KEEP CALM AND CARRY ON

AN EMPIRICAL STUDY OF HOW FIRMS CAN BUILD RESILIENCE TOWARDS SUPPLY CHAIN DISRUPTIONS IN A GLOBALISED WORLD

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Keep Calm and Carry On: An empirical study of how firms can build resilience towards supply chain disruptions in a globalised world

Abstract:

Supply chains are navigating through an evolving environment where an increasing number of disruptions occur, in magnitudes reinforced by globalisation. Covid-19 revealed the vulnerability inherent in the interconnected global supply chain networks and unveiled the unpreparedness of firms to effectively manage the disruption’s adverse effects. In the aftermath of Covid-19, firms have demonstrated an unprecedented willingness to build resilience. This study therefore addresses the issue of building resilience in the dynamic environment. Firstly, employing the difference-in-difference model, our findings affirm the prevailing notion in the literature that demonstrated resilience can enhance firms' ability to withstand subsequent supply chain disruptions, as evident during the ones that followed the Tohoku Earthquake and Tsunami in 2011 and the US-China Trade War in 2018. Although this effect could not be confirmed for the supply chain disruption induced by Covid-19. Our findings thus confirm the prevalence of distinct challenges for supply chains in the evolving environment that Covid-19 unfolded in. Secondly, using a cross-sectional regression we find that during the supply chain disruption that followed Covid-19, low leverage, a restricted cash balance, and a shortened Cash Conversion Cycle enhanced resilience. Our study thus underscores the potential for firms to enhance resilience in the face of the evolving global environment by adopting these financial policies.

Keywords:

Supply chain disruptions, Supply chains, Resilience, Financial flexibility, Covid-19

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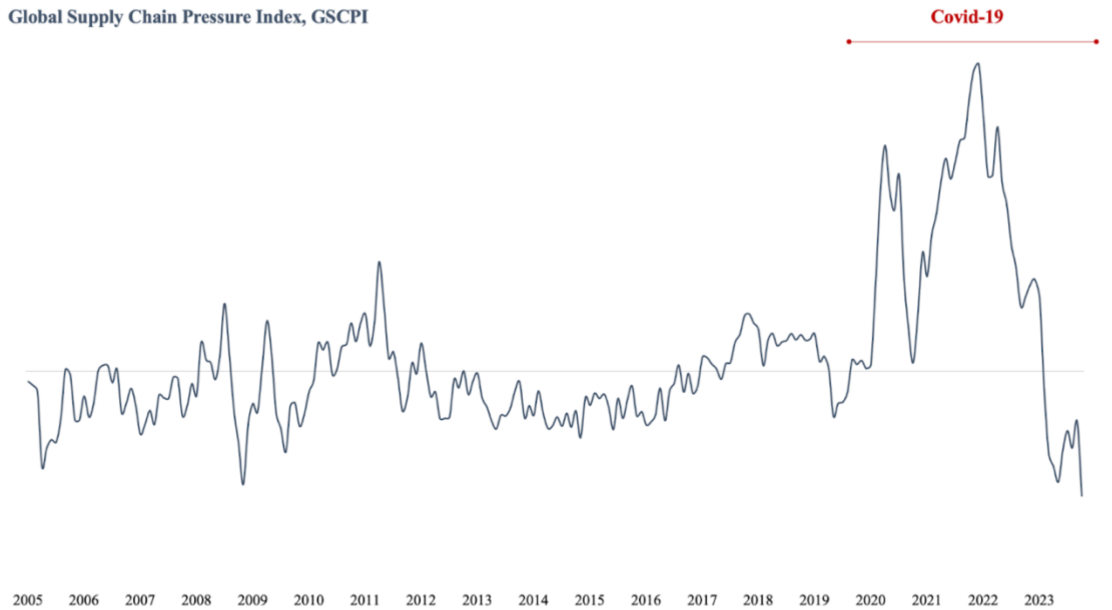
1. Introduction

Global supply chains have been under strain since the outbreak of Covid-19, revealing their vulnerability and incapability of responding to disruptions (Ivanov and Das, 2020). The global outbreak of COVID-19 prompted multiple countries to close their borders, leading to substantial disruptions in global supply chains. As showcased by the sudden spike in the Global Supply Chain Pressure index (hereafter referred to as GSCPI), Covid-19 caused supply chain disruptions with an aggregated magnitude exceeding any seen before (Benigno, Giovanni, Groen and Noble, 2022).



(Source: GSCPI, Federal Reserve Bank of New York)

Figure 1: GSCPI, depicting time varying pressure on global supply chains.

In the aftermath of Covid-19, an unprecedented focus has been placed on building resilient supply chains capable of enduring and recovering from disruptions. The Euromonitor International's Sustainability Survey 2023 reveals that 56% of global companies intend to increase their investments in supply chain resilience (Euromonitor International, 2023), underscoring its status as a top priority for companies. In the context of the current global business environment, marked by heightened geopolitical tension, and an increasing frequency of climate disasters (Benigno et al., 2022), global supply chains are under pressure, highlighting the importance of developing resilience. Covid-19 revealed the vulnerabilities that are inherent in the interconnectedness of modern supply chain networks. The noticeable shift towards prioritising resilience amongst practitioners in the aftermath of the Covid-19 pandemic, combined with the increased pressure on global supply chains, has motivated this thesis to explore how firms can build resilience towards supply chain disruptions.

Existing literature mainly focuses on redundancy strategies as means of building supply chain resilience, including strategic inventory and multiple sourcing. While these studies present strategies for how firms can improve their resilience, the Covid-19 supply chain disruption demonstrated that global supply chains lack preparedness. As a result, the question arises as to whether the evident absence of preparedness is due to the ineffectiveness of existing resilience strategies within the business environment in which Covid-19 unfolded. This thesis addresses the evident gap in the literature on how resilience can be developed in the current contemporary business landscape. Moreover, conventional resilience strategies neglect the existing trade-off between modern supply chain management, which promotes efficiency strategies (Barroso, Machado, Carvalho and Machado, 2015) and redundancy strategies. This results in a resistance among practitioners to apply precautionary strategies (Dolgui, Ivanov and Sokolov, 2021) to address the increasing global supply chain pressure. Consistent with the growing interest in aligning financial and operational decisions (Birge, 2015), we utilise conclusions from the field of corporate finance to establish how financial decisions can build resilience. Thereby we acknowledge the aforementioned trade-off, considering that the studied financial policies are decoupled from supply chain management. Leveraging insights from the unparalleled disruption brought by the Covid-19 pandemic, the research question is formulated as follows;

Did financial flexibility, as conventionally perceived, improve firms' ability to withstand the adverse effects of the Covid-19 supply chain disruption on operating performance?

To conclude on the research question, we examine U.S. publicly traded manufacturing firms in the light of Covid-19, through a two-step analysis. Firstly, we study if resilience increases firms' ability to withstand supply chain disruptions' adverse effects on operating performance. The relative difference in performance loss between resilient and non-resilient firms is assessed through an examination of supply chain disruptions triggered by three events that put high pressure on global supply chain networks, namely the Tohoku Tsunami and Earthquake in 2011, the US-China Trade War in 2018, and the Covid-19 pandemic in 2020. The first analysis serves two specific objectives: i) to determine whether resilience, measured by the resilience index (Barroso et al., 2015), enhances preparedness for subsequent disruptions, and ii) if the preparedness is sustained over time. Secondly, to reach a definitive conclusion on whether financial flexibility can enhance a firm's ability to withstand the adverse effects of a supply chain disruption, we examine resilience demonstrated by firms during the disruption that followed Covid-19. Utilising the resilience index (Barroso et al., 2015), we study whether the resilience of the observed firms during the supply chain disruption induced by Covid-19 is influenced by financial flexibility, measured through low leverage, cash holdings, and a short cash conversion cycle. In addition, the same analysis is conducted from a damping and recovery perspective to determine if there is a difference in how financial flexibility influences a firm's ability to mitigate and recover from the adverse effects of supply chain disruptions.

