ of investment}}$$

Note: "20% of investment" represents a sample average ROI, it is not a standard value

3.1.4 Application of Theoretical Methodologies

Vertical integration was decided to be quantified for each firm using Bowman and Buzzell's formula (Figure 3) which is reliant on the subsequent quantification of its key component value-added. The way value-added is defined for the purpose and context of this paper is as a measure of what a firm chose to internalize as opposed to outsourcing, only in terms of the direct production of its goods or services. This reflects the previously mentioned view of vertical integration as a make-or-buy strategy. Put simply, value-added is the difference in the price of a good or service and the cost of producing it (Buzzell, 1983). However, if calculated in this way, value-added accounts for both the value-added in-house and the value that was added through outsourcing, but the value of interest is only what was added in-house. The difficulty with this is that credible and consistently reported data for every company regarding the proportion of in-house production is not often available.

The Bloomberg Terminal, however, offers a unique resource in its supply chain analysis tool (SPLC) which uses a credibly sourced curation of data for around 900,000 supply chain relationships globally, spanning both public and some private firms (Bloomberg Professional Services, 2020). Companies are required to report firms involved in their value chain that account for over 10% of their revenues, and Bloomberg uses various sources of compiled data, financial and otherwise, and its own algorithm to estimate the percent of revenues, capital expenditures, and cost of goods sold (COGS) that each customer and supplier makes up for in their value chain relationship with a chosen focal firm, both currently and in previous years (Figure 6) (Bloomberg Professional Services, 2020). As is visible in Figure 4, the focal firm appears in the center of the analysis and shows what percent of the firm's COGS is attributable to suppliers. This percentage can then be applied to a firm's total COGS in a given year which is always disclosed in financial statements such as annual reports, conveniently also available on Bloomberg, to estimate the value it added in-house. This derived value-added can then be used in Buzzel's formula, whose components will be detailed more clearly in the next section, to arrive at a value quantifying a firm's level of vertical integration.

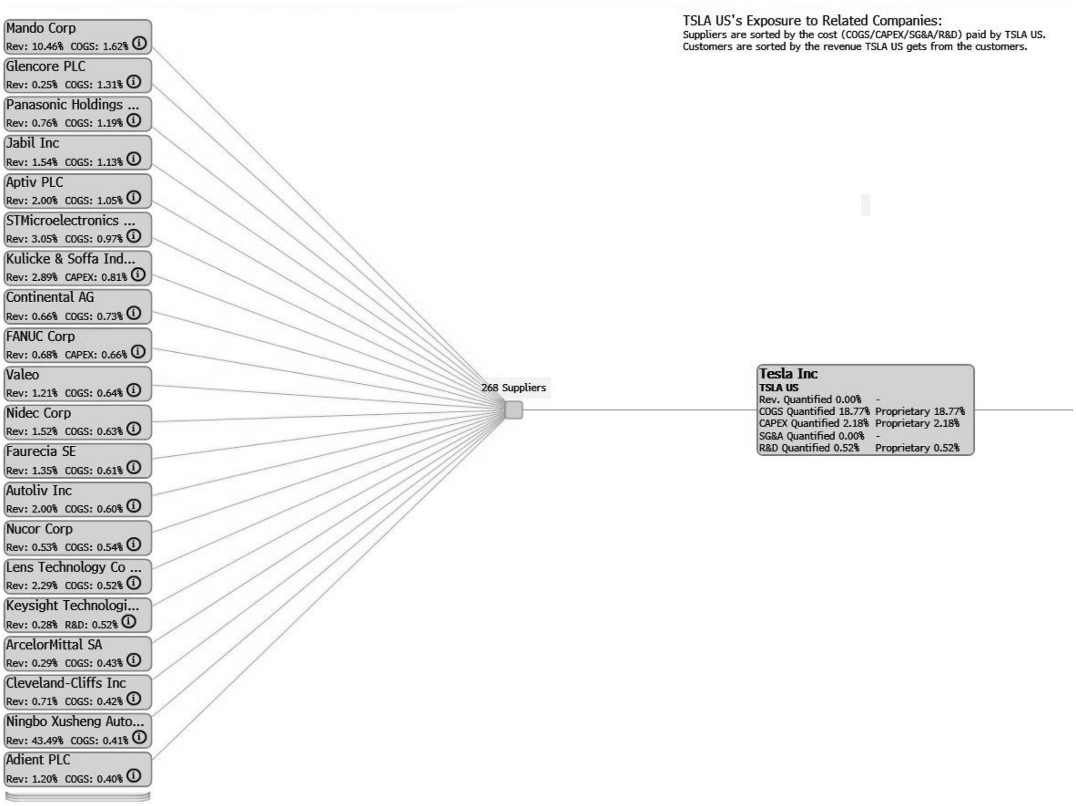

Figure 4: Sample SPLC Analysis for Tesla

3.1.5 Regression Analysis

To determine whether or not a correlation exists between the two variables, the best approach seems to be the use of a simple regression analysis (Gallo, 2015). This method of statistical analysis is most aligned with the aim of this paper as it allows one to derive the degree of influence that an independent variable, in this case, systemic risk (**β**), has on a dependent variable, in this case, the level of vertical integration (Gallo, 2015). In this way, there is an ability to test the arguably generalizable hypothesis alluded to by different facets and views of transaction cost, agency, and property rights theory which have been outlined previously, that there exists a positive relationship between risk and vertical integration. In other words, regression analysis allows for a more empirical support or rejection of this thus far overwhelmingly theoretical conclusion. Using a regression also has the benefit of showing the strength of the correlation between the two variables through the correlation coefficient, denoted by the letter *R,* which is limited to a scale between negative one and one, with a negative correlation indicating an inverse relationship and positive indicating a direct relationship. It is very beneficial to easily be able to interpret the strength of the correlation found in order to conclude whether the statistical analysis performed yields definitive results or if they should be treated with skepticism.

3.1.6 Normality Assessment Approach

To ensure that the linear model put forth is a good fit and that its regression results are accurate, it is important to test whether the dataset is adequately normally distributed. Thus, in assessing the normality of the data used and to decide whether to use absolute change or percent change in the calculation of Δ for both vertical integration and beta **β**, descriptive statistics by way of the JASP statistics program will be used, specifically measures of skewness and kurtosis. Both are widely accepted and used to test data normality, with skewness measuring symmetry or deviations from the normal distribution, commonly graphically represented by a bell curve, as well as the direction of outliers, and kurtosis measuring the weight of a distribution's tails, or outliers (NIST, 2012). Both are, in this way, uniquely beneficial in testing for the potential influential magnitude of outliers on the distribution of the dataset used in this paper. The values found for kurtosis and skewness and their respective analysis will be detailed in the next chapter.

3.1.7 Residual Analysis Approach

To further assess the validity of the model presented in this paper, it is also beneficial to take a closer look at the residuals. As residuals are a measure of the difference between the predicted value for a dependent variable and its actual value, they offer insight into the predictive accuracy of a linear regression model (Kim, 2019). If the residuals are centered around zero, this is generally indicative of an accurate model that does not predict values that are too low or too high (Kim, 2019). Residuals will thus be analyzed in a couple of different ways for this paper. First, the residual plot and residual histogram will be examined, and then, the Durbin-Watson statistic which is a way to test for autocorrelation, something unwanted in a linear regression since it violates the assumption of independence of errors and indicates that the model is in some way inaccurate (Chen, 2016). The Durbin-Watson statistic, as a general rule of thumb, should have a value of about two to verify that no autocorrelation is present, and ranges from zero to four (Chen, 2016). When looking at the residual plot, there should be no pattern in the residuals i.e. they should be random, and the histogram of the residuals should show a normal bell curve distribution since the normality of residuals is another key requirement or assumption to run an accurate linear model (Barker & Shaw, 2015). The residual analysis for the focal model of this model will be detailed in the next chapter.

3.2 Research Design

In designing a methodology to analyze the relationship between components whose quantification is quite preliminary and subjective in terms of scope, as is the case for vertical integration and risk, it is imperative to not only have robust and logical arguments behind what values or key elements should be used to represent or calculate a quantification for these components, but also that values and key elements constituting these components are able to be found in a credible and consistent manner for all firms included in the chosen statistical sample. This consideration rationalized the decision to focus on large multinational firms which are publicly listed since these types of companies are most likely to have the most publicly-available information through credible sources as they are often the most well-known. Almost all financial data was found using the Bloomberg Terminal, except for ROI's whose compilation will be discussed later in this section, in order to keep the data collection consistent source-wise as Bloomberg is the only accessible platform harboring a credible and comprehensive supply chain analysis tool. Since the SPLC tool is

Bloomberg-specific, and its relevant components i.e. COGS outsourcing percentages are, at least in part, calculated using respective financial data i.e. total COGS, it was decided to be most accurate if other relevant financial data was also pulled from the financial statements contained in the Bloomberg Terminal through the financial analysis (FA) tool. The financially-reported components used and their relevance will also be detailed in the coming sections.

3.2.1 Sampling Choices & Beta Retrieval

As mentioned previously, industries were chosen based on their exposure to systemic risks caused by semiconductor shortages during the COVID-19 pandemic, since this would give firms included in the sample a commonality in the form of a substantial risk faced. As well, only multinational firms that are not owned by another company were chosen to avoid the influence of accounting discrepancies. Doing so works to hone in on a relationship or trend to either pursue an outsourcing or vertical integration strategy as a response to heightened systemic risk. This method results in a display of the varying effect of systemic risk on each firm's stock price volatility, visible in the firm's respective change in beta from 2015 to 2021, beta **β** being chosen to represent the independent variable systemic risk. Historical and current annual betas for each of the one hundred firms were accessed through Bloomberg's BETA tool (time frame set: 01/01/2015-31/12/2015 & 01/01/2021-31/12/2021) to find the relevant measures of systemic risk in the chosen the base year of 2015 and the "risk" year 2021 (University of Pennsylvania, 2021).

3.2.2 Value-Added Calculation Methodology

The chosen method for quantifying vertical integration, the dependent variable, comes in the form of Bowman and Buzzell's profitability-adjusted formula, identified in Figure 3. As depicted, the key components in this formula include sales, value-added, sample average ROI, and profit. As explained previously, value-added was derived using the Bloomberg Terminal SPLC analysis tool which quantifies the percent of COGS that suppliers account for any given firm in the sample for both 2015 and 2021. Next, total COGS for each firm, both for the base and risk year, was pulled from income statements using the FA Bloomberg tool. The supplier-driven COGS percentages for each firm for 2015 and 2021 were then multiplied by the total COGS values for the respective years, working to reach a value representing which costs to produce the firm's goods or services were incurred due to outsourcing, rather than in-house processes. Since value-added is equal to the difference between the price of a good or service and its cost of production, gross sales for each firm for the two relevant years were also pulled from income statements using the FA tool to isolate in-house value-added from outsourcing. As can simply be deduced, the supplier-driven COGS values were then subtracted from gross sales for each firm for both 2015 and 2021, leaving the value-added solely in-house by every firm.

3.2.3 Profitability Adjustment Methodology

As mentioned before, profitability can influence the vertical integration measure for a firm if it is not accounted for. This was another reason for the choice of Bowman and Buzzell's formula to quantify vertical integration since it has a component that adjusts for profitability, namely the component where the profit of a firm is multiplied by the average ROI for the sampled firms in the respective years (Figure 3). Thus, it was ensured that vertical integration levels were not swayed by deviations in profitability amongst the sampled firms.

3.3 Data Collection Method

For the purpose of testing the hypothesis H_1, the following data is required: 100 multinational companies in the industries affected by semiconductor shortages, financial statements (income statement and balance sheet) which include gross sales, cost of goods sold, total assets, and current liabilities for the year 2015 and year 2021, a supply chain analysis which includes a share of the cost of goods sold outsourced for the respective companies for the years 2015 and 2021, and historical betas for the years 2015 and 2021.

