Comparative Analysis: How Did COVID-19 and the Chip Shortage Affect the Operational Performance of Businesses

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ABSTRACT,

This study aimed to analyze the impact of COVID-19 and the semiconductor chip shortage on the operational performance of electronic manufacturing companies in Germany, Spain and Italy from 2020 to 2024. A Kruskal-Wallis test was conducted in order to assess the impact of the supply chain disruptions on businesses. This study gathered data on financial metrics such as Operating Income and Inventories working-in-process as well as medical data such as the number of COVID-19 cases from Refinitv Eikon and World Health Organization. The findings from this research suggest that the semiconductor chip shortage had a significant impact on the operational performance of electronic manufacturing companies, whereas COVID-19 showed no significant impact. The contribution of this research pertains to the overall understanding of supply chain disruptions by assessing the effects that supply chain glitches can have on the operational performance of businesses.

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Keywords

COVID-19, Semiconductor Chip Shortage, Operational Performance, Supply Chain Disruptions, Electronic Manufacturing

1. INTRODUCTION

In today's business landscape, supply chain management has become an integral practice for businesses that enables them to decrease their costs and enhance overall operational efficiency (Sivakumar & Premrajkumar, 2024). Businesses can gain a competitive advantage when they implement effective supply chain management techniques, such as inventory management and risk management (Krishan et al., 2024). Supply chain management has seen an increase in importance as its application can help businesses compete in global markets as well as carry out their distribution and production activities (Jurík, 2022). Therefore, it is important to investigate the topic of supply chain management as it plays a crucial role in modern business practices.

Supply chain disruptions, also referred to as supply chain glitches, are unexpected events interrupting the regular flow of goods and materials in the supply chain from production to distribution (Craighead et al., 2007). Some potential consequences of supply chain disruptions are increased costs, high lead times, decreased sales, and low inventory levels (Alessandria, 2023). Thus, it is essential for businesses to continue to develop risk mitigating strategies to ensure that operations in the supply chains can run smoothly, stay competitive and sustain long-term growth (Shrivastava & Dave, 2024).

Mitigating supply chain disruptions is a critical aspect in supply chain management, especially with the sudden uncovering of the COVID-19 pandemic and the chip shortage as they have expose the weaknesses in global supply chains (Kanike, et.al, 2023; Mohammad et al., 2022). Such glitches have directly affected the economic, technological, and especially health-related supply chains (Mohammad et al., 2022; Nicola et al., 2020). Consequently, research over supply chain disruptions is contemporary and necessary (Kesavan & Marianand, 2022; Li et al., 2021; Naidu et al., 2020).

This study will explore and compare the impacts of the COVID-19 pandemic and the semiconductor chip shortage. Assessing the impact that these disruptions have on businesses is important. Additionally, comparing their effect on businesses can provide valuable information to determine which disruption had a greater impact. An analysis of this type can help identify which supply chain disruption needs to be prioritized and for supply chain risk strategies to be implement against it (Nakano and Lau, 2020, as cited in Katsaliaki et al., 2021).

The motivation behind the research for this study on supply chain disruptions and their effect on operational performance, stems from the potential in gaining a competitive advantage in the current business landscape. By analyzing the effects of supply chain disruptions on business operational performance, this study aims to contribute its insights into the effects of supply chain disruptions on businesses.

1.1 Problem Statement

This thesis aims to analyze the effect of the COVID-19 pandemic and the semiconductor chip shortage on the operational performance of the supply chains of businesses in the electronic manufacturing sector from 2020 to 2024. The COVID-19 pandemic has caused supply chains to face vulnerabilities in regards to their lead times, network disruption and demand fluctuations (Ivanov & Dolgui, 2020).

The COVID-19 pandemic has economically disrupted supply chains, changing customer demands, affecting employees through illnesses, and affecting the ability of businesses to remain open or forcing them to be temporarily closed (Bartik et al., 2020). Furthermore, the impact of COVID-19 has not only affected the electronic manufacturing sector, but its impact has also extended to the healthcare, raw materials extraction, production and service industries sectors, leading to a global economic crumble (Naseer et al., 2023; Nicola et al., 2020).

Nonetheless, the semiconductor chip shortage holds similar value to be classified as a global supply chain disruption, directly affecting the electronic sector; especially in delayed production (Pandit et al., 2023). The scarcity of semiconductor chips has highlighted how important the role of the chips are in a wide array of industries, from communication technology to electronics and even motor vehicles (Haramboure et al., 2023).

Moreover, Mohammad et al. (2022) state that there has been a serious shortage of semiconductor chips since 2020, and that the shortage is still not over. The shortage's relevance can be seen through its direct impact on the production of many important electronic devices, such as smartphones, laptops, and automated vehicles (Mohammad et al., 2022).

To summarize, the insights on the COVID-19 pandemic and the semiconductor chip shortage demonstrate that they can be identified as supply chain disruptions with significant negative effects. Some of these being health issues, change in customer demands and an impact on the manufacturing of products (Bartik et al., 2020; Mohammad et al., 2022). The severity of these disruptions, call for an analysis on their effects on the operational performance of businesses.

Furthermore, in order to assess the magnitude of these supply chain disruptions on businesses and their implications, the study will analyze operating income as a key performance indicator (KPI). Operating income can serve to measure a company's profitability while excluding non-operating income and expenses. By focusing on the electronic manufacturing industry during the 2020-2024 time period, the study seeks to highlight the impact of supply chain disruption and catalyze further research for mitigation of their adverse negative effects on businesses.