We find empirical evidence supporting that resilient firms outperform non-resilient firms during subsequent supply chain disruptions. We find that firms classified as resilient during the supply chain disruption triggered by the 2008 financial crisis encountered a 5 percentage points smaller reduction in sales growth following the Tohoku Earthquake and Tsunami in 2011 compared to non-resilient firms. Moreover, we find that the same group of resilient firms experienced a 3 percentage points smaller sales growth reduction following the US-China Trade War in 2018, compared to non-resilient firms. However, the results do not indicate such a difference in the context of Covid-19, neither when comparing firms that were resilient and non-resilient in the 2008 financial crisis, nor when comparing resilient and non-resilient firms in the more recent disruption following the US-China Trade War in 2018. These results suggest that i) resilience improved firms' ability to withstand the negative influence on sales growth during the subsequent supply chain disruptions caused by Tohoku Earthquake and Tsunami in 2011, the US-China Trade War in 2018, but not Covid-19 and ii) the superior ability demonstrated in the Tohoku Earthquake and Tsunami in 2011 sustains, but subsides, during the US-China Trade War in 2018, becoming completely insignificant during Covid-19. We thus conclude that resilience can increase a firms' ability to withstand the adverse effects of supply chain disruptions, while the disruption caused by Covid-19 is unique in its kind, proposing challenges that previously considered resilience enhancing capabilities cannot overcome.

The results further disclose a relationship between financial policies and resilience. More particularly, leverage policy exhibits a negative relationship with resilience where an increase in leverage ratio of one unit yields a subsequent decrease in resilience of 0.04. Cash reserves also report a negative relationship with resilience where an increase in cash ratio of one unit decreases resilience by 0.11, while the decrease in resilience is 0.01 lower for larger firms. Additionally, the study identifies a negative relationship between resilience and Cash Conversion Cycle in which a one unit increase in the Cash Conversion Cycle yields a decrease in resilience of 0.0001. Our results thus conclude that a firm can enhance resilience through the employment of low leverage, low cash reserves and a short cash conversion cycle.

The rest of our paper is structured as follows. Section 2 outlines the contribution of our thesis in detail. Section 3 and 4 highlights the most relevant findings of existing literature. Section 5 outlines the hypothesis of our study, aligning them with the discussion in Section 4. Section 6 presents the theoretical framework that we subsequently employ in the methodology for calculating a firm's resilience. Sections 7 and 8 detail the data and methodology employed in our study. Sections 9 present our empirical results. Section 10 relates our results to existing literature and discusses the implications of our findings. Lastly, Section 11 provides concluding remarks, presents limitations of the results, and provide suggestions for future research on the topic.

2. Contribution

Our thesis makes several contributions to the existing literature. Firstly, it anchors the resilience index developed by Barroso et al. (2015), through an analysis of how well the resilience index represents a firms' ability to withstand disruptions. In addition, we extend the framework presented by Barroso et al. (2015) by introducing two distinct indices that assess a company's ability to mitigate the adverse effects of supply chain disruptions and its ability to recover from the negative impacts caused by such disruptions. While Barroso et al. (2015) theoretically explores the differentiation between a company's damping phase and recovery phase, we add value by explicitly quantifying this distinction, marking a notable contribution.

Secondly, we contribute to the resilience literature with findings that suggest the necessity for exploring capabilities that enhance resilience in the contemporary environment. Existing research has studied how resilience is developed within the context of historical supply chain disruptions (Craighead, Blackhurst, Rungtusanatham and Handfield, 2007; Datta and Christopher, 2011; Pettit Fiksel and Croxton, 2010; Kang, Kumar and Harrison, 2011; Habermann, Blackhurst and Metcalf, 2015). However, the unprecedented magnitude of the pandemic and its supply chain disruption present evidence that supply chain disruptions in the modern economy differ from those experienced historically (Ivanov and Das, 2020). We find that, while ex ante resilience seems to have increased a firm's ability to withstand disruptions historically, the same cannot be concluded in the context of Covid-19. Therefore, our thesis contributes to both existing literature and practical knowledge by emphasising that resilience capabilities demonstrated in previous supply chain disruptions may not necessarily exhibit the same resilience to more contemporary disruptions. This underscores the significance of re-evaluating resilience capabilities in the modern business environment.

Thirdly, we present empirical evidence on how firms can develop supply chain resilience using financial policies in the context of Covid-19, unfolding in an environment marked by intense globalisation. Although our study doesn't offer an exhaustive overview of resilience-building strategies for firms, it empirically demonstrates that financial policies, specifically low leverage, low cash reserves, and a short cash conversion cycle, enhance resilience.

Lastly, our study acknowledges the trade-off between redundancy strategies and efficient supply chain management (Ivanov and Dolgui, 2021), and thus addresses the evident gap in the literature on how to achieve resilience towards disruptions without sacrificing efficient supply chain strategies. These findings are furthermore of value for practitioners. In light of the escalating number of supply chain disruptions, the enduring consequences of disruptive events on firm performance (Hendricks and Singhal, 2005b) underscore the critical need for firms to increase their resilience. Even though supply chain resilience is a top priority for companies (Euromonitor International, 2023), proven resilience capabilities are widely overlooked by firms due to their inefficient nature (Ivanov and Dolgui, 2021). Considering that financial policies are decoupled from modern supply chain paradigms, our findings suggest a way of enhancing resilience without sacrificing efficiency strategies.

3. Background

3.1. Supply chain disruptions: types and risks

A supply chain disruption is characterised as an event that interrupts the movement of goods or services within a supply chain, consequently impeding firms' regular operations and, as a result, their ability to perform (Hendricks and Singhal, 2003). There is an extensive research-body on supply chain disruptions, with the majority focusing on understanding and classifying various types of supply chain risks that can lead to disruptions.

Disruption risks encompasses the broader concept of potential threats and uncertainties that may negatively impact a supply chain. Disruption risks are typically referred to as low likelihood, but high impact events. These events are inherently unpredictable in terms of their type, scale, and nature, and they can lead to negative effects that prevail over either a short or long period of time (Ho, Zheng, Yildiz and talluri, 2015; Torabi, Baghersad and Mansouri, 2015; Dolgui, Ivanov and Sokolov, 2018). Christopher and Peck (2004) identify three main types of disruption risks: internal risks associated with disruptions to the firm's internal processes and control, risks that are external to the firm but internal to the supply chain (such as supply or demand disruptions), and environmental risks that are external to the supply chain network that can impact supply, demand, and internal operations within a network directly or indirectly. Environmental disruption risks encompass events of socio-political, economic, or technological nature and may result from predictable or unpredictable occurrences (Christopher and Peck, 2004).

3.2. Supply chain disruptions in the light of modern transnational manufacturing

Christopher and Peck (2004) underscore the misalignment between modern business strategy and the mitigation of supply chain vulnerability, recognising how these strategies amplify exposure to environmental supply chain risk. For instance, a decision to shift from domestic to global sourcing to reduce unit costs may result in heightened supply chain disruption risk associated with extended lead times, external partners being more susceptible to external events, and potential loss of control (Christopher and Peck, 2004). Bhattacharyya, Datta and Offodile (2010) and Naor, Linderman and Schroeder (2010) elaborate on the challenges associated with global supply chains. They underscore that global supply chains, spanning different continents, become vulnerable to risks arising from local events which, despite their regional origins, can have far-reaching global consequences. In the era of transnational manufacturing, where items are produced in one country and transported across national borders for additional processes, storage, remanufacturing, recycling, or disposal (Ferdows, 1997), the heightened environmental supply chain risk related to global sourcing and the complexity of supply chain networks hold particularly true for manufacturing companies.