A hundred and one companies were selected by performing a systematic search on Yahoo Finance for industries affected by semiconductor shortages and then identifying companies that would satisfy the selection criteria mentioned above. This list was created in a spreadsheet in the Microsoft Excel software, which was also used for further calculations.

Gross sales, cost of goods sold, total assets, and current liabilities from financial statements for two respective years were accessed using Bloomberg Terminal and reported into two separate spreadsheets (years 2015 and 2021) with 100 calculations, an example of which is given in Figure 5 below, to derive the vertical integration levels for each company. The data in the terminal was accessed by selecting the option “Financial Analysis” and selecting the company of interest.

Tesla	
Gross Sales	4046
COGS	3112
% COGS Outsourced	0.3699
Outsourced Value	1151.1288
Added Value	1960.8712
VI	**0.715489669**
Total Assets	8067.9
CL	2811
Capital Invested	5256.9
ROI	0.085052451
% Capital Invested	447.1122296
Profits	-888.7
Adj. VI	**0.786107588**

Figure 5: Calculation of VI for Tesla in 2015

The share of COGS outsourced was accessed by selecting the option "Supply Chain Analysis" on Bloomberg Terminal for each company for 2015 and 2021. The value was further reported in the calculation of vertical integration in Excel.

Historical betas were accessed by using the function "Historical Beta" on Bloomberg Terminal for every company by selecting its according to equity name, entering the company's domestic market index (e.g. SPX, KOSPI, HSI, TWSE), specifying the relevant time frame, and choosing the option "weekly last price". The data was then reported into a separate spreadsheet designated for the collection of beta values.

3.4 Data Analysis

To test for a relationship between systemic risk and vertical integration, a simple regression was run. Since simple regressions require two variables (in this case delta (Δ) as the dependent variable, and beta (**β**) as the independent), several steps aimed at calculating and reporting values in the required form had to take place. Upon completion of the data collection, calculations for vertical integration using (Figure 3) Bowman and Buzzell's formula (1983) were performed. The calculation was done for every sample company for both years of interest and was recorded as shown in Table 1. Further, all data was reported in a consolidated spreadsheet in a uniform format (company name, VI 2015, VI 2021, absolute change VI, relative change VI, Beta 2015, Beta 2021, Beta absolute change, Beta relative change) (Appendix A). Later, the outliers, which occurred due to methodological limitations, were removed and replaced by other companies.

For convenience, VI change and beta **β** change (both absolute and relative) were later placed in a separate file in a format suitable for JASP statistical software (.csv), which was used to run the regression. The file was later opened in JASP, and the option "Descriptive Statistics" was chosen to identify whether the absolute or relative change was a better fit for running a regression. Later, it was identified that relative changes of VI and beta were more skewed and had higher kurtosis values. Therefore, absolute change was chosen as the appropriate value for running a regression as it was normally distributed. After this, "linear regression" was chosen. Delta (Δ) was chosen as the dependent variable, and beta **β** as the independent. In the "Statistics" tab, the following options were chosen: regression coefficients (estimates, confidence interval 95%, and model fit), and residuals (Durbin-Watson). In the "Plots" tab the following plots were chosen: residuals histogram, Q-Q plot standardized residuals, and partial plot.

To test the normality of the dataset, the "Descriptive statistics" function of JASP was used. The following statistics were reported: standard deviation, skewness, and kurtosis. The following graphs were generated: distribution plot, and scatter plots of density.

3.5 Validity and Reliability

The validity of the data collected, and calculations performed can be assured in all steps of respective data collection and data analysis. Secondary sources such as literature, previous studies, and literature reviews were collected systematically to secure the reliability and relevance of the sources. All articles used were accessed through credible library sources and filtered as credible. The validity of the sample is secured by selecting a diverse sample of companies that originate from different locations, are in different stages of maturity, operate in different industries, and satisfy the selection criteria listed above. The accuracy of the calculations was secured by using credible and widely accepted calculation formulas for vertical integration consistently, applying the same calculation for the whole sample, and by the authors performing multiple calculations checks. The normality of the sample's values was assessed and confirmed by calculating the kurtosis and skewness. The data source used for accessing the elements of vertical integration calculations and historical betas, Bloomberg Terminal, is an academically credible source of financial information which in turn supports the accuracy and credibility of the data collected for this study (Kolakowski, 2021). The quality of the earlier mentioned regression analysis and model fit was secured by testing for autocorrelation, significance, and distribution of residuals. Thus, it can be concluded that the literature, data sources, and calculations should be considered reliable and accurate.

3.6 Limitations

Beta **β** is one of the most effective ways to measure systemic risk. However, there are disadvantages to using it as an overall measure of risk in this particular study. For example, beta **β** does not account for internal factors which can be disadvantageous to this research, since not considering all factors might cause inaccuracies in finding a correlation between systemic risk and vertical integration in MNCs. This is because business risk consists of systematic and unsystematic risks. Non-systemic risk is considered to be a risk that is specific to a company, something quite difficult to quantify without insider information for each firm, which is the reason it goes unaccounted for in this analysis, but it could nonetheless be very important in explaining and motivating vertical integration choices for the firms.

Furthermore, the limitations that the use of COGS presents should be considered. In the formula used to calculate vertical integration, COGS, and % of COGS is necessary to calculate the outsourced value and, as a by-product value-added, as shown in Figure 3. To derive value-added, costs of production are deducted from the price of the product or service. In turn, to calculate vertical integration, the COGS for each firm is multiplied by the % of COGS outsourced in order to get the outsourced value. That being said, even though COGS is considered to be an accurate presentation of the costs of production, it does not include certain costs like the marketing and R&D costs which are considered relevant to assessing the level of vertical integration. Thus, this analysis is limited to only quantifying and taking into account the direct costs incurred by a company in its production processes to measure integration levels.

On a related note, quasi-integration is also not able to be accounted for due to limitations regarding its quantifiability. In this study, the data is collected from publicly available financial disclosures which do not include information on partial ownership and/or non-equity agreements, something needed to identify quasi-integration (Kim, 2019).

3.7 Chapter Summary

The methodology chapter of this report details all methodological considerations regarding the research approach, research design, validity, and limitations of the study. In particular, the research approach subchapter includes an in-depth discussion on methods used for sampling, beta **β** as a measurement of systemic risk, quantification of VI, and regression analysis. The following research design subchapter includes practical details when analyzing and reporting the above-mentioned elements in relation to the research question. The data collection subchapter includes step-by-step considerations in data collection performed for this study. The validity and limitations subchapters revolve around arguments for the trustworthiness of the study and methodological limitations, respectively.

4 Results

This chapter is focused on the results of the regression analysis run in this study and will parallelly discuss methods and results for data normality assessments, performed to ensure validity, as well as noteworthy trends.

4.1 Descriptive Statistics & Normality Assessment

The simple linear regression was run in the JASP statistics program with the independent variable represented by the delta (Δ), or change, in beta **β** from 2015 to 2021 and the delta (Δ) of the dependent variable, vertical integration, 2015 to 2021. It is important to specify that delta, in the context of this paper, represents the absolute change between the two years, not the percent change, for both variables. The reason the absolute change was chosen for the regression is that its skewness and kurtosis values indicated a more normal distribution than that of percent change. Although there are many opinions around acceptable ranges for normality concerning skewness and kurtosis, a reputable rule of thumb is put forth by the University of Cambridge, identifying fairly conservative ranges to prove normality as negative three to three (-3 to 3) for kurtosis and negative two to two (-2 to 2) for skewness (Watson, 2018).

To assess data normality within this paper, these same kurtosis and skewness ranges were applied. As visible in Table 1 below, running the regression in JASP using absolute change showed skewness values for Δ beta **β** and Δ vertical integration (VI) as 0.044 and 0.895, respectively, and kurtosis values for Δ beta **β** and Δ VI of 0.179 and 2.895, respectively. When percent change (written as the relative change in Table 1) was used, skewness values for Δ beta and Δ vertical integration (VI) were 0.945 and 1.752, respectively, and kurtosis values for Δbeta and ΔVI were 3.217 and 6.578.

Because the skewness and kurtosis values for absolute change were not only within the respective key ranges but also closer to zero, thus indicating stronger normality than that of percent change, it was decided to use absolute change to ensure accurate results. Skewness values for absolute change in both variables were closer to zero, which according to Watson (2018) is the value of absolute normality regarding skewness, than percent change which supports the choice to use absolute rather than relative values. The same rationale can be applied to the kurtosis values. The percent change kurtosis values for both variables do not fall in the acceptable range, so this made for a simple secondary rejection of the use of percent change for the dataset. A graphical representation of normality is shown in Figure 6's distribution plots for both beta and VI absolute and percent changes, respectively, where it is observable that absolute change has a more normal distribution than percent change which is noted in its more symmetrical bell curve. One can also refer to Figure 7's alternative graphical representation through which one can once again observe that the linear model using absolute change seems to be a slightly better fit than that of percent change based on the distribution of data points around the line of best fit.

The previously discussed descriptive statistics output table is shown in Table 1, as well as the distribution plots in Figure 6:

Descriptive Statistics

Descriptive Statistics

	Std. Deviation	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis	Range	Minimum	Maximum
BETA CHANGE ABSOLUTE	0.368	0.044	0.240	0.179	0.476	1.758	−0.894	0.864
VI CHANGE ABSOLUTE	0.091	0.895	0.240	2.985	0.476	0.541	−0.196	0.345
BETA CHANGE RELATIVE	0.411	0.945	0.240	3.217	0.476	2.740	−0.866	1.873
VI CHANGE RELATIVE	0.176	1.752	0.240	6.578	0.476	1.207	−0.424	0.783

Table 1: Skewness and kurtosis values for absolute change in data vs percent change ("relative change" in the figure).

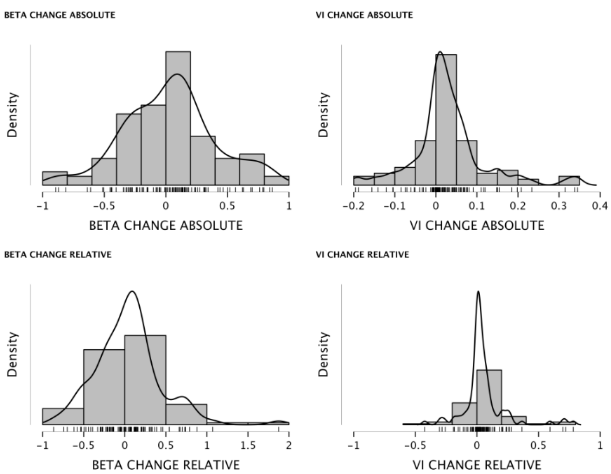

Figure 6: Distribution plots for absolute change vs percent change datasets.

The plots of Δ beta vs. Δ vertical integration in both absolute and relative values referred to above were generated to complement the distribution plots in Figure 6 and further graphically assess whether the use of absolute or relative change results in a better linear model:

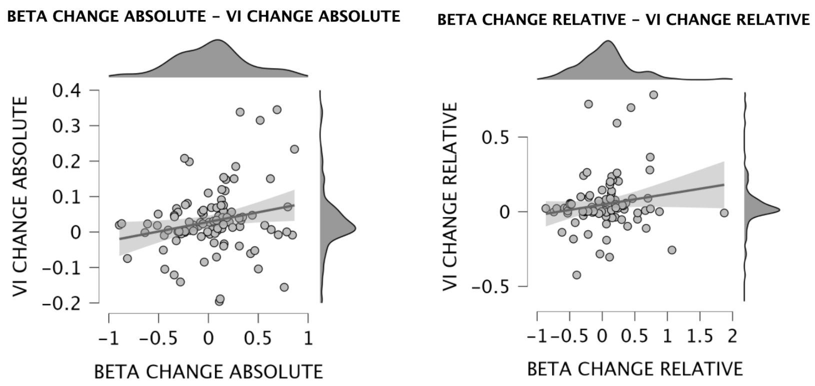

Figure 7: Plots of Δ beta vs. Δ vertical integration absolute and relative, respectively.