1.2 Research Question and Objective

To reach the objective set for this thesis, the following research question has been formulated:

"To what extent did the COVID-19 pandemic and the chip shortage compare in their effect on the operational performance of electronic manufacturing companies' supply chains?".

This research question intends to assess how the operational performance of businesses in the electronic manufacturing sector has been affected by the COVID-19 pandemic and the semiconductor chip shortage.

The chosen period for data collection is from 2020 to 2024, which represents both the pre-disruption and the mid-disruption phases of the event. This time frame allows for a thorough analysis of the enduring effects of these disruptions on the operational performance of businesses. According to the World Health Organisation (2020), the COVID-19 virus was declared a pandemic due to its severity and spread levels in March 2020. Consequently, the pandemic ceased to be considered a public health emergency in May of 2023 (World Health Center, 2023).

More specifically, the difference in the effect between both disruptions and their direct impacts on business performance is investigated. Through the narrow scope and the specific metrics chosen, a unique perspective that may have been overlooked in more general studies will be provided. Through an analysis of empirical data on key performance indicators and a comparison using different periods; this study aims to provide insights into the magnitude of how these disruptions affect the operational performance of businesses. Additionally, the findings from this study attempt to contribute to future studies, in the field of the impact of supply chain disruptions. Highlighting the importance of supply chain reliance and other supply chain risk strategies which help reduce the negative effects that arise from supply chain disruptions.

2. LITERATURE REVIEW

The following literature review aims to provide an overview of existing research on supply chain disruptions, focusing on the supply chain disruptions, their negative effects, the effects of supply chain disruptions on multiple sectors, the impact of the COVID-19 pandemic, and the impact of the semiconductor chip shortage. This literature review will examine how these supply chain glitches affect the optional performance of businesses in the electronic manufacturing sector.

2.1.1 Operational Performance

In this study, operational performance is defined by Azim et al. (2015) as "The measurable aspects of the outcomes of an organization's processes, such as reliability, production cycle time, and inventory turns". Providing context, operational performance would be measured through the KPI, operating income. Operational performance can be measured through both financial and nonfinancial metrics. For this thesis only financial metrics will be used. Financial metrics can be measured in terms of profitability and financial stability, such as ROI, ROE, and profit margin (Galankashi and Rafiei, 2021; Holmberg, 2000; Li et al., 2006, as cited in Hasan et al., 2022).

Assessing the operating income of businesses gives insight into the performance and profitability of their operations. The expected correlation between operational performance and supply chain disruptions is for the former to decrease as the disruptions arise. This relationship is reinforced by Baghersad and Zobel (2021), as they reported that there is a correlation between supply chain disruptions and a significant decrease in operating income, as well as other financial metrics such as sales and return on assets. Additionally, external risks such as economic issues and epidemics, although rare in occurrence, can strongly impact supply chain performance (Abdel-Basset & Mohamed, 2020; Moktadir et al., 2021; Rostamzadeh et al., 2018; Song et al., 2017; Wu et al., 2017; Xu et al., 2019, as cited in Duong et al., 2023).

2.1.2 Supply Chain Disruptions

A deep overview of supply chain glitches and their impact on the operational performance of businesses is provided by Hendricks & Singhal (2005). The paper highlights the association of different glitches on operating income, sales, and inventories based on the period when the glitch occurred, the size of the firm, and the industry where the glitch occurred. Although the aim is to close the gap in the literature on the financial repercussions of supply chain glitches, there still needs to be more evidence about the effects of disruptions on business performance (Hendricks & Singhal, 2005). This is also reinforced by the fact that the evidence provided is currently hypothetical, and there needs to be a clearer understanding of how supply chain disruptions impact operational performance (Hendricks & Singhal, 2005). The paper outlines three types of ramifications that comes when facing supply chain glitches: a decrease in earnings, an increase in costs, and a decrease in brand image and reputation (Hendricks & Singhal, 2005). Overall, the paper suggests that glitches will have detrimental effects on businesses.

2.1.3 Differences and Similarities in the Effect of Supply Chain Disruptions in Different Sectors

The effects of supply chain disruptions have been a topic of interest in previous research across industries. Nonetheless, it is important to consider the effects that supply chain disruptions have on different sectors. This highlights the global significance of supply chain glitches and potential similarities that may exist across different sectors.

A common trend observed, is an increase in demand and supply uncertainty after a disruption (Rinaldi & Bottani, 2023). Glitches in the supply chain affect a wide range of product demand and supply; for instance, several sectors, such as the medical, machine manufacturing, and food, have felt a high degree of uncertainty (Rastogi, 2023; Rinaldi & Bottani, 2023). In addition, Nandi et al. (2021) claim that the demand for products has become quite volatile, especially in terms of consumer preference. For instance, changing from industrial-size packaged food and cleaning products to consumer-size.

Logistical challenges were another problem that occurred across different sectors. Supply chain disruptions often cause long lead times in the distribution and procurement of goods, as well as a decrease in profits, increase in costs, and bottlenecks, leading to a decrease in performance (Magableh, 2021; Santacreu & LaBelle, 2022).

Demand fluctuations seem to be sector specific, where the medical and food sectors experienced an increase in demand; however, in contrast, the textile and fashion sectors faced a significant decrease in their sales (Rinaldi & Bottani, 2023). In addition, sectors such as the textile and fashion and metal mechanical industries were negatively affected by the COVID-19 pandemic, leading to a decrease in volumes (Rinaldi & Bottani, 2023).