An instance of a supply chain disruption affecting industries with interconnected global operations is the Tohoku Tsunami and Earthquake in Japan in March 2011. The catastrophe is considered one of the largest disruptions to global supply chains in modern history (Revilla and Sáenz, 2014), and had particularly significant repercussions on the manufacturing industry (Park, Hong and Jungbae Roh, 2013). While the disruption occurred on a local level, the global interconnectedness induced ripple effects causing significant influence on firms operating in other geographical areas. The global scalability of the earthquake and tsunami became evident by the critical component part shortage for the automotive industry and the subsequent operational shutdowns of plants in the United States. (Park, Hong and Jungbae Roh, 2013) Aerospace giants like Boeing were heavily affected as well, given that three key aerospace suppliers were located in the disruption-prone zone, and Japan stood as the world's second-largest aerospace supplier (Bloomberg, 2011).

More recurring and predictable disruptions than those originating from environmental catastrophes are those of socio-economic nature. The financial crisis in 2008 was from a supply chain perspective initially a demand disruption, leading to a 20-30% decline in demand within six months. Following a price drop of 40% throughout all levels of supply chains, the initial demand disruption evolved into a supply disruption, magnified by a significant number of supplier insolvencies. While some markets recovered more swiftly, the US market lagged in recovery. (Jüttner and Maklan, 2011) Although the Financial Crisis did not directly cause a disruption in the supply chain network by interrupting its physical flow, its extensive influence on the availability of credit, demand for goods and services (Notteboom, Thanos and Rodrigue, 2021), implies that the 2008 financial crisis can be regarded as a supply chain disruption (Jüttner and Maklan, 2011).

Another instance of a supply chain disruption stemming from a socio-economic event is the disruption following the US-China Trade War in 2018 (Blessley and Mudambi, 2022). Starting in early 2018, the US trade conflict with China involved tariff hikes on imports from China and a trade ban against Huawei (Gereffi, Lim and Lee, 2021). Gereffi et al. (2021) emphasises how trade policies, as those imposed during the US-China Trade War, can lead to unintended consequences that disrupt supply chains on a global level. Given the interconnectedness of global value chains, the impact of trade restrictions can extend beyond the two countries that the trade policy considers.

3.3. The Covid-19 supply chain disruption

Covid-19 is considered a unique supply chain disruption, unlike any seen before (Ivanov and Das, 2020), distinguished by its prolonged and unpredictably scalable nature. The pandemic which unfolded in a globalised environment, created a complex setting with simultaneous disruptions in supply, demand, and logistics infrastructure, causing both forward and backward disruption propagations. The impact of the Covid-19 pandemic demonstrates the ripple effect; how disruptions upstream in supply chains adversely affect the performance of individual firms and networks, resulting in a cascade of failures within multistage networks. (Ivanov and Dolgui, 2021)

While some view Covid-19 as a rare event, a more pessimistic view suggests that prolonged uncertainty in both demand and supply could persist, possibly shaping a "new normal". (Ivanov and Dolgui, 2021). Russia’s invasion of Ukraine, and the supply chain disruption that followed related to for instance agri-food products and energy supply (Rahbari, Arshadi Khamseh and Sadati-Keneti, 2023) indicates that the aforementioned pessimistic view has substance. As a response to the severe consequences on supply chains post Covid-19, combined with the belief of persistent heightened supply chain disruption risk, The Federal Reserve Bank of New York developed the Global Supply Chain Pressure index. The index monitors the state of global supply chains and is measured in terms of standard deviations from the historical average. (Benigno et al., 2022)

4. Literature review

4.1. Supply chain disruptions' adverse effect on operating performance

Previous research acknowledges the impact of supply chain disruptions on the operating performance of vulnerable firms. Hendricks and Singhal (2005) report empirical evidence of a negative association between supply chain disruptions and sales, operating income, respectively return on assets, indicating adverse effects. Hendricks and Singhal (2005) furthermore find that firms faced by a supply chain disruption did not fully recover from the negative impact on operating performance even two years after the announcement, highlighting the enduring consequences of disruptive events on firm performance. Baghersad and Zobel (2020) find consistent results in their study, while also highlighting an immediate negative impact at the quarter of the disruption, indicating an instant effect derived from disruptions (Baghersad and Zobel, 2020).

The degree to which firms suffer following a supply chain disruption seem to vary depending on the characteristics of the firm. Baghersad and Zobel (2020) empirically show that there are differences across industries in firms' ability to recover from a disruption's initial effect. Hendricks and Singhal (2005) moreover find that the operating performance of larger firms is less negatively impacted than smaller firms, indicating a difference in ability to withstand the effects of a disruption. Baghersad and Zobel (2020) confirm this finding while also showing that smaller firms are able to recover more quickly from the initial loss derived from a supply chain disruption. The consensus that there is a difference between how well firms cope with the adverse effects of a supply chain disruption (Hendricks and Singhal, 2005; Baghersad and Zobel 2020) is of interest to this thesis, since it signals that the ability to withstand and recover from disruptions is not coincidental but can rather be developed.

4.2. Supply chain resilience

An extensive research body has focused on preventing the adverse effect of disruptions by minimising the likelihood that disruptive events occur (Tomlin 2006; Ritchie and Brindley 2007; Zwikael and Sadeh 2007; Manuj and Mentzer 2008a; Wagner and Bode 2008; Fragniére et al. 2010; Wang et al. 2010; Yang and Yang 2010). However, while some events triggering supply chain disruptions can be foreseen, the majority are unpredictable and unpreventable in their nature (Torabi and Baghersad, 2015, Dolgui et al., 2018). In recent years, significant attention has therefore been directed towards supply chain resilience (Hosseini, Morshedlou, Ivanov, Sarder, Barker and Khaled 2019b). A resilient firm effectively responds to adverse consequences of unexpected events, maintains growth patterns, and promptly returns to its original state (Christopher and Peck 2004; Carvalho and Areal, 2016). Rather than preventing incidents, resilience enables system recovery in the aftermath of a disruption with adverse effects (Dinh, Pasman, Gao and Mannan, 2012), making it a crucial element in addressing unforeseeable disruptions like those affecting a supply chain (Sheffi and Rice 2005). Barroso et al. (2015) introduced the resilience index, quantifying resilience as the area beneath a response curve relative to the expected area in the absence of the disruption. This framework assesses a firm’s ability to dampen the effects of and recover from a disruptive event, making it useful for analysing a firm’s individual resilience (Barroso et al., 2015). Applying the resilience index to companies in an automotive supply chain, the authors observed distinct differences in firms’ specific resilience indices when facing the same disruption (Barroso et al., 2015). This suggests the presence of underlying factors contributing to the varying levels of resilience.

Other studies have attempted to identify specific factors that influence a firm’s resilience, with a primary focus on those stemming from the actual construction of supply chain systems, including supply chain collaboration (Christopher and Peck, 2004; Datta and Christopher, 2011; Pettit et al., 2010; Tang, 2006), supplier selection (Hosseini et al., 2019b), and network structure and design (Craighead et al., 2007; Habermann et al., 2015; Nair and Vidal, 2011; Kang et al., 2011). MacKenzie and Zobel (2016) emphasise that in order to optimise firm resilience, resources should be allocated to the mitigation of a disruption’s impact and the recovery from them, highlighting the importance of separately examining what factors that increase a firm’s resilience in these two phases.

Resilience is primarily structured around three key assets; risk mitigation inventories and backup supply, disruption orientation, and contingent recovery plans (Hosseini et al., 2019b). However, implementing such redundancy strategies involves a trade-off with modern supply chain management paradigms like lean manufacturing, just-in-time, and global sourcing (Ivanov and Dolgui, 2021), known for reducing operating costs and enhancing competitiveness (Barroso et al., 2015). Since supply chain disruptions have been unlikely in their nature with a magnitude that is difficult to predict (Ho et al., 2015), it is easier for firms to recognize the profitability gained from efficiency than to grasp the potential loss resulting from a disruption. Despite the established importance of resilience capabilities among researchers, they are thus often overlooked by practitioners (Ivanov and Dolgui, 2021).