4.2 Residual Analysis

A residual analysis, as described and supported in the previous chapter, was also implemented to further assess the accuracy of the linear model. First, the plot of residuals was looked at to observe whether or not they appeared random or if there was a pattern. As observable in Figure 8 below, the residuals can be considered adequately random which supports the argument that the linear model is a good fit. As additional support for this, one can look at the distribution of residuals, which, as visible in Figure 9, are normally distributed, noted in the symmetry of the bell curve. This again indicates that the model used is a good fit and accurate in its predictions. Finally, the Durbin-Watson statistic was used to test for the presence of autocorrelation amongst the residuals. As mentioned previously, this statistic should be around 2.0 to reject that autocorrelation is present, and the result for the model used was 1.827, as visible in Table 2, with a p-value of 0.367. This means that at the 0.05 significance level, the null hypothesis that no autocorrelation exists between residuals cannot be rejected, and thus one can again assume that the model is accurate.

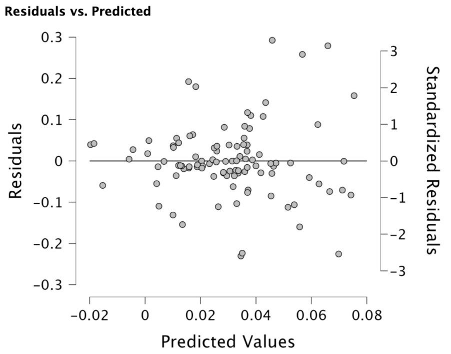

Figure 8: Residuals vs Predicted Plot

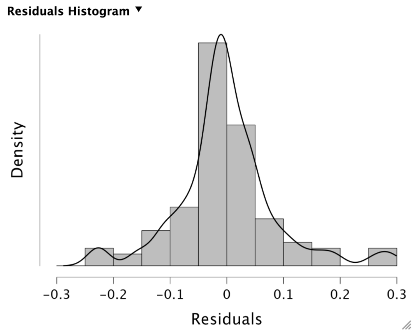

Figure 9: Residuals Histogram

					Durbin-Watson		
Model	R	R^2	Adjusted R^2	RMSE	Autocorrelation	Statistic	p
H_0	0.000	0.000	0.000	0.091	0.097	1.780	0.264
H_1	0.219	0.048	0.038	0.089	0.069	1.827	0.367

Table 2: Durbin-Watson Test; Note: H_1 statistic and p-value are of interest.

4.3 Trends in Data Collected

The values of **β** that have been collected for 101 companies for the years 2015 and 2021 indicate some important trends. The absolute change of **β** was found to be positive for fifty-seven sample companies, while for forty-four companies **β** has decreased. It indicates that for the majority of the companies from the sample the stock volatility, and thus riskiness, has increased in relation to the market index. It is therefore reasonable to state that there was indeed a trend towards higher market volatilities in the year 2021 compared to 2015. As seen in Table 3, the mean of the **β** change is 0.030 while the median is 0.057. Some of the companies from the sample have experienced a more drastic increase in **β** with the maximum **β** change reaching 0.864 increase, while a few companies from the sample have experienced a drastic decrease in **β** change with the value reducing by as low as -0.895, due to a relatively high **β** in the base year of 2015.

Values for the absolute vertical integration change of the sample companies between the respective timeframe (2015 to 2021) have indicated an overall increase in vertical integration with an increase for seventy-three companies, while twenty-eight companies have experienced a decrease in vertical integration value. As seen in Table 2, the mean of vertical integration change between 2015 and 2021 is 0.030, while the median is 0.020. The maximum value of change in vertical integration is 0.345, and the minimum is -0.196. It is reasonable to say that there is a trend towards an increase in vertical integration of the sample companies; however, the change was less dispersed and less extreme due to the nature of vertical integration. Vertical integration values reflect the internal organization of a company's value chain, thus the value is very unlikely to change substantially over a short period as re-organization of the value chain of a multinational organization is a timely process.

Descriptive Statistics

	Valid	Median	Mean	Range	Minimum	Maximum
BETA CHANGE ABSOLUTE	101	0.057	0.030	1.758	−0.894	0.864
VI CHANGE ABSOLUTE	101	0.020	0.030	0.541	−0.196	0.345

Table 3: Descriptive statistics of vertical integration and beta change.

4.4 Regression Results

The results of the linear regression are first displayed in a correlation table, as shown in Table 4, which summarizes the sample size, correlation coefficient (R) and p-value:

Pearson's Correlations

Variable		BETA CHANGE ABSOLUTE	VI CHANGE ABSOLUTE
1. BETA CHANGE ABSOLUTE	n	—	
	Pearson's r	—	
	p-value	—	
2. VI CHANGE ABSOLUTE	n	101	—
	Pearson's r	0.219*	—
	p-value	0.028	—

* p < .05, ** p < .01, *** p < .001

Table 4 : Correlation Table

A more comprehensive overview of the results is given by the full linear regression summary shown in Tables 5, 6 and 7:

REGRESSION ON ABSOLUTE CHANGE ▾

Model Summary - VI CHANGE ABSOLUTE

					Durbin-Watson		
Model	R	R^2	Adjusted R^2	RMSE	Autocorrelation	Statistic	p
H_0	0.000	0.000	0.000	0.091	0.097	1.780	0.264
H_1	0.219	0.048	0.038	0.089	0.069	1.827	0.367

Table 5: Regression Model Summary; Note: R & R^2 are of interest

The model summary shown in Table 5 allows one to observe the correlation between the two variables of interest, change (Δ) in vertical integration and change (Δ) in beta **β**. In addition, it provides insight into whether or not there is autocorrelation amongst the residuals which is reflected in the Durbin-Watson test. The values of interest are therefore R and R^2, and the Durbin-Watson statistic and its corresponding p-value.

ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H_1	Regression	0.040	1	0.040	4.973	0.028
	Residual	0.789	99	0.008		
	Total	0.829	100			

Note. The intercept model is omitted, as no meaningful information can be shown.

Table 6: ANOVA Table; Note: F-statistic and p-value are of interest

The ANOVA table displayed in Table 6 shows the sum of squares through which one can observe the differences between the means. The F-statistic and its corresponding p-value are thus of interest as they show whether or not the deviations amongst the means are statistically significant. If the p-value is below $\propto = 0.05$, like in this study's case, the null hypothesis that the population means are equal can be rejected. However, this part of the model summary was deemed not quite as integral to the data analysis relative to the others and will thus not be analyzed further.

Coefficients ▼

Model		Unstandardized	Standard Error	Standardized	t	p	95% CI Lower	95% CI Upper
H_0	(Intercept)	0.030	0.009		3.345	0.001	0.012	0.048
H_1	(Intercept)	0.029	0.009		3.217	0.002	0.011	0.046
	BETA CHANGE ABSOLUTE	0.054	0.024	0.219	2.230	0.028	0.006	0.102

Table 7: Linear Regression; Note: Δ beta as the independent variable and Δ vertical integration as the dependent variable, p-value is of interest.

The final part of the model summary, pictured in Table 7, shows the actual linear regression. This is the most important part of the regression analysis as it provides a p-value indicating whether or not there is indeed a statistically significant relationship between vertical integration and systemic risk. It is important to note that the chosen significance level was ninety-five percent, meaning $\propto = 0.05$.

4.4.1 Regression Results Interpretation

The regression analysis, testing for a relationship between beta **β** and vertical integration, as shown in Figure 7 and Table 1, revealed a correlation coefficient (R) of 0.219 and a coefficient of determination (R^2) of 0.048. The R-value of 0.219 signifies a low to medium strength correlation or relationship between vertical integration and systemic risk (**β**), and the R^2 of 0.048 means that about five percent of the variation in vertical integration can be explained by the variation in systemic risk (**β**). In addition, the p-value was found to be 0.028 at the 0.05 significance level and respective 95% confidence level. This means that the results are statistically significant at the 0.05 level, and thus the null hypothesis that there is no relationship between vertical integration and systemic risk can be rejected. However, these results have a more complex interpretation since it is obvious that the indication given by the low R-value conflicts with the indication given by the statistically significant p-value, something that will therefore be analyzed in the next chapter.

5 Analysis and Discussion

This chapter will serve as an interpretation and analysis of the results given by the regression analysis, specifically in rationalizing whether or not one can reject the null hypothesis (H_0) that there is no relationship between vertical integration and systemic risk. Relevant and interesting trends in the collected data will also be discussed alongside possible explanations for them. In addition, the validity of the calculated vertical integration levels will be analyzed, and the statistical results will be interpreted and criticized using a connection to the theoretical conclusions presented in the literature review chapter, not only with regard to the interplay between vertical integration and risk, but also various other factors that drive the choice of a firm to pursue an integrative strategy. The connection to literature will center around three of the most important articles regarding the relationship between systemic risk and vertical integration presented in the literature review, namely those written by Stuckey and White (1996), Helfat and Teece (1987), and Krickx (2000), as well as one particularly influential empirical study by Buzzell (1983). Finally, the limitations and key considerations of this paper, particularly as they relate to methodology, will be discussed.

5.1 Results Analysis

5.1.1 Regression Results

As explained in the results chapter, a relatively low R-value was found by the linear regression for the two variables which would usually indicate little to no correlation between an independent and dependent variable, meaning it would be expected to be accompanied by a higher p-value, as this logically leads to consistent and definitive results regarding the presence, or lack thereof, of a relationship or correlation. However, since the regression yielded inconsistent results with regard to the correlation coefficient and p-value, there is an indication that another dimension needs to be considered, namely the influence of other factors on the dependent variable, vertical integration. Thus, the way one can interpret the results of the regression analysis is that they are significant at the 0.05 level, indicating that the alternative hypothesis (H_1), claiming that there is indeed a relationship between vertical integration and systemic risk, should be accepted. However, due to the low correlation coefficient R, one can conclude that although there exists a relationship between the two variables as indicated by the p-value, there are other factors influencing changes in vertical integration, not just systemic risk. What these other factors may be will be analyzed in the coming sections. One key aspect to note is that because the calculation of vertical integration is integral, no pun intended, to the statistical analysis within this study and has very few credible ways to be benchmarked or checked for accuracy, it is important to explain how one can ensure or argue for the validity of the calculated values, at least to some extent. The validity of the calculated vertical integration values will therefore be discussed as part of the considerations and limitations of this study later in this chapter.

5.1.2 Outliers

Throughout the course of the data retrieval, there have been some outliers identified which were later removed from the data set. Apple is one of the most significant, as, in the calculation of the vertical integration level for the company, the adjusted value turned out to be negative, which is logically incorrect as vertical integration levels are contained within a range between zero and one. This occurred due to methodological reservations and Apple's accounting for prepayment activities.

Already since 2013, Apple has been investing heavily in the prepayment of inventory for the upcoming releases with outstanding prepayments amounting to 3.3 billion $, however, the company stopped disclosing its prepayments the same year (Niu, 2017). In this analysis, Apple showed an extremely different VI value from the other consumer electronics companies. The COGS% outsourced for Apple was 1.316 (Figure 10). This value, compared to the rest of the MNCs in this study, has an unusually high percentage of COGS% outsourced and the reason for that is considered to be due to their extreme amount of third-party suppliers in their supply chain. In 2015, Apple had 200 key suppliers that are 97% of the total number of 585 remaining in the supply chain.