The negative effects of COVID-19 are expanded at a faster rate to essential goods, such as vaccines, medical equipment and medicine, and different food products have faced an increase in demand (Hasan et al., 2022; Nicola et al., 2020; Rastogi, 2023). In contrast, non-essential goods such as automotive, textiles and electronics experienced a decrease in sales volumes as demand cannot be satisfied, due to the lockdown, reducing store visit frequency (Cai and Luo., 2020; Chowdhury et al., 2021; Khan et al., 2021, as cited in Rinaldi & Bottani, 2023).

Although all sectors faced pressures in the supply chain regarding the raw materials available and logistic challenges, there was a great difference in demand. Some sectors saw an increase, such as medical and partially food and beverage, while fashion and textile, automotive and electronic saw a decrease.

2.1.4 COVID-19 Pandemic Impact

Beginning with the first supply chain disruption to be discussed in this literature, the COVID-19 pandemic has had a great impact on the world, particularly on multiple sectors of businesses. Moosavi et al. (2022) examine the global impact of the COVID-19 disease, including the implications of social distancing, mask-wearing, and the temporary closure of businesses. COVID-19 has disrupted supply chains through shifts in demand, product performance, finances, and lead time, necessitating a call to action and an adaptive response to this crisis (Devi et al., 2020; Moosavi et al., 2022).

Similarly, the COVID-19 pandemic has been considered as one of the most devastating disruptions, altering societal norms and business operations and leading to a significant number of health cases and deaths (Smith & Fatorachian, 2022). The authors stressed the urgent need for effective management strategies in response to the COVID-19 crisis. This urgency is further underscored by Hammad et al. (2023), who report that approximately 265.5 million people were affected by COVID-19 cases and 5.32 million deaths were recorded in 2021.

Furthermore, Moosavi et al. (2022), focus on another aspect of the consequences caused by the COVID-19 pandemic, including food shortages, demand fluctuation in the food sector due to panic buying, and a drop in demand for automobiles in China and Europe. The ripple effect of such a supply chain disruption on the global economy, highlights the interdependence and vulnerability of international supply chains.

Focusing specifically on the financial impact of COVID-19, Frieske and Stieler (2022) discuss how the pandemic has led to profit losses and how a halt in production would lead to even more losses of around 90 million EUR for the partners of the consult company Alix. Furthermore, COVID-19 negatively impacted the performance of companies as their total revenue has decreased due to factors such as quarantine and shifts in customer demands (He et al., 2023; Shen et al., 2020).

The impact of the pandemic can also be seen as the disruption of materials of the suppliers has affected the cash flow, lead time and performance of manufacturing activities. This can be seen especially within the electronic industry, as demand for electrical products has increased in the presence of COVID-19, such as computers (Haselton, 2020; Kan, 2020; Paul et al., 2021; and Sarkis et al., 2020; as cited in Zhuang, 2022). The authors underline the severity of negative impact caused by COVID-19 on these operational aspects.

2.1.5 Semiconductor Chip Shortage Impact

The semiconductor chip shortage has notably impacted the electronic manufacturing sector and its supply chains.

Literature has also looked at the potential causes of the semiconductor chip shortage. Casper et al. (2021) briefly state that the main cause of the chip shortage in the US was the COVID-19 pandemic, which raised issues in the manufacturing of electronics such as cars and laptops. Factory shutdowns, an overall increase in demand for electronic products and limited logistic capacity have all contributed to semiconductor chip shortage (Beibit et al., 2023).

Although the COVID-19 pandemic was a reason for the semiconductor chip shortage, other events have occurred that have contributed to the rise of this supply chain disruption, as this industry has been showing vulnerabilities and weaknesses before the pandemic (Beibit et al., 2023; Mohammad et al., 2022). Apart from COVID, some major events that have added to the semiconductor chip shortage have been winter streams, the Suez Canal blockage and the shortage of shipping equipment (Beibit et al., 2023).

In addition, the outstanding increase in the demand for semiconductor chips is currently exceeding its supply (Hasan et al., 2022). The increase in demand comes from the need for modern technology to contain a semiconductor chip in it to be able to function, emphasizing how important this product is for the global economy. Casper et al. (2021) also describe semiconductor chips as devices that can act as information processors and memory units and are typically used for smartphones, cars, and GPS devices, among other crucial technological devices. Mohammad et al. (2022) express how this current chip shortage has had a similar effect to the oil crisis of the 1970s, where supply chains faced problems such as products being halted, delayed, canceled, and their prices increasing.

Moreover, the shortage caused by COVID-19 led to China's production and the businesses that had their production completed overseas to be shutdown (Casper et al., 2021; Fatima and Ahmad, 2023). Overall, the authors discuss the impact of the semiconductor glitch on the economy and provides important and valuable insights into the challenges faced by global supply chains. Casper et al. (2021) continue expand this point further by stating that the impact of the semiconductor shortage has been felt through a rise in the prices of consumer goods caused by the shutdown in China during the pandemic.

Furthermore, literature has also focused on the different industries affected by the semiconductor chip shortage, especially the automotive and electronical (Mohammad et al. 2022; Young , 2021). The pivotal role that semiconductor chips play across industries highlights the fundamental significance of the overall production of technology and the severity of the shortage.