In a more recent study on supply chain resilience Mohammed, Lopes de Sousa Jabbour and Diabat (2023), recognises the distinction between external resilience, being the vulnerability of a firm’s supply chain network, and internal resilience, being a firm’s ability to integrate and reconfigure internal resources to address a changing business environment (Mohammed et., al, 2023). Within the area of internal resilience, a few studies exist. Tang and Tomlin (2008) identify flexibility as the single most important capability for supply chain resilience (Tang and Tomlin, 2008). Similarly, Ambulkar, Blackhurst, and Grawe (2015), find that resource reconfiguration increases a firm's resilience since it enables the firm to quickly respond to changes brought by a supply chain disruption. They also argue that resource rigidity prevents firms from adjusting their resource base in response to changes in the operational environment (Ambulkar et al., 2015). Parker and Ameen (2018), moreover discusses that since smaller firms more regularly resource reconfigure, they prove to be more flexible and agile. Previous literature seems to agree that internal, dynamic capabilities can increase supply chain resilience (Mohammed et al., 2023; Ambulkar et al., 2015; Tang and Tomlin, 2008). However, empirical evidence on how these capabilities, that build internal resilience, can be developed is notably absent. This gap in research serves as the motivation for the study and forms the basis for the contribution of this thesis.

Recent attention has been directed to explore a joint optimization of operational and financial decisions (Birge, 2015), sparking an interest in exploring the interconnectedness of financial policies and operational implications during supply chain disruptions. Within the research body of corporate finance, financial flexibility is seen as a strategic asset that increases agility and strengthens the ability to navigate unexpected periods of insufficient resources (Denis, 2011). Since financial flexibility makes firms less vulnerable to unforeseen changes in the operating environment (Fahlenbrach, Rageth, Stulz and Mueller, 2021), it demonstrates similarities to the dynamic capabilities that provenly yield resilience. This thesis therefore aims to investigate whether a company can enhance its supply chain resilience through financial flexibility.

In an empirical study of the East Asian crisis 1997-1998, Arslan-Ayaydin, Florackis and Ozkan (2013), found that firms exhibiting higher levels of financial flexibility before the crisis performed better during the crisis than those with lower financial flexibility. While Arslan-Ayaydin et al. (2013) do not explicitly study the relation between financial flexibility and resilience towards supply chain disruptions, their study indicates the existence of such a relation.

4.3. Supply chain resilience through financial flexibility

Existing studies mainly consider low leverage policies (Lins, Servaes and Tufano, 2010; Campello, Graham and Harvey, 2010), and cash holdings (Opler, Pinkowitz, Stulz and Williamson, 1999; Almeida and Campello, 2004; Acharya, Almeida and Campello, 2007; Faulkender and Wang, 2006; Pinkowitz and Williamson, 2006; Dittmar and Mahrt-Smith, 2007; Harford, Mansi and Maxwell, 2008) as ways of achieving financial flexibility. However, McNeil and Moore (2023) observe that the flexibility attained from cash is counteracted by a decrease in capital allocation efficiency derived from large cash holdings. Moreover, working capital management has received considerable attention in previous years within the field of corporate finance and financial flexibility (Peng and Zhou, 2019) for its proven influence on operating performance (Aktas, Croci and Petmezas, 2015). Management of working capital can enhance a company's financial flexibility by releasing capital, diminishing the need for financing daily operational activities (Aktas et al., 2015). Efficient working capital management is traditionally considered to be achieved through a short Cash Conversion Cycle (hereafter referred to as CCC) (Banerjee, Kundu and Sivasankaran, 2021), which essentially measures the duration it takes for a company to convert its resources into cash flows (Harris and Hampton, 2021). The CCC can be further broken down into cycles of accounts receivable, accounts payable, and inventories. It is quantified as the sum of Days of Sales Outstanding (DSO) and Days of Inventory Outstanding (DIO), minus the Days of Payables Outstanding (DPO) (Ding, Guariglia and Knight, 2013).

Past research suggests that the choice of leverage policies can influence the extent of adverse effects experienced during turbulent periods. This is illustrated in a study conducted by Nguyen, Le, Vu, and Tran (2023), where they observe that companies with a lower debt capital structure demonstrated greater resilience to financial instability amid the challenges posed by Covid-19. DeAngelo, DeAngelo and Whited (2011) argue that maintaining low leverage, conceptualised as unused debt capacity, allows a firm to retain the ability to access capital markets in the event of unexpected earnings shortfalls.

Additionally, McKoen and Denis (2012) underscore that leverage, which entails fixed obligations and repayment schedules, constrains the flexibility of a firm in allocating resources.

Moreover, cash reserves are considered to create value in the supply chain by increasing adaptability (Carnes, Cavanaugh, David and O'Brien, 2023). Kulchania and Thomas (2017), find empirical evidence that the ongoing trend of increased average cash holdings amongst U.S firms can be explained by the increased supply chain pressure, indicating that companies rely on cash reserves as a hedge against supply chain disruptions. Moreover, their results indicate a significant post supply chain disruption decline in cash holdings, consistent with the idea that cash is used as the primary source of financing during a disruption (Kulchania and Thomas, 2017). While not tested empirically, firms with substantial cash holdings are perceived as better positioned to possess the slack resources needed to adapt their supply chain to evolving environments (Carnes et., al, 2023).

Enqvist, Graham, and Nikkinen (2014) underscore the significant correlation between working capital management and corporate profitability during economic downturns, highlighting the importance of working capital management in times of disruption. The conventional view of CCC is that all companies should strive to minimise it, given that a shorter CCC signifies efficient cash management (Das, 2015). Contrary, Afza and Nazir (2007) identify a positive correlation between corporate profitability and extended inventory periods during production interruptions, which in a traditional view is seen as inefficient working capital management.

Appuhami (2008) more broadly defines efficient working capital management as a company's ability to swiftly respond to unexpected shifts in market conditions. This perspective implies that the determination of whether the CCC should be extended or shortened is contingent on the prevailing market conditions. Ding et al. (2013) find that firms with substantial working capital stock demonstrate enhanced ability to adjust their working capital in the presence of cash flow shocks. This indicates that a firm’s working capital management approach prior to a disruption has an effect on its ability to be flexible during a disruption. Peng and Zhou (2019) elaborate on the issues posed by the traditional view of efficient working capital management. They argue that this approach, encouraging rapid turnover of inventory and cash, can exert financial pressure on a firm's suppliers or distributors.

5. Hypothesis formulation

While existing literature proves a difference in how much firms' operating performances are influenced by a supply chain disruption (Baghersad and Zobel, 2020; Hendricks and Singhal, 2005b), they offer limited explanation behind the varying degrees. The question emerges as to whether it is the resilience of a firm that contributes to variations in performance when confronted with a supply chain disruption. As suggested by the literature, resilience enables a firm to respond better to the consequences of unexpected events and thus limits the pre and post discrepancy in growth (Christopher and Peck, 2004). Therefore, it is anticipated that firms that have exhibited higher resilience, proxied by the resilience index (Barroso et al., 2015), are less influenced by a subsequent supply chain disruption, motivating the following hypothesis;

1. Firms demonstrating resilience possess an enhanced ability to withstand subsequent supply chain disruptions

If the first hypothesis is confirmed, the resilience index can be grounded in its theoretical framework. This, in turn, enables the accurate identification of characteristics that enhance resilience, providing valuable guidance for how firms can increase preparedness towards a supply chain disruption. The second hypothesis utilises the supply chain disruption caused by Covid-19 to identify if financial flexibility enhanced resilience of the observed firms.

Previous research has demonstrated that resource reconfiguration plays a crucial role in enhancing a firm's resilience by creating agility (Ambulkar et al., 2015). Additionally, flexibility as a dynamic capability has been identified as a key factor in enhancing resilience, as exemplified in Tang and Tomlin's study (2008). Considering that financial flexibility increases agility (Dennis, 2011) and mitigates vulnerability to unforeseen changes in the operating environment (Fahlenbrach et al., 2021), it suggests that the resilience brought by dynamic capabilities (Tang and Tomlin, 2008) can be achieved through financial flexibility. Further support for this hypothesis is drawn from the outcomes of Arslan-Ayaydin et al.'s (2013) study on the East Asian crisis, where financially flexible firms demonstrated superior performance during the crisis. Consequently, the second hypothesis can be formulated as follows;

2. Financial flexibility enhanced resilience during the supply chain disruption following Covid-19

While financial flexibility is fundamentally a conceptual framework, it is identified through specific financial policies adopted by a firm (Denis, 2011). Consequently, the second hypothesis is deconstructed into three distinct and measurable sub-hypotheses, each with metrics related to financial flexibility.