The strategy that Apple applies to gain a comparative advantage is maintaining long-term exclusive agreements with its suppliers, motivating them by prepayments (AICD, 2015). Due to these prepayments, the values that Apple shows seem different from the average VI and COGS% compared to the majority of MNCs in the Consumer Electronics industry due to the supply chain strategy that Apple is using in order to gain a comparative advantage. Since they are a giant within this industry, applying this type of strategy is logical and the unusual values that were shown seem accurate taking this factor into consideration. As seen in Figure 10, Apple seems to be pursuing the same strategy in 2021 as in 2015 since the

COGS% outsourced are still at an illogically high percentage, resulting in a negative, in the case of 2015, or extremely low VI value. The value of the vertical integration of Apple might be somewhat accurate since the company does not own its production activities and invests heavily in its suppliers, but due to the inability to account for prepayments in the vertical integration formula using the chosen method, it was decided to keep the company out of the sample. However, even though the prepayments are not disclosed, in Bloomberg's supply chain analysis the prepayments are still shown as separate investments into different supplier relationships which results in the function indicating that Apple has outsourced more than a hundred percent of the costs of goods sold. This results in a calculation indicating that the vertical integration level of Apple is negative, thus, the company has been removed from the sample.

Apple	
Gross Sales	233715
COGS	140089
% COGS Outsourced	1.316
Outsourced Value	184357.124
Added Value	-44268.124
VI	**0.21118831**
Total Assets	290345
CL	80610
Capital Invested	209735
ROI	0.08505245
% Capital Invested	17838.4758
Profits	53394
Adj. VI	**0.06965275**

Apple 2015

Apple	
Gross Sales	365817
COGS	212981
% COGS Outsourced	1.679
Outsourced Value	357595.099
Added Value	-144614.099
VI	**0.022475448**
Total Assets	351002
CL	125481
Capital Invested	225521
ROI	0.105411275
% Capital Invested	23772.45604
Profits	94680
Adj. VI	**-0.21255895**

Apple 2021

Figure 10: Apple VI and COGS% outsourced for 2015 and 2021

5.2 Theoretical Reflections

5.2.1 Asset Specificity and Transaction Frequency

Transaction cost economics provides a good explanation of the trends observed in the sample data. Especially, considering asset specificity and transaction frequency elements of the theory, as previously mentioned, Stuckey & White (1993) argue that if a firm faces high transaction frequency and high asset specificity, it would integrate. Some argue that semiconductors are a commodity and thus asset specificity is low; however, this is not exactly the case. Microchips are divided into two kinds, logical and memory, and while there are commodity semiconductors on the market that are used for simple purposes and limited operations, the majority of chips have numerous qualities, such as size, processing power, etc, that are customized depending on the need (Investopedia, 2021). Semiconductors are usually designed for a single purpose only which indicates that microchips have high asset specificity from the perspective of the manufacturing firm. For example, semiconductors used for autopilot in a modern car cannot be used in a smartphone. From the transaction frequency perspective, it is obvious that the number of purchases of semiconductors by a technological manufacturing firm is extremely high. Since a single firm produces multiple products with an output of hundreds of millions of units, each of which requires a microchip, the order volumes are simply enormous. It can be thus concluded that from the perspective of transaction costs economics, there is a high asset specificity and transaction frequency in relation to semiconductors. In case of failure of market contracts to secure the supply of semiconductors, such as times of semiconductor shortages, it would be logical that companies pursue integration, as suggested by Stuckey & White (1993). Since this study has identified that there was an increase in integration in light of increased systemic risk, it would be apparent that some of this increase can indeed be explained by TCE.

5.2.2 Innovation and Vertical Integration

A certain share of the observed results might also be due to the relationship between innovation and vertical integration. Buzzell (1983) and Harrigan (1984) suggest that a high level of integration gives companies an advantage in innovating through improving control over internal processes, which is supported by numerous researches stating that there exists a positive relationship between R&D expenditures and innovation and integration within technological firms. For instance, Armour & Teece (1980) have identified a strong positive relationship between R&D expenditures and vertical integration in the energy sector in the US. In a fairly recent study Liu (2016) has discovered similar relationships within advanced healthcare and biotechnology companies, where general production processes might be outsourced, but innovative production stages are kept in-house.

Automotive, communication technology, healthcare, and technology are considered amongst the most innovative industries with heavy R&D expenditures (OECD, 2017). These industries are also characterized by extensive patenting, which leads to a consolidation of these industries as firms tend to acquire smaller companies developing new technologies to keep the threat of new entrants low. Thus, these companies are inherently highly integrated and tend to keep innovation in-house.

Automotive companies specifically, tend to outsource common stages of production oriented at producing commodity components and assemblies. These stages account for a substantial share of the production process, however, new technological developments and innovations usually, similarly to the medical device manufacturers, are kept in-house (Ciravegna and Pilkington, 2013). Although automotive companies inherently heavily rely on outsourcing, in a situation where market contracts are failing to secure smooth outsourcing due to semiconductor shortages, these companies would likely consider or start integrating these production stages. The dominating majority of the companies from these industries included in the sample for this study have indicated a high level of integration in the base year already; however, the value of integration has increased in the year 2021 as well. This might indicate that some of the production stages have been moved in-house, partially due to new developments in replacing lacking microchips. One of the brightest examples to support this claim is Tesla as the company has started manufacturing its own semiconductors to satisfy the needs of production in light of global semiconductor shortages (Cohen, 2021). The company has developed its own microchips for multiple purposes, e.g. AI, vehicles, and other developments, and respective unique production processes which allows a reduced reliance on suppliers and works to secure a more streamlined production process in times of uncertainty (Cohen, 2021).

5.2.3 Theorized Strategic Response to Uncertainty & Risk

An additional theoretical connection that can be made within the interpretation of this study's results lies in theorized strategic responses to uncertainty and risk with regard to make-or-buy decisions. Quite a bit of theoretical evidence and reasoning concludes that there is a close connection between systemic risk and uncertainty, and, in turn, when facing environmental uncertainty, firms are likely to pursue an integrative strategy to obtain more control over their value chain to allow the company more agility in accommodating and mitigating uncertain events and/or conditions (Dwirandra & Astika, 2020). Krickx's (2000) article, used in this paper as a way to benchmark statistical expectations, explores the relationship between uncertainty and vertical integration and hypothesizes a positive relationship between the two based on previous theoretical evidence like that of Dwirandra and Astika (2020), yet the statistical analysis yielded ambiguous results across different types of uncertainty. Perhaps this was due to uncertainty being difficult to quantify which likely only gets more challenging when discerning between and quantifying various types.

However, although there were ambiguous results across specified types of uncertainty like technological and demand-related, the study showed that uncertainty, when not otherwise specified, as well as performance ambiguity, were positively related to vertical integration, both of which are reflected in the nature of the COVID-19 pandemic and semiconductor shortages for semiconductor-reliant companies (Krickx, 2000). Therefore, although this article explores uncertainty and not risk in relation to vertical integration, the tentative conclusion that a positive relationship exists between uncertainty and vertical integration is relevant in setting expectations and explaining this study's results indicating a positive relationship with systematic risk, as risk can be considered a type or quantifiable subset of uncertainty (Park & Shapira, 2017).

As additional empirical support, Helfat and Teece's (1987) study of the interplay between vertical mergers and changes in systemic risk which was also measured using beta **β**, offers interesting and relevant findings. As described in the literature review, the study found that the systemic risk level (**β**) for merging firms decreased after their participation in a vertical merger (Helfat & Teece, 1987). This result provides logical support for the results of this paper's study since one can conclude that vertical integration strategies seem to reduce systemic risk for firms, thus it is not unusual that a period of high systemic risk caused by supply disruption is conducive to firms choosing to integrate to a greater extent as a risk mitigation strategy. In other words, the positive and statistically significant relationship found between systemic risk and vertical integration for companies greatly affected by the semiconductor shortage is not unusual and seems to be in line with previous similar empirical studies and the conclusions of transaction cost theory.

Finally, an increase of the level of integration across the sample can also be explained by the exploitation of the benefits of vertical integration outlined by Buzzell (1983) and Harrigan (1984). An increase in supply assurance, improved supply chain coordination, and an increase in innovation capabilities that come with an increase in integration enable a prompt response to a rapid change in the business environment, such as the semiconductor shortage (Buzzell, 1983). This is in line with Harrigan's (1984) take on the advantages of vertical integration as well, who also suggested that vertical integration allows for better differentiation possibilities and increases supply chain efficiency which are critical for the above-mentioned response to a rapid change in the business environment.

5.2.4 Vertical Integration & Profitability

Thus, another dimension to consider with regard to vertical integration as a strategy is whether or not it actually enhances profitability when implemented, especially when using it for risk mitigation. Buzzell's (1983) study on whether or not this is the case yielded ambiguous results, concluding that whether or not it was a profitable strategy depended on firm size. Although Buzzell's study does not specifically measure whether vertical integration is profitable when faced with heightened systemic risk, its findings are quite interesting to analyze as they relate to those of this paper (Buzzell, 1983).

The claim that firm size impacts how profitable using a vertical integration strategy can be considered relevant, as the finding of this paper's analysis is that there is a positive relationship between vertical integration and systemic risk, specifically amongst multinational companies affected by the semiconductor shortage. Buzzell (1983) asserts that firms having a large market share experience the greatest benefits from vertically integrating, something that one could argue to be aligned with this study. This alignment is observable in that multinational companies tend to be the largest companies on global markets and thus often hold a substantial market share, and based on this study's results, indeed tend to become more vertically integrated when facing higher levels of systemic risk which indicates that this strategy must benefit them profitability-wise. Buzzell's claim thus seems to be confirmed by this statistical analysis, at least to some extent. However, it is still unclear whether smaller firms can benefit just as much as firms with large market shares under systemic risk, even though it seems like this is not the case under stable economic and social conditions.

This point is where one might be able to disagree with Buzzell, as one could argue based on theoretical conclusions and trends in the study at hand, that vertical integration is beneficial in mitigating systemic risks like supply shortages regardless of firm size, as it offers supply assurance and swifter coordination, while it also lowers transaction costs. Thus, it might be of interest to test Buzzell's claim by comparing the profit levels of the multinationals becoming more vertically integrated to mitigate systemic risk in this study, to that of a sample of small-to-medium-sized enterprises (SME's) that did the same. Perhaps, one might find that small and large businesses benefit fairly equally profitability-wise from vertically integrating as a response to systemic risk while discrepancies exist amongst the payoffs of integrating under the status quo.

5.3 Limitations & Considerations

Although this study can arguably be supported well in terms of validity and accuracy, both theoretically and statistically, there are some relevant limitations and considerations that should be disclosed. This section will detail these aspects and also provide insight into how these limitations and considerations, though relevant, do not undermine the value of this study.

5.3.1 Limitations

COGS Limitations

For example, the decision to use COGS to measure value-added in the vertical integration formula could present a limitation of this study due to the nature of COGS and the level of information that it provides. What is important to note is that COGS does not account for indirect costs, like R&D and marketing costs, incurred in the value-adding process and production in general. This can be considered a limitation since activities like R&D and marketing are relevant in the level of integration as they can also be outsourced or integrated. However, indirect costs could not be accounted for as they are not usually individually quantified and disclosed by firms in publicly available financial reports. If there was a way to access quantifications for each source of indirect costs, they would be quite interesting to include in an analysis of vertical integration levels, as one could likely then observe patterns in indirect cost factors like R&D expenditure and employee wages. For example, if a firm like Tesla would like to offset semiconductor shortages that could slow down its production, it would likely have higher R&D expenditures due to the development of new capabilities and processes to allow integration, and it would also likely then have higher wage expenditures as specific knowledge in the area of chip production would need to be brought in. However, since there is thus far unfortunately no consistent or accessible way to factor in indirect costs, the use of direct costs still provides an accurate reflection of a firm's integration level, as will be discussed in the "Considerations" section.