Mohammad et al. (2022) assert that nowadays, semiconductors are considered the brains of modern technology, with their importance evidently seen in a wide variety of industries, such as electrotechnology, automotive, and healthcare. Additionally Casper et al. (2021), explore the issue of semiconductor supply chain shortages across multiple industries, but more specifically in the automotive industry. Keohane (2021 as cited in Hasan et al. 2022), states how Volkswagen is facing shortages as chip suppliers save and reserve their units for tech companies who focus on manufacturing smartphones and tablets.

2.1.6 COVID-19 and Semiconductor Chip Shortage Overlap

The start of the semiconductor chip shortage is stated to have followed right after the start of the COVID-19 pandemic, and to have caused an increase in demand, resulting in shortages in the automotive industry as well as other industries (Ramani et al., 2022). Because of the lockdown as well as new health regulations, the overall demand for cars caused manufacturing factories to shut down production, which subsequently caused orders for components such as semiconductor chips to be canceled (Ramani et al., 2022; Hristova, 2022).

2.1.7 Difference in Supply Chain Disruptions

This last section of the literature review will focus on the different types of supply chain disruptions, and how their effects differ. Unnikrishnan et al. (2022), discuss 2 different types of supply chain disruptions, high frequency low duration and low frequency high duration. The focus for this thesis will be on low frequency and high duration disruptions, since both the COVID-19 pandemic and the semiconductor chip shortage fall under this category. Such disruptions occur rarely however, their effects last a very long time and its necessary to address them properly.

Supply chain disruptions can be categorized into several type, due to their causes. Kanike (2023), describes the different causes of supply chain disruptions, COVID-19 would fall under the natural disasters, while the semiconductor chip shortage under the technological breakdowns. The natural disasters disruptions, such as COVID-19 cause economic loses, cause declines in profitability and productivity (Kanike, 2023). On the other hand, technological breakdowns directly affect the efficiency of the supply chain processes (Khan and Huang 2013 as cited in Kanike, 2023). Based on the literature mentioned prior it can be expected for both disruptions to have a significant impact on operational performance, however COVID-19 would be expected to have a greater impact. COVID-19's effect on the health and economic sector in comparison with the semiconductor chip shortage attributes to the reason behind the expectation mentioned.

2.2 Hypothesis

Building upon the findings from the literature review, which discusses in detail the disruptions caused by the COVID-19 pandemic and the semiconductor chip shortage, leading to the following proposed hypothesis:

H1: The COVID-19 pandemic as a supply chain disruption had a negative effect on the operational performance of businesses in the electronic manufacturing sector.

H2: The semiconductor chip shortage as a supply chain disruption had a negative effect on the operational performance of businesses in the electronic manufacturing sector.

3. METHODOLOGY

3.1 Research Design

The approach taken is a quantitative research. The nature of the research question allows for this type of approach, in which we look at data to illustrate the different levels of performance executed by companies before and after the disruptions have taken place. According to Kandel (2020), quantitative research deals with numbers and is used to answer questions about the relationship between one thing and another in a population. Furthermore, since the variables that will be studied are numerical ones, quantitative research is most fitting.

First a regression analysis was considered as it matched well with the specifications of this study, as it can simultaneously analyze the effects of 2 independent variables on a continuous dependent variable (Slinker & Glantz, 2008). However, it is necessary to test for the statistical assumptions before the test is conducted. This step will help determine which statistical test is the most appropriate for the study considering the type of variables and data sampled (Shamsudheen & Hennig, 2023).

After conducting the tests, the normality, linearity, and homoscedasticity assumptions were not met, thus it was evident that another test had to be chosen. A Kruskal-Wallis test was chosen as the statistical test for this study. The Kruskal-Wallis test is a nonparametric test used when the assumptions of parametric tests are not met, such as normality that compares three or more groups interpedently (Macunluoğlu & Ocakoğlu, 2022; Selvi & Jaisurya, 2022). To conduct this test, the continuous independent variables were transformed and grouped into categories to be ranked to fit the test specifications (Chan & Walmsley, 1997; Macunluoğlu & Ocakoğlu, 2022).

The analysis aims to determine whether the operational performance of electronic manufacturing companies significantly changed due to COVID-19 and the semiconductor chip shortage during the selected time frame.

The statistical analysis will compare the operational performance across four different years: 2020, 2021, 2022 and 2023. Each of the years chosen to represent a different state of the disruptions: 2020 captures the initial impact of COVID-19, 2021 serves as the initial year for the semiconductor chip shortage as well as the first full year after COVID-19, and 2022 shows the continued effects of the chip shortage and the end of the COVID-19 pandemic, and finally 2023 will show how the industry started to recover from the disruptions. Furthermore, this study aims to analyze and compare the KPIs chosen for the businesses from the selected time frame. This analysis is divided into the following four time periods:

Time Frame 1: Peak COVID Impact (1st of March 2020 -1st of March 2021).

The first period chosen is from the 1st of March, 2020 to the 1st of March, 2021, as this time captures the peak of the COVID-19 impact on society. Bloom et al. (2021), state that the peak of the economic impact of Covid was during 2020 Q2, Thus the selected time frame would be able to determine COVID's highest impact.

Time Frame 2: Peak Chip Shortage Impact and Ongoing COVID-Imapct (1st of March 2021 – 1st of March 1 2022).

Regarding the semiconductor chip shortage, Mohammad et al. (2022) stated that "Since 2020, there has been a major supply shortage of semiconductors across the globe with no end insight." Thus, the selected time period will be from March, 2021 to March, 2022, which will explain the time frame when the chip shortage was most present after a year of its introduction. On the other hand, this time period will also be chosen for the COVID-19 disruption as it captures the peak of the pandemic's impact.