Existing research indicates that financial flexibility can be achieved through low-leverage policies (Lins et al., 2010; Campello et al., 2010). Furthermore, companies with lower debt structure exhibited greater stability when confronted with the financial challenges posed by Covid-19 (Nguyen et al., 2023). Thus, the first testable component of hypothesis two is formulated as follows;

2a. Low leverage policy enhanced resilience during the supply chain disruption following Covid-19

Maintaining cash reserves is also recognized as a strategy for preserving financial flexibility (Opler et al., 1999; Almeida and Campello, 2004; Acharya et al., 2007; Faulkender and Wang, 2006; Pinkowitz and Williamson, 2006; Dittmar and Mahrt-Smith, 2007; Harford et al., 2008). Empirical evidence presented by Kulchania and Thomas (2017) suggests that practitioners build cash reserves as a consequence of increased supply chain pressure and rely on cash as their primary source of financing during disruptions. Given the perception that firms with substantial cash holdings are better at adapting their supply chains to evolving market conditions (Carnes et al., 2023), we anticipate that cash reserves influence resilience positively.

Existing literature suggests that smaller firms have an increased ability to swiftly reorganise available resources as a result of their, on average, more constrained resource base. This makes them better equipped to address unforeseen challenges of a disruption. (Parker and Ameen, 2018) Therefore, we expect that the positive impact of cash on a firm's resilience is more pronounced for larger firms. This expectation arises from the notion that larger firms, with limited experience in resource reconfiguration, tend to rely more heavily on readily available resources. Thus, the second testable component of hypothesis two is formulated as follows;

2b. Cash reserves enhanced resilience during the supply chain disruption following Covid-19, with an effect that were more pronounced for larger firms

Although the traditional view on efficient management of working capital is that a firm should aim for a short cash conversion cycle (Banerjee et al., 2021), the accelerated turnover of inventory and cash inherent in this strategy places financial strain on both the firm's suppliers and the firm itself (Peng and Zhou, 2019). This pressure can ultimately lead to significant adverse effects on the supply chain (Peng and Zhou, 2019), suggesting that a short CCC during times of disruptions has negative effects on a firm. Additionally, the research conducted by Afza and Nazir (2007) provides further support. Their study indicates that extended inventory periods, effectively prolonging a firm's CCC all else equal (Ding et al., 2013), have been demonstrated to improve corporate profitability during production interruptions such as those associated with supply chain disruptions.

Similar to the view of Appuhami (2008), we anticipate that characteristics of efficient working capital management are contingent on the market conditions. We therefore expect that efficient working capital management is achieved through a long cash conversion cycle during a supply chain disruption, challenging the traditional view of efficient working capital. Thus, the third testable component of hypothesis two is formulated as follows;

2c. Longer cash conversion cycles enhanced resilience during the supply chain disruption following Covid-19

Optimising firm resilience requires allocating resources to both the mitigation of the disruption's impact and the enhanced recovery (MacKenzie and Zobel, 2016). To separately examine what policies to consider for increased resilience in these two phases, the aforementioned policies' impact on a firm's ability to dampen and recover from a supply chain disruption will be analysed. While existing literature does not specifically deconstruct resilience into damping and recovery phases, it is acknowledged that resilience positively influences a firm's ability to both mitigate the initial impact of a disruption (Carvalho and Areal, 2016) and recover systems to a normal state post-disruption (Dinh et al., 2012). This suggests that resilient firms can effectively dampen and promptly recover from the adverse effects of a supply chain disruption. In the absence of findings suggesting that capabilities enhancing the ability to dampen and recover will differ from those necessary to build overall resilience, we anticipates the following hypothesis;

3. *The ability to dampen and recover from the adverse effects of the Covid-19 supply chain disruption is achieved through the implementation of the same financial policies that contribute to building overall resilience*

6. Theoretical framework

Drawing inspiration from disaster research, Tierney and Bruneau (2007) introduced a method to quantify the relative loss over time following a disruption (Tierney and Bruneau, 2007). In a theorisation of this resilience triangle, Barroso et al. (2015) proposed the resilience index which quantifies a firm's resilience to a risk. We utilise the resilience index as a metric to quantify resilience to a disruption. The following section elaborates on its individual components.

6.1. Resilience triangle

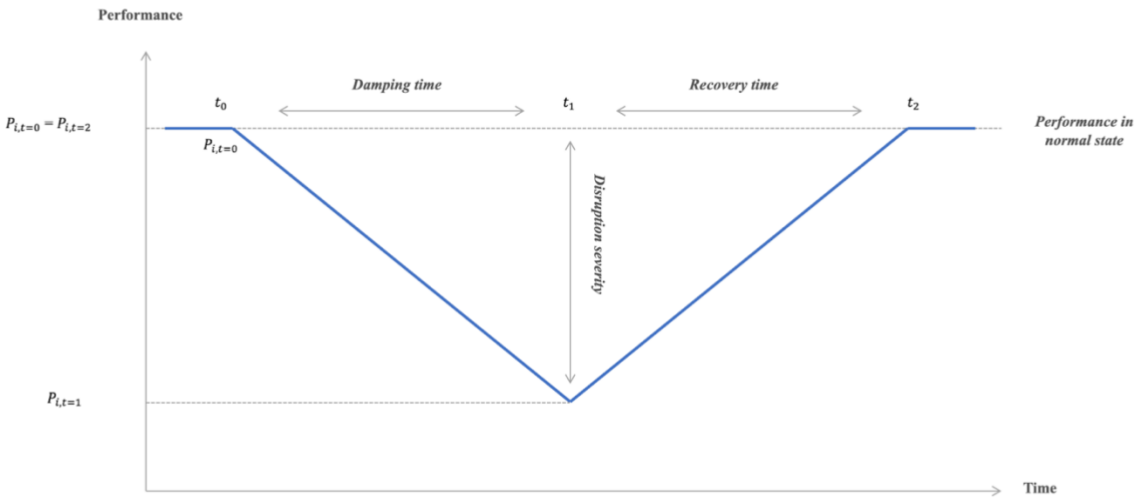


Figure 2: Resilience triangle

The resilience triangle visualises the loss in performance due to a disruption's negative impact on a firm. The depth of the triangle represents the disruption severity, hence the magnitude of loss. The length between normal state prior to the disruption until the point in time of the disruption severity represents the damping time. The length of the triangle following the disruption severity point until performance levels have returned to normal pre-disruption levels represents the recovery time. The smaller the triangle is, the more resilient a firm is and therefore the resilience triangle should be minimised.

6.2. Resilience index

The resilience index, with the basis in the resilience triangle, proposes a hierarchical index that makes it possible to compare resilience between firms. The resilience index ranges from 0 to 1, with 0 indicating a non-resilient firm and 1 indicating a resilient firm.