Database Limitations

The limitations of the use of the COGS value are also extended to the use of a singular database. In order to quantify vertical integration, there is certain information that is not publicly disclosed by companies, or not disclosed consistently, thus making it difficult to gather without the help of a financial database, in this case, Bloomberg. Even though Bloomberg is considered to be a credible database for financial data, one could consider it a limitation that it is unique in certain features required for this study such as its extensive supply chain analysis tool. This presents a reliance on the values and data provided by Bloomberg and no way to cross-check them with another source since they are not available elsewhere. That being said, Bloomberg is still the largest provider of financial analysis, news, tools, data, and research worldwide which leads one to believe that it is quite credible for this analysis and that one can have confidence in the values that it provides (Chen, 2021).

Time Frame for Beta and VI

When it comes to the time frame that was used for analysis in this study, there are certain choices that were made that merit clarification. The chosen period of analysis was between 2015 (stable economic year) and 2021 (destabilized economic year), with the year 2021 being chosen in order to reflect a full year of heightened systemic risk due to the COVID-19 pandemic and parallel semiconductor shortages. 2015 was chosen as the base year for analysis not only because it is the last year having consistent information for the calculation of integration levels in the Bloomberg database, but it also reflects arguable economic stability compared to the years leading up to 2021, as it was not influenced by the political and economic instability in the US during and after 2016 and accompanying trade wars between the US and China which destabilized the global market in upcoming years (United Nations, 2015). Thus, the year 2015 presents an accurate and current reflection and benchmark of the integration strategy for the sampled firms after operating in comparatively stable economic conditions, providing a good way to gauge the strategic make-or-buy reactions of firms reflected in integration values for 2021 after facing a full year of high levels of systemic risk.

The limitation of using this time frame is that other factors may have affected integration levels in the years leading up to 2021 besides the semiconductor shortage, but this is something that seems to be reflected in the regression results. Systemic risk level, however, remains unaffected by factors in previous years due to the use of annual betas rather than five-year betas. Nonetheless, it is also difficult to reflect upon or assess if vertical integration levels increased or decreased consistently between the two years due to the dynamic nature of firm strategy and the difficulty of predicting and controlling how firms react to various factors, especially to geopolitical tensions in the years 2016, 2017, 2018, 2019, and 2020. However, one can still argue that the sample firms' levels of vertical integration can still be accurately calculated using relevant data from 2021, as it allows for a reflection of an integration strategy change, or lack thereof, after a full year of supply disruptions. This approach, using years 2015 and 2021 as years of interest, is arguably the best way to control for the effects of the semiconductor shortages specifically, although it has its flaws. Some factors affecting integration strategies besides risk simply cannot be quantified or controlled due to their subjective nature, like differing managerial risk preferences across firms and industries for example, but they deserve consideration to provide a more complete analysis of the statistically analyzed relationship between systemic risk and vertical integration.

Risk Preferences and Managerial Behavior

That being said, this paper does not account for managerial behavior and risk preferences since this is something that cannot be evaluated using public information. However, it is arguably a factor of interest in a firm's pursuit of a vertical integration strategy as a response to risk, as strategy is reliant on the perceptions and judgments of various levels of a firm's management system. Therefore, a firm's change in the level of vertical integration as a response to risk has another hidden dimension because the strategy to integrate more heavily or not, especially the extent of integration or disintegration, depends on how a firm's management perceives the magnitude of the risk that the chip shortage poses. This perception, in turn, varies from one firm to another due to differing management systems and cultures which is why it is difficult to factor in and quantify for this study. Although varying risk preferences go unaccounted for in this statistical analysis due to methodological limitations, they can still be considered an influential force in driving vertical integration decisions. In this way, it is important to note that they were indeed taken into consideration in analyzing the results of this study and provide another avenue for research regarding potential factors driving integration strategies.

5.3.2 Considerations

Vertical Integration Value Validity

Although there was no way of finding sources, academic or otherwise, that estimate the level of vertical integration numerically for most firms included in this study, some supporting benchmarks were able to be found for a select few. For example, an article centering around a visit to Tesla's factories by a Goldman Sachs analyst in early 2016 was used to check the accuracy of the calculated level of integration for Tesla in this study. According to the analyst, Patrick Archambault, Tesla was about 80% vertically integrated by February of 2016 (Lambert, 2016). This aligns with the calculated level of vertical integration within this paper which, as displayed in Figure 6, provided a value of 0.78611 for the year 2015, meaning Tesla was 78.6% vertically integrated. This value can accurately be rounded up to 80% as the article also claims, thus providing support for the accuracy of both the method and result of the vertical integration calculations performed for the purpose of this paper's statistical analysis.

Another, though far less specific, benchmark was used for a couple of firms in the study at hand, including Sony and Samsung. There was a noticeable trend amongst the sampled consumer electronics companies to be highly vertically integrated, most being over seventy percent vertically integrated in both 2015 and 2021 (Table 8, below). An article from Investopedia discusses various business models and strategies amongst publicly-listed tech companies, specifically Apple and Samsung, validates the high integration levels observable for firms in this paper's sample of interest. For example, the article notes that a focus on vertical integration is particularly common amongst Asian producers like Samsung and Sony, giving support to the finding of integration levels for these companies of around seventy-five percent in 2015 and over eighty percent in 2021, as observable in Table 9 (Ross, 2021). Although there are no quantitative estimates to be found regarding integration levels for these companies, Ross' (2021) article confirms that the calculated values should indeed be on the higher end.

Company Name:	**VI 2015:**	**VI 2021:**	**Δ VI:**
Microsoft	0.887	0.903	+ 0.016
IBM	0.898	0.948	+ 0.050
Panasonic	0.854	0.882	+ 0.028

Table 8: VI for Microsoft, IBM and Panasonic in 2015 and 2021

Company Name	**VI 2015**	**VI 2021**	**Δ VI**
Samsung	0.737	0.828	+ 0.091
Sony	0.759	0.869	+ 0.110

Table 9: Change in VI for Samsung and Sony (2015 & 2021)

Another trend was found in the sampled energy sector firms which had the highest vertical integration values of the industries sampled, all having values of over eighty percent and many over ninety percent (Table 10, below). In addition, almost all energy companies sampled, besides Iberdrola and NextEra Energy, showed decreased vertical integration values from 2015 to 2021 (Table 10). The high integration values can be explained due to the strict regulations experienced in the energy sector which increases regulatory risks, thus making vertical integration a profitable strategy since there is then no risk of a supplier violating regulatory requirements, for example (Arocena, 2008). The decrease in vertical integration from 2015 to 2021 seen in the calculations can also be supported and explained by increasing efforts from regulatory authorities globally, specifically in Europe and the United States, to counteract the subsequent monopoly power held by small groups of highly integrated energy firms by incentivizing divestiture and the splitting of large firms into smaller units to increase competition (Arocena, 2008). Thus, it seems that trends and values observable in the calculated vertical integration values for this paper's sampled firms can be empirically supported, as discussed in this section with regard to Tesla, Samsung and Sony, and the energy sector as a whole, allowing one to argue that the derived integration levels are indeed accurate.

Company Name	**VI 2015**	**VI 2021**	**Δ VI**
Jinko Solar	0.990	0.938	- 0.052
Enphase	0.990	0.801	- 0.189

Table 10: Sample Decrease in VI between 2015 and 2021: Enphase & Jinko Solar

6 Conclusion

The final chapter of this paper will outline its achievements in terms of reaching the research aims and objectives, while also elaborating on the importance, contributions, and practical implications of the findings. Finally, avenues for future research will be presented.

6.1 Research Aims

Theoretical conclusions, as well as a couple of preliminary empirical studies, regarding the relationship between vertical integration and risk, contribute to the framework of this paper in the sense that they set the expectation that there is indeed a relationship between the two. However, as mentioned throughout this paper, while a fair amount of qualitative research on the relationship between VI and risk exists, there is relatively little quantitative research done. Thus, the aim of this paper was to identify and verify such a relationship through the use of statistical analysis, in order to test for a relationship between changes in vertical integration level and systemic risk level in light of the recent semiconductor shortages posing substantial systemic risk across various industries. This aim has been fulfilled by identifying a statistically supported and positive relationship between the vertical integration level of semiconductor-reliant multinational firms and systemic risk in the form of semiconductor shortages. In this quantitative study, a sample of 101 firms operating in semiconductor-reliant industries was implemented to perform a simple linear regression analysis on the changes in vertical integration values, or levels, and beta **β** change of the respective companies between the years 2015 and 2021. The regression analysis reflected a statistically significant relationship between vertical integration and systemic risk for the sample companies in the respective years, as well as a medium-to-low correlation. Such an outcome supports the conclusion that there is a significant, positive relationship between the two factors and that the null hypothesis can be rejected; however, there are other factors that influence vertical integration level as well that have not been accounted for, reflected in the relatively low correlation between the two variables.

6.2 Research Objectives

The objective of this study was to develop a robust and accurate method for quantifying the level of vertical integration of a large sample of multinational firms in order to perform a statistical analysis testing the hypothesis of whether a relationship between systemic risk and

VI exists. The objectives of the study were thus successfully reached by developing appropriate quantification methods for both vertical integration and risk and using their changes across two years of interest in a linear regression analysis to statistically prove or disprove that a relationship exists between the two. In particular, vertical integration was calculated using the formula developed by Bowman and Buzzell (1978 & 1983) which credibly quantifies the integration of production activities through the use of value-added. This study thus went on to develop an accurate and unique way to measure value-added and in turn vertical integration, namely through the application of COGS percentages attributed to outsourcing to calculate each firm's value-added in-house. The level of risk each company was exposed to in light of the semiconductor shortage was decided to be quantified using historical beta **β** values, as they were concluded to accurately reflect individual systemic risk levels. Such considerations and methodological choices effectively allowed the fulfillment of the set objectives, as they allowed one to conduct the research in a credible and comprehensive way and deliver insightful results, which worked to provide a well-supported answer to the research question of this thesis, as well as suggesting potential directions for future research.

6.3 Implications

That being said, the findings of this paper have a plethora of implications. As reflected in recent global events like the COVID-19 pandemic and the semiconductor shortage, many companies struggled to handle the substantial disruptions and systemic risk posed by this time period, particularly from a strategic standpoint. There are many possible reasons for this, ranging from the abrupt and intense nature of the pandemic to the destabilization of business networks due to self-oriented strategic changes by many firms, a lot of which are large key players as shown in this paper's analysis of the behavior of multinational companies in particular. Thus, this paper's results can set expectations for the reactive behavior and strategies of large, multinational firms, with regard to vertical integration or outsourcing decisions, in response to periods of increased systemic risk.

6.3.1 Strategic Benchmarking

These behavioral expectations can be particularly valuable for smaller, supplier firms, upstream in the value chain, since they can then anticipate the potential disruption of demand for their products and services in times of heightened systemic risk due to large, multinational clients integrating production functions rather than outsourcing as a result of recognizing the clear, positive relationship between VI and systemic risk indicated by this paper. This recognition would then allow smaller suppliers to preempt this disruption in demand and their business networks by developing a strategy early on to most effectively maintain profitability, despite the potential temporary loss of key contracts and clients, and avoid facing substantial financial troubles. Although this study does not show that VI is more effective or profitable than other strategies, it does in fact demonstrate that MNCs tend to vertically integrate as systemic risk increases, which is a valuable finding in and of itself and is interestingly in line with theoretical conclusions thus far. In other words, firms can either take this paper as a benchmark for their own strategies in response to systemic risk, namely considering increasing their vertical integration level like many multinational firms tend to do, or preemptively reacting to this likely strategic change among many large, key players if a firm does not have the resources or need to integrate.