Time frame 3: End of COVID-19 and Ongoing Chip Shortage Impact (1st of March of 2022 - 1st of March of 2023).

The World Health Organization (2023) states that COVID-19 was no longer listed as a global health emergency on May 5, 2023. This period is crucial for understanding the most significant disruptions. Thus, in for the this third time frame, COVID-19 will take a smaller role as this time frame illustrates the culmination of the pandemic. On the other hand, the Semiconductor Chip Shortage was still ongoing (Mohammad et al., 2022).

Due to the nature of both glitches, the time of occurrence overlaps, which presents a challenge in identifying the individual influence of each factor, which serves as a limitation of this study. Frieske and Stieler (2022) argue how COVID-19 led to an increase in demand in the automotive industry, leading to bottlenecks in the supply champion of the electronic sectors during the fourth quarter of 2020. Finally, a comparison between results of the Kruskal-Wallis test will take place in order to determine which type of disruption had a higher magnitude of effect on business operational performance.

Time frame 4: Stabilization of COVID-19 and Semiconductor Chip Shortage (1st of March of 2023 - 1st of March of 2024).

Lastly, for the final period, the time chosen was from 1st of March, 2023, to the 1st of March, 2024, representing the phase of stabilization for both the semiconductor chips shortage and the COVID-19 cases. During this time period, the impact of the COVID-19 pandemic started to stabilize and decrease (World Health Organization's declaration, 2023). On the other hand, 2023 to 2024 for the semiconductor chip shortage serves

Finally, the programming software R-Studio will be used to analyze the data for the Kruskal-Wallis. According to Krotov (2017), R-Studio is a programming tool used for numerous functions, such as basic and intermediate statistical analysis, statistics, and regression.

3.2 Assumptions

Furthermore, a key set of assumptions must be met before conducting the analysis; these assumptions help determine whether the study provides valid results and gives validity and reliability (Sarstedt & Mooie, 2014). These are: 1. The regression model can be expressed in a linear way, 2. The residuals of the error terms must be normally distributed, 3. The variance of the errors is constant (homoscedasticity), and 4. The errors are independent (no autocorrelation).

The first assumption concerns linearity, where the regression model must be expressed linearly (Sarstedt & Mooi, 2014). The linearity assumption, according to Flatt and Jacobs (2019), requires a linear relation between the two variables. The test chosen to check whether this assumption has been met is the Ramsey-RESET test, which can help determine if a nonlinear regression term can explain the model (Flatt & Jacobs, 2019). For this test, if the result is $P > 0.05$, then we can assume that the model is linear.

The second assumption discusses the normality of residuals of the error terms normally distributed (Flatt & Jacobs, 2019). In this study, the way this assumption will be checked through a statistical test since this type of test has the advantage of objectively looking at the normality of the data. Thus, to test the assumption of expected normality of residuals, the ShapiroWilk test will be used as it is the most appropriate for a small sample and since it is the most commonly used to test the normality of the residuals (Mishra et al., 2019). When conducting the Shapiro-Wilk test, if the p-value > 0.05, then the residuals can be considered normally distributed (Mishra et al., 2019).

The third assumption, homoscedasticity, states that the model's error variance is constant in the regression model, while if the variance of values is not constant, then it is considered heteroskedasticity (Sarstedt & Mooi, 2014). In order to test the assumption of homoscedasticity, a Breusch-Pagan test will be conducted as this provides a numerical and formal evaluation of homoscedasticity, and since it is one of the most important methods to test for heteroscedasticity (Flatt & Jacobs, 2019). Lastly, to check whether the assumption is met through the Breusch-Pagan test, a significant result of $P > 0.05$ must be obtained to indicate that the error variance is constant and validate the assumption of homoscedasticity (Flatt & Jacobs, 2019).

Finally, the fourth assumption concerns no autocorrelation, which expects the regression model errors to be independent and the model to be uncorrelated through all the observations (Sarstedt & Mooi, 2014). Regarding this assumption, the error for one observation cannot be used to generalize other observations. To test this assumption, a Durbin-Watson test will be used as it assesses whether there is autocorrelation present by testing against an upper and lower bound for both a negative and positive autocorrelation (Sarstedt & Mooi, 2014). This method works by measuring the residual difference over time, where the score varies from 1 to 4, and where a score less than 1 signifies that the residuals are positively related, whereas a score higher than 3 means a negative relation. The Durbin-Watson test ensures that the assumption of no autocorrelation is met when the significant residual autocorrelation is at a value of 2 (Flatt & Jacobs, 2019).

3.3 Data Collection

To obtain the necessary data for this study, Refinitv Eikon will serve as the primary source, as it offers reliable data on the financial metrics of different companies. Refinitv Eikon provides access to both operating income and inventories work-in-process. This data allows for a quantitative analysis and comparison of the financial performances over time among the businesses sampled.

Helping address the research question on supply chain disruptions and their impact on optional performance.

When it comes to the data extraction process, the "Screener" analytical app in Refinitv Eikon allows users to scan, access and extract financial data categories. For this study the following categories were chosen, country of headquarters and the Global Industry Classification Standard (GICS). This application facilitates users in creating screens and visualizing the results from the reports.

Regarding the sample selection part of this thesis, companies from 3 countries were chosen: Italy, Spain, and Germany. The selection of these 3 countries is attributed to their importance and pivotal role in Europe.

Additionally, the selection of only 3 countries was done to show the effects of the independent variables in a more specific scope rather than a larger one.