The resilience index is quantified as follows. Firm performance is measured at the end of each period t (between t_0 and t_2), generating a curve with the performance along time (P_{it}). If the firm is not affected by the disruption, the performance level of the firm at each point in time is given by P_i. When the firm is negatively affected by the disruption, the curve drops, reflecting its negative impact on performance. After some periods the firm recovers to the initial state P_i and a triangle pattern emerges, representing the loss of the company's performance. To compute the triangle area a simple algorithm based on straight line approximations between the performance measure values for the time period between the time at which the disruption occurs and the time at which the firm exhibits full recovery is used. The resilience index for company i is computed using Equation 1:

$$Res_i = 1 - \frac{\sum_{t=t_0}^{t_2}(P_i - P_{it})}{P_i(t_2 - t_0)} \tag{1}$$

P_i: is the performance level of company i when it is not affected by the negative effects of a disruption
P_{it}: is the performance level of company i in time period t
t_0: is the lower limit of the time period of which the resilience index is based on and corresponds to the time prior to the time instant at which the performance level is affected by the negative effects of the disruption
t_2: is the upper limit of the time period of which the resilience index is based on and corresponds to the time instant at which the performance level has recovered from the negative effects of the disruption

6.3. Thesis extension; recovery and damping index

Building upon the theoretical framework of the resilience triangle, our study distinguishes the two different phases of firms' responses to a disruption; the damping phase and the recovery phase, which are detailed in figure 2. As an extension to the resilience index, this thesis constructs two separate indices for each phase. The damping index for company i is given by Equation 2, and the recovery index for company i is given by Equation 3:

$$D_i = 1 - \frac{\sum_{t=t_0}^{t_1}(P_i - P_{it})}{P_i(t_1 - t_0)} \tag{2}$$

$$Rec_i = 1 - \frac{\sum_{t=t_1}^{t_2}(P_i - P_{it})}{P_i(t_2 - t_1)} \tag{3}$$

P_i: is the performance level of company i when it is not affected by the negative effects of a disruption
P_{it}: is the performance level of company i in time period t
t_0: is the lower limit of the time period of which the damping index is based on and corresponds to the time prior to the time instant at which the performance level is affected by the negative effects of the disruption
t_1: is the upper limit of the time period of which the damping index is based on and corresponds to the time instant at which the performance level is the most negatively impacted, hence the severity point
t_2: is the upper limit of the time period of which the recovery index is based on and corresponds to the time instant at which the performance level has recovered from the negative effects of the disruption

6.4. Applied assumptions for the resilience, damping and recovery index

We calculate the resilience index within a disruption time frame, in line with Barroso et al. (2015). This timeframe extends from the quarter preceding the disruption quarter until the quarter when the adverse effects of the disruption are deemed to have diminished for the population. We furthermore use sales as the performance measure to quantify a firm's resilience, ability to dampen, and ability to recover. The anticipation of a decline in sales following a supply chain disruption aligns with existing literature, which has observed a substantial reduction in quarterly sales subsequent to the announcement of a supply chain disruption (Hendricks and Singhal, 2005). Furthermore, for all three indices, the recovery point in time is defined as the initial occurrence of two consecutive quarters within the outlined disruption time frame where sales equalled or exceeded pre-disruption levels.

7. Data description, sample selection and filtering

The data sample comprises US companies that are publicly listed and operate within the manufacturing sector. The sample scope stems from delimitations on three aspects; company type, geography, and sector. Publicly traded firms are selected due to the requirement for such companies to report firm fundamentals on a quarterly basis, providing access to frequent data. The geographical focus on US firms is motivated by the intention to analyse a large dataset while minimising the risk of unobservable cross-country differences affecting the results. Furthermore, we study manufacturing firms because of their proven exposure to supply chain disruptions (Park, Hong and Jungbae Roh, 2013) with a vulnerability derived from global sourcing and the inherent complexity of their supply chain networks (Ferdows, 1997). Additionally, the examination of firms within the same sector is justified by the likelihood that they share comparable positions in the global supply chain network. This increases the probability of these firms being affected by a supply chain disruption simultaneously.

Data for firm fundamentals is retrieved from Capital IQ and comprises US publicly traded manufacturing firms for the time frame Q1 2008 - Q2 2023. The identification of manufacturing firms derives from Standard Industrial Classification (SIC) codes, more specifically firms with SIC codes ranging from 2000-3999. The timeframe is motivated by the intention to analyse supply chain disruptions from the financial crisis that occurred in 2008, to the Covid-19 pandemic, with lasting impact until 2023.

With the purpose of maintaining a balanced panel with a consistent sample throughout the entire sample period (Wooldridge 2010), firms lacking observations on relevant variables for the present data analysis are excluded. In preparation for analysis one, firms without available data on sales and assets are filtered out, resulting in a balanced panel dataset with quarterly sales and asset observations for 523 unique firms over 61 quarters (Q3 2008-Q2 2023). As a next step in the preparation of the first analysis, the resilience index was computed for the firms in the dataset. Firms that did not exhibit a resilience index, i.e firms that either were not negatively impacted or did not recover within the specified disruption timeframe, were filtered out. This filtering process resulted in a final dataset of 2 firm fundamentals for 340 firms over 61 quarters deriving 41,480 observations.

For analysis two, firms without data on sales, assets, inventory, cost of goods sold, accounts receivable, accounts payable, debt and cash are filtered out. This process leads to a balanced dataset with 8 firm fundamentals observations for 871 unique firms over 15 quarters (Q4 2019 - Q2 2023). Furthermore, the resilience index was calculated for the firms within the disruption time frame. Firms without a resilience index were filtered out, yielding a final dataset comprising 602 firms with 8 firm fundamental observations over 15 quarters, resulting in 72,240 unique observations. Note that all firms with a resilience index also possess a damping and recovery index, indicating that the filtering process resulted in an equal number of unique observations.

To prevent the risk that our empirical results are driven by extreme outliers, all included variables in the models have been winsorized. We implement winsorizing at the first and 99th percentiles, thereby capping the top and bottom 1% of values in the dataset.

8. Empirical methodology

8.1. Do more resilient firms outperform relatively less resilient firms in the face of a supply chain disruption?

To test the second hypothesis that companies with heightened resilience demonstrate superior ability to sustain performance post a supply chain disruption, we performed three difference-in-difference analysis regressions (hereafter referred to as diff-in-diff). A diff-in-diff approach is often used to assess the causal effect of a policy or intervention where there are clear pre-and post-intervention periods (Fredriksson and Oliveira, 2019). The diff-in-diff analyses considered in this study specifically assessed the causal effect of firms' resilience on their ability to sustain sales growth post three individual supply chain disruptions. Firms were categorised into the treatment (resilient) and control group (non-resilient) based on their resilience index (Barroso et al., 2015).

We performed the analysis on three distinct supply chain disruptions across the same set of firms. The three supply chain disruptions considered are;

i) The Tohoku Earthquake and Tsunami

The first analysis was performed on the supply chain disruption induced by the Tohoku Earthquake and Tsunami in Japan in 2011. The event occurred in the latter part of Q1 2011 and had for the majority of value chains, almost instant impact, especially for those firms with strong ties to Japan's manufacturing export activities (Park, Hong and Jungbae Roh, 2013). Q1 2011 is therefore designated as the disruption quarter.

ii) US-China Trade War

The second analysis was performed on the US-China Trade War. The first trade tariff on Chinese goods was introduced in the US in July 2018 (Huang, Lin, Liu and Tang, 2023) and therefore Q3 2018 is considered the disruption quarter.

iii) Covid-19

The third analysis was performed on the supply chain disruption that followed Covid-19. The outbreak of Covid-19 occurred in Q1 2020 following a significant elevation in the GSCPI, escalating from 0 in December 2019 to 2.5 in March 2020, surpassing any historical levels covered by the index (Benigno et al., 2022). Therefore, Q1 2020 is considered the disruption quarter.

The diff-in-diff model performed on each of the three supply chain disruptions was estimated using linear regression as illustrated below;

$$Sales\ growth_i = \beta_0 + \beta_1 \times Period_i + \beta_2 \times Treated_i + \beta_3 \times DiD_i + \beta_4 \times Size_i + \beta_5 \times Age_i$$

Model 1: Difference-in-difference regression

8.1.1. Regression variables

8.1.1.1. Dependent variable

Sales growth

To quantify the performance impact of the disruption, sales growth was used, compliant with Hendricks and Singhal (2005) and Baghersad and Zobel (2021). Previous literature suggests that resilient firms outperform non-resilient firms in sustaining growth during times of disruption (Carvalho and Areal, 2016; Ma, Xiao and Yin, 2018), further motivating the relevance of analysing sales in relation to resilience. Following the methodology of a diff-in-diff regression, the dependent variable, sales growth, was analysed at pre- and post-disruption levels. Firms' specific sales growth levels for both pre- and post-disruption periods, were computed as the quarterly sales growth average. Thus, sales growth levels for the pre- and post-period were computed as illustrated below;

$$\text{Sales growth} = \frac{\frac{S_{t1}}{S_{t0}} - 1 + \cdots + \frac{S_T}{S_{T-1}} - 1}{T - t_1 + 1} \tag{4}$$

t_1 is the starting quarter of the pre-period (post-period)
T is the end quarter for the pre-period (post-period)
S_t is sales in quarter t

8.1.1.2. Independent variables

Period

The time period variable is represented by a dummy, denoted "Period" in Model 1. For each of the three supply chain disruptions assed, the pre-disruption period is represented by a dummy value equal to 0, while the post-disruption period is represented by a dummy value of 1.