6.3.2 Implications for Management Teams

Thus, this paper also holds practical implications for management teams of various levels. With reference to the previously discussed implications regarding behavioral trend anticipation, the findings presented can help guide managerial decisions when choosing a strategy to navigate unusual systemic risk levels suitable for the company and its interaction with its competitive and geopolitical environment. Keeping the conclusions of this paper in mind, management within large, multinational companies may be more inclined to pursue a vertical integration strategy and imitate the behavior of similar firms as a response to high systemic risk. Or, on the other hand, they may decide to pursue an opposing strategy, perhaps taking advantage of the demand disruption to smaller supplier firms induced by the integration strategies of many multinational firms further downstream, in order to secure diversified sources of supply to mitigate shortage risks and avoid the administrative costs associated with VI.

6.3.3 Implications for Researchers

Furthermore, this study can be found useful for researchers examining factors affecting vertical integration levels of firms, particularly as they relate to the dynamic nature of the global business environment and its respective value chains. This paper offers a unique, and thus far rare, empirical exploration of the relationship between risk and vertical integration which can help benchmark expectations for future studies that not only specify the interactions between these two variables, but also ones examining other factors theorized to impact vertical integration decisions amongst firms. This is something that will be further discussed as part of the recommendations for future research. In addition, this paper offers a credible method for quantifying a firm's level of vertical integration, along with completed quantifications for 101 multinational firms. This is certainly of value as integration levels are often estimated quite subjectively, if estimated at all, therefore making their comparison quite difficult without a uniform way of measurement. Finally, and in a more general sense, this study can not only be used in order to identify and predict trends in response to heightened systemic risk amongst multinational firms but it can also be used to reason further into and explain the difference in trends between industries and how companies respond to risk with regard to industry-specific factors.

6.3.4 Implications for Public Officials

This paper's findings also have a particularly interesting relevance for public officials in the sense that they could be able to anticipate market behavior, specifically during times of unprecedented or heightened systemic risk which is something quite valuable. As this paper demonstrates not only the existence of a relationship but also a positive one, between vertical integration and systemic risk, politicians can anticipate that at least multinational companies will tend to become more vertically integrated when facing heightened systemic risk and vice versa. Multinational companies tend to be some of the largest key players in global industries, thus having a large influence on global value chain structure and business-to-business networks due to their inherent international dispersion and subsequent size. Therefore, being able to predict their behavior, especially in times of uncertainty and heightened risk, can allow policymakers to counteract the systemic destabilization of markets and competitive distortions, at least to some extent. For example, in the case of another pandemic, if one expects that the larger multinational companies will tend to vertically integrate more operational processes, one can in turn expect outsourcing relationships with smaller supplier firms upstream within the value chain to be neglected and negatively impact their financial performance, as they lose out on key contracts with large multinational firms. This abrupt change in business-to-business networks due to the self-orientation of multinational firms in response to systemic risk thus can have the unfavorable effect of distorting competition across various markets through their consolidation, as smaller players are phased out due to profitability issues. That being said, if politicians were to consider the empirical findings of this paper, they could preempt this market consolidation and potential monopolization of industries by introducing policies incentivizing competition and/or having support and resources in place for small businesses ahead of time to avoid their widespread bankruptcies.

6.4 Future Research

Although this study makes several valuable contributions to the study of organizational behavior and strategy, it holds some limitations, as presented previously, which provide avenues for future research. As discussed, one of the key limitations in this study was the reliance on COGS to calculate vertical integration levels due to the fact that it does not account for factors like R&D and marketing costs, for example. Therefore, an extension of this study can be made through the quantification of such relevant factors to allow them to be accounted for as well within the statistical analysis. Or, they can be quantified and used individually to test for a potential relationship between the vertical integration of particular operating functions like R&D and marketing and environmental factors such as systemic risk or policy, to name a couple.

Along the lines of other factors affecting the variables of interest in the study, it was identified that vertical integration has a positive relationship with systemic risk; however, this relationship is characterized as moderate to weak, leaving room to assume that there are other factors that affect the level of integration of a given company besides systemic risk. Thus, a suggestion can be made for future research to identify these factors that thus far remain unaccounted for yet influence integration preferences, in order to test their relationship with vertical integration individually. For example, theoretically proposed factors interacting with vertical integration decisions are asset specificity and transaction frequency. A potential future study could identify how the asset specificity of semiconductors influences vertical integration decisions amongst firms in various industries, as there are markets for both generic microchips and highly specialized semiconductors. Transaction frequency should thus be studied in a bundle with asset specificity as well as it was argued previously that a certain combination of both provides a strong motivation to integrate.

In addition, this study was based on a sample of 101 MNCs operating in seven different industries affected by the semiconductor shortage paralleling the COVID-19 pandemic. This in itself is a very specific analysis due to its scope and specific time frame. Although the choice of a narrower scope and time frame were made due to methodological reservations and considerations, it would be beneficial to measure the strategic reaction of a wider set of industries, with regard to the integration decisions of firms, to a common stimulus such as the 2008 financial crisis, for example. The reason this was not considered as a focal period of this study is the lack of access to consistent financial data further back than 2014; however, if the relevant information needed is accessible to other researchers, studying other sources of systemic risk and subsequent firm responses in terms of "make-or-buy" decisions would be quite beneficial and interesting.

A final suggestion for future research might be to consider a longer time span for a similar study. Organizational changes such as vertical integration are timely processes within MNCs, thus adaptations to a fast-changing environment might be delayed. Since the semiconductor shortage is a relatively new phenomenon, it is difficult to confidently state that all the organizations have fully adapted to it. Therefore, it would be beneficial to consider a longer period of time within a similar study, perhaps ten years, in order to get a more accurate picture of, in particular, how extensively firms integrate or not in response to risk in terms of their VI level.

6.5 Chapter Summary

The final chapter of this paper includes a description of the way that the research aims and objectives were achieved, the implications of the findings, and how this study can segue into further research. Specifically, implications for smaller supplier firms are noted as they are vulnerable to the integration decisions and strategies of large key players explored in this study, as well as the relevance to public officials who can use this study to prevent the development of unfavorable market conditions. The importance of this quantitative study and its variety of contributions are also brought to light and explained to not only encourage the pursuit of future studies and/or the amelioration of the one presented in this paper, but also to stress the importance of the results for the study of organizational behavior.

References

AICD. (2015). A case study of Apple's supply chain, *AICD*, Available online: https://aicd.companydirectors.com.au/advocacy/governance-leadership-centre/governance-driving-performance/a-case-study-of-apples-supply-chain [Accessed 9 May 2022]

Alfaro, L. (2016). Multinational Firms, Value Chains, and Vertical Integration, *NBER*, Available online: https://www.nber.org/reporter/2016number3/multinational-firms-value-chains-and-vertical-integration [Accessed 17 April 2022]

Arocena, P. (2008). Cost and Quality Gains from Diversification and Vertical Integration, *Energy Economics, Elsevier*, Available online: https://ideas.repec.org/a/eee/eneeco/v30y2008i1p39-58.html. [Accessed 19 April 2022]

Armour, H. O., & Teece, D. J. (1980). Vertical Integration and Technological Innovation, *The Review of Economics and Statistics*, 62(3), 470–474, Available online: https://doi.org/10.2307/1927118 [Accessed 9 May 2022]

Arrow, K. J. (1985). The economics of agency. In J. W. Pratt & R. J. Zeckhauser (Eds.), Principals and agents: The structure of business (pp. 37–51), *Cambridge, MA: Harvard Business School Press*, Available online: https://www.worldcat.org/title/principals-and-agents-the-structure-of-business/oclc/300594772 [Accessed 9 May 2022]

Barker, L. E., & Shaw, K. M. (2015). Best (but Oft-Forgotten) Practices: Checking Assumptions Concerning Regression Residuals, *The American Journal of Clinical Nutrition*, vol. 102, no. 3, pp. 533–539, Available online: https://doi.org/10.3945/ajcn.115.113498. [Accessed 23 Apr 2022]

Bloomberg Professional Services. (2020). How to Analyse Coronavirus-Related Risks, *Bloomberg*, Available online: https://www.bloomberg.com/professional/blog/researching-supply-chain-exposures-how-to-analyse-coronavirus-related-risks/ [Accessed 17 April 2022]

Burkacky, O., Dragon, J., & Lehmann, N. (2022). The semiconductor decade: A trillion-dollar industry, *McKinsey*, Available online: https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry [Accessed 23 April 2022].

Buzzell, R. D. (1983). Is Vertical Integration Profitable?, *Harvard Business Review*, Available online: https://hbr.org/1983/01/is-vertical-integration-profitable [Accessed 3 April 2022]

CFA Institute. (2022). Systemic Risk & Management in Finance, *CFA Institute*, Available online: https://www.cfainstitute.org/en/advocacy/issues/systemic-risk#sort=%40pubbrowsedate%20descending [Accessed 26 April 2022]

Chen, J. (2021). Bloomberg Definition, *Investopedia*, Available online: https://www.investopedia.com/terms/b/bloomberg.asp [Accessed 10 May 2022].

Chen, Y. (2016). Spatial Autocorrelation Approaches to Testing Residuals from Least Squares Regression, *PLOS ONE*, vol. 11, no. 1, 2016, Available online: https://doi.org/10.1371/journal.pone.0146865 [Accessed 22 Apr 2022]

Ciravegna, L., & Pilkington, A. (2013). Outsourcing practices in automotive supply networks: an exploratory study of full service vehicle suppliers, *International Journal of Production Research*, Available online: https://www.researchgate.net/publication/235634686_Outsourcing_practices_in_automotive_supply_networks_an_exploratory_study_of_full_service_vehicle_suppliers [Accessed 5 May 2022]

Coase, R. H. (1937). The Nature of the Firm, *Economica*, vol. 4, no. 16, pp.386–405, Available online: https://onlinelibrary.wiley.com/doi/10.1111/j.1468-0335.1937.tb00002.x [Accessed 2 May 2022]

Cohen, A. (2021). Tesla Flexes Innovative Muscle By Manufacturing Own Chips During Supply Crunch, *Forbes*, Available online: https://www.forbes.com/sites/arielcohen/2021/09/22/tesla-flexes-innovative-muscle-by-manufacturing-own-chips-during-supply-crunch/?sh=179aea5a1618 [Accessed 11 May 2022].

Downey, H.K., Hellriegel, D. and Slocum, J.W. (1975). Environmental Uncertainty: The Construct and Its Application, *Administrative Science Quarterly*, vol. 20, no. 4, p.613, Available online: https://www.jstor.org/stable/2392027?origin=crossref&seq=1 [Accessed 11 May 2022]

Dwirandra, A. A. N. B., & Astika, I. B. P. (2020). Impact of Environmental Uncertainty, Trust and Information Technology on User Behavior of Accounting Information Systems, *The Journal of Asian Finance, Economics and Business*, Available online: https://www.koreascience.or.kr/article/JAKO202034651879586.page [Accessed 20 April 2022]

Gallo, A. (2015). A Refresher on Regression Analysis, *Harvard Business Review*, Available online: https://hbr.org/2015/11/a-refresher-on-regression-analysis [Accessed 20 April 2022]

Gil, R. (2007). “Make-or-buy” in movies: Integration and ex-post negotiation, *International Journal of Industrial Organization*, vol. 25, no. 4, p. 643–655, Available online: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.337.235&rep=rep1&type=pdf [Accessed 12 April 2022]

Grant, R. M. (2015). *Contemporary Strategy Analysis: Text and Cases*, 9th ed., *John Wiley & Sons*

Gwennap, L. (2022). Chipmakers Spend Billions to Break Semiconductor Bottleneck, but Is It Too Much?, *Forbes*, Available online: https://www.forbes.com/sites/linleygwennap/2022/01/24/chipmakers-spend-billions-to-break-semiconductor-bottleneck-but-is-it-too-much/?sh=5ab3a8e818b1 [Accessed 21 April 2022]

Harrigan, K. R. (1984). Formulating Vertical Integration Strategies, *The Academy of Management Review*, vol. 9, no. 4, p. 638, Available online: https://www.jstor.org/stable/258487?seq=1 [Accessed 15 April 2022]