Refinitv Eikon has a larger number of companies that could potentially have been used for this analysis; however, during the data cleaning process, it was found that some companies lacked complete data for all of the variables, thus rendering them ineligible for this analysis. After the cleaning the data, the final sample was 18 "Electrical Equipment" companies since this industry sector would involve the electronic manufacturing companies which this thesis aims to analyze.

The data regarding the number of COVID-19 cases, was accessed through the World Health Organization (2024). The website provided the number of COVID-19 cases per year for Germany, Italy, and Spain.

3.4 Operationalization of Variables

Firstly, to measure the impact that the disruptions had on businesses, it is necessary to operationalize both the independent and the depend variables.

For this thesis, operating income will serve the chosen KPI that will measure operating performance as the dependent variable, since this is the metric that we aim to predict. This KPI helps determine how well a company is generating income. Jayathilaka (2020) defines operating income as the profit gained while excluding interests and taxes. Operating income reflects a business's profitability, which makes it a suitable metric to assess the efficiency and proficiency of businesses.

In contrast, the independent variables for this study will be the number of COVID-19 cases and the inventories work-in-process. The number of COVID-19 cases in each specific country will measure the COVID-19 pandemic and for the chip shortage, this would be the inventories working-in-process of the electronic manufacturing companies.

Regarding the number of COVID-19 cases, this variable illustrates the severity of the virus in a specific region, which affects various aspects of economic activity. While a higher number of COVID-19 cases often correlated with stricter containment policies such as social distancing and lockdowns, different areas responded with different containment policies (Coccia, 2022). Countries with high containment policies, such as Germany, Italy and Spain, faced a higher number of confirmed COVID-19 cases in contrast to those with low containment policies. (Coccia, 2022).

On the other hand, inventories work-in-process according to Refinitiv Eikon (2024), refers to goods that are partially manufactured and are still waiting to be completed. Inventories work-in-process can serve as a crucial metric to define the chip shortage, especially for electronic manufacturers. As these companies depend heavily on semiconductors for their products, any delays in the inventories work-in-procress can directly affect their overall production output.

As mentioned previously to conduct the Kruskal-Wallis, the independent variables had to be transformed to categorical ones. This led a categorization of the continuous variables to be binned (Chan & Walmsley, 1997; Macunluoğlu & Ocakoğlu, 2022).

For the number of COVID-19 cases, 3 bins were chosen and labeled as low, medium and high. This number was chosen as it provided the closest results for an equal distribution of the observations for each of the groups, which is recommend practice to ensure ideal conditions for testing (Gleason, 2013).

The threshold selected was 1,119,498 for low, 9,892,214 as the medium scale, and finally 23,215,241 for the highest cases. The thresholds were specifically chosen as they allowed for the closest distribution between the samples and the number of bins.

Similarly, for the number of inventories work-in-process, 3 bins were chosen. The low threshold was of 7.000,000, the medium was 95,000,000, and the high was 3,557,000,000. In a similar manner, the specific number of bins were chosen as it would allow for the most equal distribution of the samples.

3.5 Kruskal-Wallis Formula

The formula for the Kruskal-Wallis formula is the following:

$$H = \frac{12}{N(N+1)} \sum \frac{{R_i}^2}{n_i} - 3(N+1)$$

Here, N is the total number of observations in the model, n_i, is the number of observations in the i-th category, and ${R_i}^2$ is the total sum of the ranks in the i-th category (Hoffman, 2019). Furthermore, the H is then tested against the chi-squared distribution with k-1 degrees of freedom, where k is the number of groups.

For the test regarding the number of COVID-19 cases and the inventories work-in-process, N= the total cases from the model, $n_1, n_{2,} n_3$, would be the number of samples in each of the ranked categories, ${R_1}^2\, {R_2}^2\, {R_3}^2$would be the sum of the values in each of the ranked categories.

4. RESULTS

This section of the thesis will provide an overview of the results from the statistical assumption tests and the Kruskal-Wallis test. The results for the assumption test will help determine which tests to conduct. While the Kruskal-Wallis test will analyze the impact of the COVID-19 pandemic in the form of COVID-19 cases and the semiconductor chip shortage in the form of inventories work-in-process, on operating income.

4.1 Descriptive Statistics

Before analyzing the results from the previously mentioned tests, it is important to also present the descriptive statistics for the sample in the study. This overview provides a summary of the data, enhances transparency and can show potential trends. Intable1,

Table 1

Descriptive Statistics Overview

Variable	*n*	*M*	*SD*	*Median*
1. Operating Income	72	-27,365,144	35,988,448	4,821,595
2. Number of Covid Cases	72	8,520,111	951,792	3,049,366
3. Inventory Working-in-Process	72	263,910,879	8,8061,960	15,665,000

4.2 Testing Assumptions

The following are the results to the statistical assumptions:

Firstly, table 2 presents the results to the linearity test assumption. The results were obtained after conducting the Ramsey RESET test. The p-value from the RESET test was 0.0172, which is lower than 0.05. The results indicates that the assumption of linearity is not met, and it is rejected. This means that the relationship between the independent variables (Inventories_WIP and Covid_Cases) and the dependent variable (Operating_Income) is not linear.

Table 2

Linearity Assumption

	Statistic	*df1*	*df2*	***P*-value**
Ramsey - Reset	4.3192	2	67	0.0172

Table 3 presents the results obtained test for the norrmality of residuals assumption. As mentioned prior in the methodology, when testing for the normality of residuals, a Shapiro-Wilk is conducted. The results from the Shapiro-Wilk test showed that the p-value was 2.615e-12, which is lower than 0.05. The results indicate that the assumption of normality is not met meaning that the that residuals of the model are not normally distributed, and the assumption is rejected.