Treated

The treatment variable, denoted "Treated" in Model 1 is a dummy variable. The dummy variable takes the value of 1 for firms in the treated group and the value of 0 for firms in the control group.

DiD

The diff-in-diff estimator is expressed through an interaction term of the dummy variables "Time Period" and "Treated." This interaction term quantifies the causal impact of treatment on the dependent variable, sales growth, during the post-disruption period compared to the pre-disruption period.

8.1.1.3. Control variables

Size

Samuels (1965) reports a positive correlation between firm size and sales growth, while other findings suggest that smaller firms grow relatively faster (Dunne and Roberts, 1989;

Variyam and Kraybill, 1992). While previous findings are ambiguous regarding whether firm size is positively or negatively correlated with sales growth, they suggest that firm size does have an impact. This observation motivates the inclusion of size as a control variable in our study. Compliant with previous studies (Lee, 2009), size is estimated as the natural logarithm of a firm's asset;

$$Size_{i,t} = \ln (Assets_{i,t}) \quad (5)$$

Age:
Previous studies indicate a negative relationship between firm age and sales growth, proving that sales growth is, on average, lower for older firms (Delmar, Davidsson and Gartner, 2003). To control for its influencing effect, company age is included in the model;

$$Age_{i,t} = Current\ year_t - \ Founding\ year_i \quad (6)$$

8.1.2. Underlying assumptions of the diff-in-diff model and their validation

In contrast to a conventional diff-in-diff setup, the impact of supply chain disruptions extends to firms at all levels of the resilience index, thus affecting both the treatment group and the control group. While the diff-in-diff model in this study proposes an uncommon setup, the method is still considered an appropriate framework. Our study assumes that resilience, the treatment of interest, differs significantly between the treatment and control group and is already observable before the outbreak of the supply chain disruptions studied. This assumption ensures that any observed differences in trends can be attributed to whether they are categorised as resilient or non-resilient, rather than pre-existing differences between the treatment and control group.

Diff-in-diff analyses must adhere to two essential assumptions. Firstly, the stable unit treatment value assumption assumes the absence of spillover effects, meaning the outcomes of one group should not influence the other. (Fredriksson et al., 2019) The stable unit treatment value assumption, holds for the analysed set of resilient and non-resilient firms for each of the three supply chain disruptions. Within a supply chain, the interlinkage of included firms suggests a plausible connection between the resilience of a firm's supplier and the firm's performance during disruptions, potentially influencing its demonstrated resilience. Nonetheless, given that the sample group solely comprises manufacturing firms, the likelihood of spillover effects is limited, presuming these firms operate on the same level but within distinct value chains. Consequently, the second assumption is validated. Secondly, the diff-in-diff model assumes a parallel pre-intervention trend between the treatment and control groups. To meet this assumption, we carefully considered and validated it in the construction of our pre-and post-disruption periods, as outlined below.

8.1.3. Determination of pre- and post-disruption periods

As noted by Hendricks and Singhal (2005), prior research investigating the impact of various disruptive events on operating performance lacks a consistent theoretical or empirical basis for determining the appropriate period. Previous studies measuring operating performance in association with a supply chain disruption have utilised periods ranging from one to ten years (Baghersad and Zobel, 2021)

8.1.3.1. Pre-disruption periods

In their study on the influence of supply chain disruptions on firms' performance, Baghersad and Zobel (2021), utilise an event study methodology, thereby identifying a pre-disruption period. They confine the pre-disruption period to four quarters prior to the disruption quarter. Compliant with their delimitation, this thesis initially evaluates a prospective pre-disruption period of four calendar quarters. Applying this reasoning, in relation to the disruption quarters outlined above, yields the following pre-periods for each disruption respectively;

i) The Tohoku Earthquake and Tsunami: Q1 2010 to Q4 2010
ii) US-China Trade War: Q3 2017 to Q2 2018
iii) Covid-19: Q1 2019 to Q4 2019

Considering the parallel pre-intervention trend assumption of the diff-in-diff model, the prospective pre-disruption periods have been analysed and adjusted accordingly, as detailed below.

i) The Tohoku Earthquake and Tsunami

The parallel pre-intervention trend assumption between the treatment and control groups for the Tohoku Earthquake and Tsunami is validated for the four quarters pre-disruption, as demonstrated in Appendix Figure 1.

ii) US-China Trade War

Upon examining Appendix Figure 2, it becomes apparent that during Q3 and Q4 2017, the treatment and control groups displayed distinct sales growth trends. Therefore, the parallel pre-intervention trend assumption does not hold for the prospective pre-disruption period of four quarters. To satisfy the parallel pre-intervention trend assumption, the diff-in-diff analysis was conducted on a pre-disruption period spanning two quarters, from Q1 2018 to Q2 2018.

iii) Covid-19

As evident in Appendix figure 3, the parallel pre-intervention trend does not hold for the first of the four quarters in the prospective pre-disruption period Covid-19. To satisfy the parallel pre-intervention trend assumption, the diff-in-diff analysis for Covid-19 was conducted over a pre-disruption period spanning three quarters, from Q2 2019 until Q4 2019.

8.1.3.2. Post-disruption periods

Considering that disruptions vary in their impact on a company's performance (Hendricks and Singhal, 2005), the adopted post-disruption periods are dependent on the unique characteristics of each specific supply chain disruption. Consequently, there will be variations in the duration of the three analysed post-disruption periods. As highlighted by Fredriksson et al. (2019), diff-in-diff models only require a single post-treatment data point to detect evidence of the treatment effect, mitigating any potential concerns in this regard.

i) The Tohoku Earthquake and Tsunami

The Tohoku Earthquake and Tsunami triggered a supply chain disruption through a single event, leading to prolonged adverse effects on the operational performance of companies, particularly in the manufacturing sector (Park, Hong and Jungbae Roh, 2013). The actual disruption to the supply chains was confined to a single day, yet its repercussions strained global systems for an extended period. Given that the disruption occurred locally in Japan, its impact on US manufacturing firms resulted from ripple effects (Todo, Nakajima and Matous, 2015). Consequently, the impact is anticipated to unfold with variations in timing for the sample firms. The selected timeframe for post-disruption analysis is determined as the four quarters following the disruption quarter to comprehensively capture the enduring effects of the supply chain disruption on the sample firms.

ii) US-China Trade War

The supply chain disruption stemming from the US-China Trade War was initiated by the introduction of cross-border tariffs (Gereffi et al., 2021). The trade war persisted for around one year due to a series of tariff introductions before the initial relief. Each newly introduced tariff can be considered a distinct disruption to the supply chains. Given the recurring nature of these disruptions throughout this one-year period, a post-disruption period of four quarters has been established to comprehensively capture the complete impact arising from the tariffs.

iii) Covid-19

The supply chain disruption caused by Covid-19 was closely linked to varying restrictions imposed, which fluctuated with the spread of infections. By summer 2020, restrictions eased (CNN, 2020) relieving pressure on supply chains. This is evident by the drop in the GSCPI, which returned to normal levels in Q3 and Q4 2020, followed by a subsequent upswing in the beginning of 2021, as shown by figure 1 in section 1.