Harrington, D. R. (2014). Stock Prices, Beta, and Strategic Planning, *Harvard Business Review*, Available online: https://hbr.org/1983/05/stock-prices-beta-and-strategic-planning [Accessed 18 Apr 2022]

Helfat, C. E., & Teece, D. J. (1987). Vertical Integration and Risk Reduction, *The Journal of Law, Economics, and Organization*, vol. 3, no. 1, pp. 47–67, Available online: https://doi.org/https://www.jstor.org/stable/764804 [Accessed 14 Apr 2022]

Howley, D. (2021). These 169 Industries Are Being Hit by the Global Chip Shortage, *Yahoo! Finance*, Yahoo!, Available online: https://finance.yahoo.com/news/these-industries-are-hit-hardest-by-the-global-chip-shortage-122854251.html [Accessed 19 April 2022]

Investopedia. (2021). The Main Types of Chips Produced by Semiconductor Companies, *Investopedia*, Available online: https://www.investopedia.com/ask/answers/042115/what-are-main-types-chips-produced-semiconductor-companies.asp [Accessed 10 May 2022]

Kaplan, R. S., & Mikes, A. (2012). Managing Risks: A New Framework, *Harvard Business Review*, Available online: https://hbr.org/2012/06/managing-risks-a-new-framework [Accessed 14 April 2022]

Kenton, W. (2021). Beta, *Investopedia*, Available online: https://www.investopedia.com/terms/b/beta.asp [Accessed 14 April 2022]

Kenton, W. (2022). The Ins and Outs of Business Risk, *Investopedia*, Available online: https://www.investopedia.com/terms/b/businessrisk.asp [Accessed 14 April 2022]

Kim, C., & Mauborgne, R. (2009). How Strategy Shapes Structure, *Harvard Business Review*, Available online: https://hbr.org/2009/09/how-strategy-shapes-structure [Accessed 12 April 2022]

Kim, H. (2019). Statistical Notes for Clinical Researchers: Simple Linear Regression 3 - Residual Analysis, *The Korean Academy of Conservative Dentistry*, Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6387894/ [Accessed 26 April 2022]

Kim, J. (2019). Vertical integration and the theory of the firm, Available online: https://www.researchgate.net/publication/337111624_Vertical_integration_and_the_theory_of_the_firm [Accessed 26 April 2022]

Kolakowski, M. (2021). Bloomberg vs. Reuters: What's the Difference?, *Investopedia*, Available online: https://www.investopedia.com/articles/investing/052815/financial-news-comparison-bloomberg-vs-reuters.asp [Accessed 21 April 2022]

Krickx, G. A. (2000). The Relationship between Uncertainty and Vertical Integration, *Emerald Insight*, Available online: https://www.emerald.com/insight/content/doi/10.1108/eb028921/full/pdf [Accessed 15 April 2022]

Kvaløy, O. (2007). Asset Specificity and Vertical Integration, *The Scandinavian Journal of Economics*, vol. 109, no. 3, pp. 551–72, Available online: http://www.jstor.org/stable/4626232. [Accessed 14 April 2022]

Lambert, F. (2016). Tesla Is Now ~80% Vertically Integrated, Says Goldman Sachs after a Tesla Factory Visit, *Electrek*, Available online: https://electrek.co/2016/02/26/tesla-vertically-integrated/ [Accessed 3 May 2022]

Liu, X. (2016). Vertical integration and innovation, *International Journal of Industrial Organization*, Available online: https://www.sciencedirect.com/science/article/pii/S0167718716300029?via%3Dihub [Accessed 2 May 2022]

Macneil, I. R. (1978). Contracts: Adjustment of Long-Term Economic Relations under Classical and Neoclassical, and Relational Contract Law, *Northwestern University Law Review*, Available online: http://alliancecontractingelectroniclawjournal.com/wp-content/uploads/2017/04/MacNeil-I.-1977-1978-%E2%80%98Contracts-Adjustment-of-Long-Term-Economic-Relations-Under-Classical-Neoclassical-and-Relational-Contract-Law%E2%80%99.pdf [Accessed 27 April 2022]

Mahoney, J.T. (1992). The Choice of Organizational Form: Vertical Financial Ownership Versus Other Methods of Vertical Integration, *Strategic Management Journal*, vol. 13, no. 8, pp.559–584, Available online: https://www.jstor.org/stable/2486651?seq=1 [Accessed 20 April 2022]

Martínez-Mesa, J., González-Chica, D. A., Bastos, J. L., Bonamigo, R. R., & Duquia, R. P. (2014). Sample Size: How Many Participants Do I Need in My Research?, *Anais Brasileiros De Dermatologia*, vol. 89, no. 4, pp. 609–615, Available online: https://doi.org/10.1590/abd1806-4841.20143705 [Accessed 25 April 2022]

Masten, S. E., Meehan, J. W., & Snyder, E. A. (1991). The costs of organization, *Journal of Law, Economics and Organization*, vol. 7, no. 1, pp. 1–25, Available online: https://heinonline.org/HOL/Page?collection=journals&handle=hein.journals/jleo7&id=8&men_tab=srchresults [Accessed 18 April 2022]

McKinsey. (2015). McKinsey on Semiconductors, *McKinsey & Company*, Available online: https://www.mckinsey.com/industries/semiconductors/our-insights/mckinsey-on-semiconductors-number-5 [Accessed 19 May 2022]

Monteverde, K., & Teece, D. J. (1982). Supplier switching costs and vertical integration in the automobile industry, *Bell Journal of Economics*, vol. 13, no. 1, pp. 206–213, Available online: https://doi.org/10.2307/3003441 [Accessed 12 May 2022]

Nguyen, J. (2021). Learn How Systemic and Systematic Risk Are Both Threats to Investors, *Investopedia*, Available online: https://www.investopedia.com/ask/answers/09/systemic-systematic-risk.asp#:~:text=Systemic%20risk%20is%20the%20risk,%2C%20and%20market%2Drelated%20events [Accessed 19 May 2022]

NIST. (2012). 1.3.5.11. Measures of Skewness and Kurtosis, *National Institute of Standards and Technology (NIST)*, Available online: https://www.itl.nist.gov/div898/handbook/ [Accessed 25 April 2022]

Niu, E. (2017). Apple awards Corning $45 million from its Advanced Manufacturing Fund, Available online: https://www.apple.com/newsroom/2021/05/apple-awards-corning-45-million-from-its-advanced-manufacturing-fund/ [Accessed 9 May 2022]

Nugent, E. J., & Hamblin, D. J. (1996). Improved Methodologies for Vertical Integration Research, *Integrated Manufacturing Systems*, vol. 7, no. 1, pp. 16–28, Available online: https://doi.org/10.1108/09576069610108462 [Accessed 13 April 2022]

OECD. (2021). Global Value Chains: Efficiency and Risks in the Context of COVID-19, *OECD*, Available online: https://www.oecd.org/coronavirus/policy-responses/global-value-chains-efficiency-and-risks-in-the-context-of-covid-19-67c75fdc/ [Accessed 19 April 2022]

OECD. (2017). OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, Available online: https://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017_9789264268821-en [Accessed 19 April 2022]

Park, F. K., & Shapira, Z. (2017). Risk and Uncertainty, *The Palgrave Encyclopedia of Strategic Management*, pp. 1–7, Available online: https://doi.org/10.1057/978-1-349-94848-2_250-1 [Accessed 9 May 2022]

Rizwan, M. S., Ahmad, G., & Ashraf, D. (2020). Systemic Risk: The Impact of COVID-19, *Finance Research Letters*, vol. 36, p. 101682, Available online: https://doi.org/10.1016/j.frl.2020.101682 [Accessed 7 May 2022]

Ross, S. (2021). Samsung vs. Apple: Comparing Business Models (AAPL, SSNLF), *Investopedia*, Available online: https://www.investopedia.com/articles/markets/110315/samsung-vs-apple-comparing-business-models.asp#:~:text=Apple%3A%20Design%2C%20Integration%2C%20and,no%20small%20degree%20of%20risk [Accessed 4 May 2022]

Ruzzier, C. A. (2009). Asset Specificity and Vertical Integration*:* Williamson's Hypothesis Reconsidered, Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1374687 [Accessed 14 April 2022]

Schewe, E. (2021). Semiconductor Shortages End an Era of Globalization, *JSTOR Daily*, Available online: daily.jstor.org/semiconductor-shortages-end-an-era-of-globalization/ [Accessed 16 May 2022]

Stuckey, J., & White, D. (1993). When and When Not to Vertically Integrate, *McKinsey & Company*, Available at: https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/when-and-when-not-to-vertically-integrate [Accessed 14 April 2022]

UNDRR. (2021). COVID-19 and Systemic Risk, *UNDRR*, Available online: https://efdrr.undrr.org/covid-19-and-systemic-risk [Accessed 26 April 2022].

United Nations. (2015). World Economic Situation and Prospects 2015: The Global Economic Outlook, *United Nations Department of Economic and Social Affairs (DESA)*, Available online: https://www.un.org/en/development/desa/publications/wesp-2015.html [Accessed 11 May 2022]

University of Pennsylvania. (2021). Penn Libraries FAQ, *University of Pennsylvania*, Available online: https://faq.library.upenn.edu/business/faq/45560 [Accessed 20 April 2022]

Vakil, B., & Linton, T. (2021). Why We're in the Midst of a Global Semiconductor Shortage, *Harvard Business Review*, Available online: hbr.org/2021/02/why-were-in-the-midst-of-a-global-semiconductor-shortage [Accessed 26 April 2022]

Watson, P. (2018). Testing Normality Including Skewness and Kurtosis, *Cambridge University Press*, Available online: https://imaging.mrc-cbu.cam.ac.uk/statswiki/FAQ/Simon [Accessed 25 April 2022]

Williamson, O. E. (1979). Transaction-cost economics: The governance of contractual relations, *Journal of Law and Economics*, vol. 22, no. 2, pp. 233–261, Available online: https://www.jstor.org/stable/725118?seq=27 [Accessed 14 April 2022]

Williamson, O.E. (1989). Chapter 3 Transaction cost economics, *ScienceDirect*, Available at: https://www.sciencedirect.com/science/article/pii/S1573448X8901006X [Accessed 14 April 2022]

Witt, M. A. (2019). De-globalization: Theories, predictions, and opportunities for international business research, *Journal of International Business Studies*, Available online: https://link.springer.com/article/10.1057/s41267-019-00219-7?vid=190&error=cookies_not_supported&code=857e6094-53a4-4926-bc05-5ef4e78dda1f [Accessed 24 April 2022]

Woodruff, C. (2002). Non-contractible investments and vertical integration in the Mexican footwear industry, *International Journal of Industrial Organization*, vol. 20, no. 8, pp. 1197–1224, Available online: https://www.sciencedirect.com/science/article/pii/S0167718701000856 [Accessed 12 April 2022]

Young, S. (2013). Transaction Cost Economics, *Encyclopedia of Corporate Social Responsibility*, Available online: https://link.springer.com/referenceworkentry/10.1007%2F978-3-642-28036-8_221 [Accessed 12 April 2022]