Table 3

Normality of Residuals Assumption

	W	***P*-value**
Shapiro-Wilk	0.6229	2.615e-12

For the homoscedasticity assumption, the results for the Breusch-Pagan test, can be found in table 4. The p-value for the Breusch-Pagan is 1.164e-05, which is lower than 0.05. The test shows that the result was significant. Thus, the assumption of homoscedasticity is rejected, meaning that there is evidence for heteroscedasticity, and that the homoscedasticity assumption was not met.

Table 4

Homoscedasticity Assumption

	BP	***df***	***P-Value***
Breusch -Pagan	22.723	2	1.164e-05

Lastly, table 5 shows the results for the Independence Assumption. The result obtained for the Durbin-Watson test was 1.9429, which is close to 2; while the p-value was around 0.36. The result for the test indicates that there is no sign of autocorrelation but rather of independence, meanng the independence assumption was met, and the assumption is not rejected.

Table 5

Independence Assumption

	DW	***P-Value***
Durbin-Watson	1.9429	0.3675

4.2 Kruskal Wallis Test

In table 6, the results for the Kruskal-Wallis Rank sum test on the number of COVID-19 cases are presented. The results from the Kruskal-Wallis test show a p-value of 0.055. Based on the result, we do not reject the null hypothesis for H1. There is no significant evidence that the number of COVID-19 cases had an impact on operating income

Table 6

Kruskal-Wallis Sum Test for number of COVID-19 cases

	Kruskal-Wallis chi-squared	***df1***	***P*-value**
Kruskal -Wallis Test	5.7956	2	0.055

Furthermore, in table 7, the results for the Kruskal-Wallis Rank sum test for the inventory work in-process variable are presented. The results from the Kruskal-Wallis test show a p-value of 0.0012. Thus, we reject the null hypothesis for H2, showing that there is significant evidence that inventories work-in-process had an impact on operating income.

Table 7

Kruskal-Wallis Sum Test for inventories work-in-process

	Kruskal-Wallis chi-squared	***df 1***	***P*-value**
Kruskal -Wallis Test	13.432	2	0.0012

5. DISCUSSION

The goal of this study was to determine whether the COVID-19 pandemic and the semiconductor chip shortage had a significant effect on the operational performance of electronic manufacturing companies' supply chains. This discussion aims to explain the results obtained, assess whether the literature review was in accordance with them, and explain how such results can advance the current state of theory. Additionally, two hypotheses were formulated to reach this goal.

For the first hypothesis, "The COVID-19 pandemic as a supply chain disruption had a negative significant effect on the operational performance of businesses in the electronic manufacturing sector", the Kruskal-Wallis test was conducted. The findings in table 6 indicate that there is no statistical evidence to say that the number of COVID-19 cases had a significant effect on operational income. The results from the test generated a p-value of 0.055, which although close to the significance threshold, it does not fall under it. Therefore, we reject the hypothesis.

The results for the Kruskal-Wallis Sum test in table 6 do not align with the findings of Hendricks and Singhal (2005), which discuss the different ramifications that come from supply chain disruptions, such as decreased earnings and increased costs. This is further reinforced as Devi et al. (2020) describe how the crisis caused by COVID-19 will certainly affect profits and financial performance Thus, based on this literature the results from the test should have been significant and demonstrate that there is a an impact from the number COVID-19 cases on operational income. We can assume certain factors affected the results of this test, such as sample size and the KPI chosen to measure the dependent variable. The sample size used and the KPI chosen for the study might have influenced the results of the Kruskal-Wallis analysis. In terms of the sample size, a larger sample might have shown significance; regarding the KPI chosen, perhaps operating income was not able to capture the impact of the COVID-19 impact to its fullest extent.

Another cause for the deviation of the results could be attributed to the economic relief that governments provided to companies during the COVID-19 pandemic. The Spanish, Italian and German governments all introduced policies and programs that would financially support different businesses during the pandemic (Marois, 2020; Piernas, 2020; Vandone 2020). Therefore, the lack of significance for the COVID-19 pandemic on operational performance may be attributed to the financial aid that governments placed.

Lastly, the transformation process of the independent variables may have also served as a reason why the test did not show a significant result. As previously stated, it is recommended to have an equal sample size in each category in a statistical test (Gleason, 2013). As the samples for the number of COVID-19 cases were distributed to the ranked categories, their number was not uniform. This was due to the companies within each country to have the same number of cases per year.

A potential solution to this issue could be to have the specific number of COVID-19 cases in each of the regions where the companies were based. This way the distribution of the ranked categories could have been more uniform, and the companies would have shown different number of COVID-19 cases. These adjustments could have shown significance in the Kruskal-Wallis test for the COVID-19 pandemic.

For the second hypothesis, “The semiconductor chip shortage as a supply chain disruption had a negative significant effect on the operational performance of businesses in the electronic manufacturing sector”, a Kruskal-Wallis test was also conducted. The findings in table 7 indicate, that there is a significant impact of inventories work-in-process on operational income. The result from the test generated a p-value of 0.0012, therefore, we accept the hypothesis.

The findings from Frieske and Stieler (2022) align with the results found in this study, as they state how bottlenecks caused by both disruptions led to profit losses of up to 2.5 billion USD and how a decreased volume of vehicles manufactured would result in around 90 million EUR worth of losses for Alyx partners. Thus, the results obtained in table 7, do align with the literature mentioned, where inventories work-in-process do significantly impact operational income. A reason behind why the results aligned well with prior literature can be attributed to inventories work-in-process having a more direct impact on electronic manufacturers (Mohammad et al., 2022).

Based on the parameters of the study research, the semiconductor chip shortage had a greater impact on operational performance than the COVID-19 pandemic. These results do not align with the expectations made based on the prior literature, which predicted COVID-19 to have a greater impact than the chip shortage on the operational performance of electronic manufacturers (Khan and Huang 2013 as cited in Kanike, 2023).

While previous research has discussed the effects of the distortions across various sectors (Nicola et al., 2020; Rastogi, 2023; Rinaldi & Botani, 2023). This study offers a nuanced view, specifically of the effect of glitches on electronic manufacturing companies in three different European countries.

5.1 Conclusion

The aim of this thesis was to answer the research question, “To what extent did the COVID-19 pandemic and the chip shortage compare in their effect on the operational performance of electronic manufacturing companies' supply chains?”. To fully answer this research question, a Kruskal-Wallis test was used to measure the effect of the COVID-19 and the semiconductor chip shortage.

Based on the results, it can be said that the COVID-19 pandemic did not have a significant effect on the operational performance of electronic manufacturing companies' supply chains. On the other hand, the semiconductor chip shortage did have a significant impact on the operational performance of electronic manufacturing companies' supply chains. According to the findings, it can be concluded that, the electronic manufacturing companies were resilient towards the effect of COVID-19, while for the semiconductor chip shortage they were more vulnerable.

To summarize, this study investigated the impact of COVID-19 and the semiconductor chip shortage on the operational performance of electronic manufacturing companies in Germany, Spain and Italy between the time frame of 2020-2024. The Kruskal-Wallis test indicated that while the semiconductor chip shortage had a statistically significant impact on operational income, the COVID-19 cases did not reveal a significant effect. This study showed that within the scope of this research, the semiconductor chip shortage had a greater magnitude of impact on operational performance than the COVID-19 pandemic. Although the results from this study show a lack of a significant impact of COVID-19 on operational performance, this could have been because the scope chosen and the limitations faced during this analysis.

In conclusion, the absence of a significant effect of COVID-19 on operational performance compared with the semiconductor chip shortage highlights the need to continue research in the area of supply chain disruptions. Future research can benefit from a larger sample size and the inclusion of other independent variables and KIPs to examine the negative effects that arise from supply chain disruptions. Such limitations will be discuses later this chapter.

5.2 Practical Implications

This study's findings have practical implications in the scope of developing robust and rigorous supply chain strategies to mitigate the risks that arise with disruptions and glitches. Based on the findings of this study, companies should aim to have a diverse supplier base and enhance their logistical capacities. By doing this, companies can decrease the dependency of single suppliers of goods materials. As companies increase their logistical capacity, they can become more adaptivity and flexible in the face of future disruptions. Such strategies can be beneficial when coping with future disruptions and their negative effects on the operational performance of businesses.

5.3 Limitations

Even though this study's objective is to provide an analysis of the impact of COVID-19 and the semiconductor chip shortage on the operational performance in business, several limitations must be acknowledged.

First is the reliance on the data from Refinitv Eikon, meaning that the study is limited to the data provided by this platform. More specifically, regarding the financial metrics and KPIs, there was a set number of KPIs available; thus, confining the study to the available metrics. The impact of this limitation is seen specially in the selection of the variable to measure the impact of the semiconductor chip shortage. Backlog units is a KPI which can be used to measure the impact of the semiconductor chip shortage, as it measures the number of units which have not been delivered yet (Refinitv Eikon, 2024). However, Refinitv Eikon only had this variable available for companies in the homebuilding industry, thus the decision of utilizing backlog units was not possible.

Additionally, another limitation was the missing data from certain companies. Certain companies would have missing data in a certain year, making them ineligible for the analysis and thus reducing the sample size. The way this limitation was mitigated was by removing the companies with missing data, as a lack of data would have caused an error in the statistical analysis.

The nature of both disruptions also presents a challenge in isolating each glitch individually. During the time frame of 2021-2023, both disruptions occurred at the same time, making it difficult to examine the specific effect that each disruption had on operational performance.

Another area for improvement during this research was meeting some of the assumptions for statistical test, these being the normality, homoscedasticity linearity assumptions. A potential reason for this could have been the sample size, which had to be reduced after conducting a sample cleansing, as well as the nature of the data. When using financial data, an issue that can rise is dealing with the negative values, which end up affecting the normality of the model. These limitations in the data led to a change to a non-parametric test in the Krulis-Walis.

The last limitation faced was the scope chosen for the analysis. As this research was focused on electronic manufacturing companies in Germany, Italy, and Spain, it is limited to only this niche group. Consequently, the findings of this paper cannot be used to generalize other sectors or regions.

5.4 Future Research

To further enhance and build upon the findings of within this thesis, future research should expand the scope of the sample taken. Analyzing electronic manufacturing companies across more Europe countries rather than just Germany, Italy , and Spain could show patterns that were not found in this research. Additionally, it can provide a deeper understanding of the impact of these disruptions across different markets. Therefore, replicating the study with a larger and more representative sample of European companies could align better with previous literature. Future research could also use the study as a springboard to study mitigation strategies that firms can utilize to decrease the overall negative effect when encountering disruptions. Lastly future research could investigate resilience techniques against future these disruptions.

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