Appendix

Appendix A

Consolidated Data

Industry	Company	VI 2015	VI 2021	Δ VI	Beta 2015	Beta 2021	Δ Beta
Consumer Electronics	Apple Inc.	0.070	-0.213	-0.282	1.145	1.307	0.162
Consumer Electronics	Samsung Electronics Co. Ltd.	0.737	0.828	0.091	0.938	1.068	0.130
Consumer Electronics	Motorola	0.893	0.860	-0.033	0.789	0.946	0.157
Consumer Electronics	Lenovo	0.274	0.340	0.066	1.113	0.793	-0.320
Consumer Electronics	LG Electronics	0.539	0.689	0.150	0.851	1.473	0.622
Consumer Electronics	ASUS	0.285	0.164	-0.121	0.879	0.535	-0.344
Consumer Electronics	Sony Corporation	0.759	0.869	0.110	1.180	1.178	-0.002
Consumer Electronics	Nokia Corporation	0.856	0.785	-0.071	1.273	1.354	0.081
Consumer Electronics	ZTE Corporation	0.847	0.848	0.001	1.124	0.817	-0.307
Consumer Electronics	Panasonic Corporation	0.854	0.882	0.028	1.136	1.143	0.007
Consumer Electronics	Toshiba Corporation	0.753	0.951	0.198	0.819	0.627	-0.192
Consumer Electronics	Microsoft Corporation	0.886	0.903	0.016	1.251	1.150	-0.101
Consumer Electronics	IBM	0.898	0.948	0.051	1.020	0.515	-0.505
Consumer Electronics	Hitachi	0.941	0.957	0.015	0.937	1.253	0.316
Consumer Electronics	Hewlett-Packard Company (HP)	0.299	0.215	-0.085	1.178	1.136	-0.042
Consumer Electronics	Dell Technologies Inc.	0.644	0.448	-0.196	0.970	1.079	0.109
Consumer	Philips	0.924	0.944	0.020	0.882	0.729	-0.153

Electronics							
Consumer Electronics	Funai Electric Co., Ltd.	0.902	0.922	0.020	1.032	0.138	-0.894
Consumer Electronics	Fujitsu Ltd.	0.884	0.929	0.045	0.902	1.004	0.102
Consumer Electronics	Canon	0.930	0.961	0.031	0.730	0.781	0.051
Consumer Electronics	Intel	0.843	0.877	0.033	1.013	1.340	0.327
Consumer Electronics	Haier Smart Home	0.738	0.888	0.150	1.029	1.286	0.257
Consumer Electronics	GoerTek	0.983	0.987	0.004	1.105	1.196	0.091
Consumer Electronics	Garmin	0.945	0.973	0.028	0.894	1.103	0.209
Consumer Electronics	Kyocera Corporation	0.954	0.982	0.027	1.149	1.070	-0.079
Consumer Electronics	Sharp Corporation	0.783	0.744	-0.040	0.573	0.883	0.310
Consumer Electronics	Electrolux AB	0.834	0.915	0.081	1.026	0.814	-0.212
Consumer Electronics	Tianma Microelectronics	0.954	0.978	0.024	1.502	0.631	-0.871
Consumer Electronics	Nintendo	0.693	0.643	-0.051	1.090	0.637	-0.453
Consumer Electronics	Zebra Technologies	0.869	0.918	0.050	1.351	1.299	-0.052
Consumer Electronics	Renesas Electronics	0.855	0.915	0.060	1.132	1.282	0.150
Consumer Electronics	Tokyo Electron	0.967	0.928	-0.040	0.996	1.149	0.153
Automotive	Toyota Motor Corporation	0.581	0.580	-0.001	1.003	0.995	-0.008
Automotive	Volkswagen Group	0.724	0.766	0.042	0.943	1.286	0.343
Automotive	Ford Motor Co.	0.547	0.623	0.076	1.054	1.205	0.151
Automotive	General Motors (GM)	0.581	0.594	0.013	1.024	1.266	0.242
Automotive	Tesla	0.786	0.857	0.071	1.136	1.932	0.796
Automotive	Honda Motor Co.	0.663	0.704	0.041	1.077	1.217	0.140
Automotive	Hyundai Motor Group	0.537	0.585	0.047	0.950	1.390	0.440
Automotive	BMW Group	0.674	0.707	0.033	0.955	1.035	0.080

Automotive	Daimler AG	0.747	0.757	0.010	1.016	1.091	0.075
Automotive	FAW Group	0.541	0.467	-0.075	1.315	0.502	-0.813
Automotive	Renault Group	0.723	0.780	0.057	1.176	1.408	0.232
Automotive	Nissan	0.551	0.667	0.116	1.036	1.203	0.167
Automotive	Guangzhou Automobile Industry Group (GAIG)	0.945	0.920	-0.025	1.110	0.787	-0.323
Automotive	Subaru Corporation	0.703	0.780	0.077	1.215	0.983	-0.232
Automotive	Volvo AB	0.787	0.844	0.056	1.205	1.136	-0.069
Automotive	Paccar	0.289	0.496	0.208	1.142	0.902	-0.240
Automotive	CNH Industrial	0.911	0.918	0.007	0.953	1.583	0.630
Automotive	Mazda	0.629	0.777	0.148	1.215	1.390	0.175
Automotive	Suzuki	0.660	0.780	0.120	1.150	1.284	0.134
Automotive	KIA	0.606	0.451	-0.156	0.711	1.472	0.761
Automotive	Stellantis	0.624	0.563	-0.061	1.087	1.510	0.423
Agr.Machinery	John Deere	0.820	0.861	0.041	0.906	1.092	0.186
Agr.Machinery	AGCO Corp	0.898	0.937	0.039	1.000	1.308	0.308
Healthcare	Medtronic	0.982	0.987	0.004	1.009	0.826	-0.183
Healthcare	Johnson & Johnson	0.961	0.952	-0.009	0.836	0.392	-0.444
Healthcare	GE	0.906	0.900	-0.006	1.001	1.016	0.015
Healthcare	Abbott Laboratories	0.962	0.985	0.023	1.139	0.528	-0.611
Healthcare	Fresenius	0.996	0.995	-0.001	0.889	0.651	-0.238
Healthcare	Becton Dickinson	0.986	0.984	-0.002	0.857	0.220	-0.637
Healthcare	Siemens Healthineers (Changed to Siemens AG)	0.898	0.967	0.069	0.450	0.480	0.030
Healthcare	Cardinal Health	0.560	0.616	0.056	0.927	0.621	-0.306
Healthcare	Stryker Corp	0.985	0.995	0.010	0.946	1.081	0.135
Healthcare	Hoffmann La Roche (ROG)	0.972	0.942	-0.031	1.004	1.061	0.057
Healthcare	Boston Scientific	0.988	0.997	0.009	1.056	0.910	-0.146
Healthcare	Zimmer Biomet	0.993	0.999	0.006	0.838	0.873	0.035
Healthcare	Baxter International	0.984	0.989	0.005	0.763	0.359	-0.404
Healthcare	Olympus	0.993	0.989	-0.004	1.042	1.107	0.065
Healthcare	Terumo	0.969	0.992	0.023	1.149	1.094	-0.055
Healthcare	Grifols	0.947	0.994	0.047	0.692	0.349	-0.343

Healthcare	Intuitive Surgical	0.968	0.987	0.019	0.764	1.329	0.565
Energy	Orsted	0.999	0.991	-0.008	0.450	1.293	0.843
Energy	Iberdrola	0.999	1.000	0.001	0.737	0.729	-0.008
Energy	Jinko Solar	0.990	0.938	-0.052	1.560	2.025	0.465
Energy	Vestas	0.966	0.959	-0.008	1.290	1.991	0.701
Energy	First Solar Inc.	0.998	0.985	-0.013	1.437	1.365	-0.072
Energy	Canadian Solar Inc.	0.996	0.991	-0.005	1.834	1.562	-0.272
Energy	NextEra Energy	0.989	0.999	0.010	0.660	0.752	0.092
Energy	Enphase Energy	0.990	0.801	-0.188	1.789	1.907	0.118
Electronic Components	Qualcomm	0.441	0.786	0.345	0.873	1.562	0.689
Electronic Components	Texas Instruments	0.711	0.896	0.185	1.209	1.483	0.274
Electronic Components	SK Hynix	0.768	0.922	0.154	1.255	1.408	0.153
Electronic Components	Broadcom	0.828	0.897	0.069	1.417	1.500	0.083
Electronic Components	Micron Technology	0.570	0.909	0.338	1.406	1.724	0.318
Electronic Components	TDK Corp	0.981	0.990	0.009	1.278	1.097	-0.181
Electronic Components	Nvidia	0.639	0.872	0.234	1.173	2.037	0.864
Electronic Components	AMD	0.452	0.767	0.315	1.178	1.697	0.519
Electronic Components	Everlight Electronics	0.855	0.930	0.075	1.030	1.157	0.127
Electronic Components	Seoul Semiconductor	0.927	0.786	-0.141	1.294	1.013	-0.281
Electronic Components	Eaton	0.925	0.954	0.028	1.214	1.021	-0.193
Electronic Components	Synopsys	0.999	1.000	0.000	0.895	1.681	0.786
Electronic Components	Delta Electronics	0.984	0.987	0.003	1.124	0.973	-0.151
Info. Comm. Tech	Oracle	0.979	0.980	0.001	1.041	0.755	-0.286
Info. Comm. Tech	Cisco	0.844	0.846	0.002	1.081	0.845	-0.236

Info. Comm. Tech	Ericsson	0.859	0.860	0.002	0.988	0.693	-0.295
Info. Comm. Tech	Inspur	0.572	0.468	-0.105	0.991	0.553	-0.438
Info. Comm. Tech	Verizon	0.850	0.869	0.019	0.733	0.220	-0.513
Info. Comm. Tech	AT&T	0.850	0.893	0.043	0.721	0.380	-0.341
Info. Comm. Tech	T-Mobile	0.803	0.824	0.021	0.724	0.875	0.151
Info. Comm. Tech	Vodafone	0.857	0.918	0.062	0.956	0.905	-0.051
Info. Comm. Tech	Arista Networks	0.937	0.833	-0.104	0.743	1.244	0.501

Appendix B

Alternative Vertical Integration Formulas

Sichel's Measure (1973):

$$\text{Minimum}\ (\%ABC, \%AB)$$

Note: where %AB is the percentage of companies engaged in the A and B production stages only and %ABC is the percentage of companies engaged in the A, B and C production stages.

Maddigan's Measure (1979):

$$VIC = 1 - \frac{1}{P\ Q}\ \text{(measure 7)}$$

where:

$$P = (1 + \sum_{i=2}^{n} c_{i1}^2) \times (1 + \sum_{\substack{i=1 \\ j=2}}^{n} c_{i2}^2) \ldots (1 + \sum_{i=1}^{n-1} c_{in}^2)$$

$$Q = (1 + \sum_{j=2}^{n} d_{1j}^2) \times (1 + \sum_{\substack{i=1 \\ j=2}}^{n} d_{2j}^2) \ldots (1 + \sum_{j=1}^{n-1} d_{nj}^2)$$

Note: where: c_{ij} is the percentage of the value of industry s(j)'s net output contributed by industry s(i), i, j = 1, …n; d_{ij} is equal to the percentage of the value of industry s(i)'s net output used as an input to industry s(j), i, j = 1 …n; s(i) is one of the industries in which the firm operates, indexed by i, j = 1 …n; and n is equal to the total number of industries in which the firm operates.

Burgess' Measures (1983):

Measure 1: Business Unit Level

$$1/V = \frac{\text{Internal purchases}}{\text{Internal purchases} + \text{internal sales}} \times \frac{1}{\text{Internal purchases/ total purchases}} + \frac{\text{Internal sales}}{\text{Internal purchases} + \text{internal sales}} \times \frac{1}{\text{Internal sales/ total sales}}\ \text{(measure 8)}.\ \frac{\text{Inter-unit trade}}{\text{Total trade}}.$$

Measure 2: Corporate Level

$$1/V_{i,ii} = \frac{w_i}{\text{Inter-unit trade/Total trade}} + \frac{w_{ii}}{\text{Inter-unit trade/Total purchases}}$$

where:

$$\frac{\text{Inter-unit trade}}{\text{Total trade}} = \frac{\text{Internal sales}}{\text{Total sales}} + \frac{\text{Internal purchases}}{\text{Total purchases}};$$

Note: w_i , w_{ii} are the proportions of the inter-unit trade done at the two interfaces; and $w_i + w_{ii} = 1$