Considering the alleviation of supply chain pressure following the relaxed restrictions in Q3 and Q4 2020, a post-disruption period stretching into the latter part of 2020 might present a misleading picture. The alleviation of supply chain pressure contributed to a temporary improvement in sales growth in Q3 and Q4 2020 as shown in Appendix figure 4. The drop in sales to unusually low levels in Q1 and Q2 2020 following the disruption, is a plausible reason for notably high sales growth in Q3 and Q4 2020 when the restrictions were relaxed, and businesses could temporarily return to near-normal state. Although the average sales levels post the disruption quarter confirms the adverse effects of the disruption, the abrupt and temporary increase in sales growth during Q3 and Q4 2020 could lead to misleading results if included in the post-disruption period. The post-disruption period examined for Covid-19 is consequently defined as solely the quarter following the supply chain disruption, namely Q2 2020, further supported by Fredriksson et al. (2019).

8.1.3.3. Final pre- and post-disruption periods

The distinct pre- and post-disruption periods were individually defined for each disruption as;

i) The Tohoku Earthquake and Tsunami

The pre-disruption period spans from Q1 2010 to Q4 2010 and the post-treatment period extends from Q2 2011 until Q1 2012.

ii) US-China Trade War

The pre-disruption period spans from Q1 2018 to Q2 2018 and the post-disruption period extends from Q4 2018 until Q3 2019.

iii) Covid-19

The pre-disruption period spans from Q2 2019 until Q4 2019 and the post-disruption period is defined as Q2 2020.

8.1.4. Determination of treatment and control group

The treatment group consists of resilient firms and the control group of non-resilient firms. To select the treatment and control group, firms were individually assessed based on their resilience index, computed following the methodology of Barroso et al. (2015) as outlined in Equation 1 in section 6. Each firm's respective index was computed based on a supply chain disruption that occurred before the three analysed disruptions, namely the supply chain disruption that followed the 2008 financial crisis. The following section describes the specifics of how the resilience indices based on the 2008 financial crisis were determined and how the firms were divided into the treatment and control group.

Disruption time frame for the 2008 financial crisis

The resilience index, derived from the 2008 financial crisis, was computed within a disruption time frame spanning from Q3 2008 to Q1 2012, with Q3 2008 representing normal pre-disruption sales levels. Establishing the starting point for the supply chain disruption poses a challenge due to its gradual development. Choosing an early starting period introduces the risk of including performance impacts unrelated to the financial crisis. Conversely, opting for a late starting period may lead to the oversight of negative impacts resulting from the disruption. The widely acknowledged trigger of the 2008-2009 financial crisis, the Lehman Brothers' crash in September 2008, marked the escalation of the financial crisis (ABC News, 2009). As a result, Q3 2008 is considered a suitable benchmark for baseline sales levels. The end of the disruption period is recognized as 3.5 years, or 14 quarters, post the disruption quarter, concluding in Q1 2012. The decision for the prolonged disruption time frame is influenced by the enduring effects of the financial crisis, marked by numerous ripple effects. (Jüttner and Maklan, 2011)

Treatment and control group based on the resilience index

We divided firms into the treatment and control groups based on quartiles of resilience indices within the sample group. The top 25% of firms, exhibiting the highest resilience indices, constituted the treatment group. The 25%, with the lowest resilience indices, comprised the control group. The remaining 50% of firms were excluded from the two groups in the regression to ensure significant differences in resilience between the treatment and control group. This approach aimed to mitigate the randomness associated with allocating firms with resilience levels close to the median to either group.

8.1.5. Descriptive statistics

Descriptive statistics of resilience

Table 1: Descriptive statistics - Resilience within the sample, treatment and control group

Resilience	Sample group	Treatment group	Control group
Mean	0.864	0.967	0.736
Median	0.884	0.969	0.752
Min	0.576	0.939	0.576
Max	0.997	0.997	0.812
Std dev.	0.095	0.017	0.071
Nr of firms	340	85	85

The sample group comprises all 340 observed firms and each firm's resilience is computed based on the supply chain disruption following the 2008 financial crisis. The treatment group, consisting of 85 firms, represents the upper quartile of the sample group with the highest resilience, while the control group, consisting of 85 firms, represents the lower quartile of the sample group with the lowest resilience.

Table 1 presents the descriptive statistics of resilience for the entire sample of 340 firms, before the division into treatment and control groups, as well as for the final treatment and control groups. The resilience mean and median for the entire sample indicates a concentration of resilience at higher levels, motivating the use of upper and lower quartiles for categorisation into the treatment and control group. As evident from the data on the treatment and control group, a significant disparity in means exists between the two groups, with the treatment group centred around high levels of resilience, while the control group consists of firms with lower levels of resilience. The descriptive statistics in Table 1 thereby validate the intended distinction in exhibited resilience between the two groups.

Table 2: Descriptive statistics - Treatment and control group characteristics

	Tohoku Earthquake and Tsunami		**US-China Trade War**		**Covid-19**	
Size	Treatment group	Control group	Treatment group	Control group	Treatment group	Control group
Mean	6.251	5.631	6.94	6.391	7.125	6.513
Median	6.404	5.638	7.336	6.626	7.538	6.845
Min	2.342	1.787	2.621	2.551	2.851	2.657
Max	10.237	9.215	10.669	9.836	10.762	9.867
Std dev.	2.321	1.962	2.335	2.027	2.297	2.051
	Tohoku Earthquake and Tsunami		**US-China Trade War**		**Covid-19**	
Age	Treatment group	Control group	Treatment group	Control group	Treatment group	Control group
Mean	53	42	61	50	62	51
Median	29	36	37	44	38	45
Min	14	8	22	16	23	17
Max	143	114	151	122	152	123
Std dev.	43	30	43	30	43	30
	Tohoku Earthquake and Tsunami		**US-China Trade War**		**Covid-19**	
Industry	Treatment group	Control group	Treatment group	Control group	Treatment group	Control group
Number of industries	49	47	49	47	49	47
Av. nr of firms per industry	1.735	1.816	1.735	1.816	1.735	1.816

Descriptive statistics for the characteristics of the treatment and control group for the three separate analyses. These statistics encompass size indicated by the natural logarithm of total assets, age measured as the number of years since incorporation, and industry specifications derived from the SIC codes.

Table 2 outlines the descriptive statistics for the characteristics of firms within the treatment and control groups. The firms in both groups remain consistent across all three analyses, with variations in size and age attributed to changes in firm characteristics over time. The similar mean values for size suggest comparable sizes between the two groups, although the treatment group appears slightly biassed towards larger firms, as evident from the minimum and maximum values. Concerning age, the treatment group consists of slightly older firms on average, compared to the control group, as indicated by the higher mean, with a wider dispersion in age as implied by the higher standard deviation. Turning to industry, both the treatment and control group encompass almost the same number of unique sub-industries. The average number of firms per sub-industry is furthermore relatively similar, suggesting a comparable dispersion of sub-industries between the two groups. While the firms report slight differences, the treatment and control group can be deemed as comparable with regards to size, age and industry.

Descriptive statistics for the regression variables

i) The Tohoku Earthquake and Tsunami

Table 3: Descriptive statistics - Sales growth, Tohoku Earthquake and Tsunami

	Treatment group		Control group	
Sales growth	Pre-disruption	Post-disruption	Pre-disruption	Post-disruption
Mean	3.20%	2.75%	13.21%	4.33%
Median	2.47%	2.10%	9.79%	3.21%
Min	0.54%	0.01%	-1.80%	-1.97%
Max	6.35%	6.17%	40.20%	12.02%
Std dev.	0.023	0.023	0.114	0.054

Descriptive statistics for the sales growth observed in the treatment and control groups. These observations span the pre- and post-disruption period. Sales growth for the pre-and post-disruption period are calculated as the average of quarterly sales growth over a number of quarters as detailed below.

	Treatment group		Control group	
Nr of observations	Pre-disruption	Post-disruption	Pre-disruption	Post-disruption
Quarters in each period	4	4	4	4
Quarterly firm observations	340	340	340	340

Specification of the number of quarters designated as the pre- and post-disruption periods, and the total number of quarterly firm observations

ii) The US-China Trade War

Table 4: Descriptive statistics - Sales growth, US-China Trade War

	Treatment group		Control group	
Sales growth	Pre-disruption	Post-disruption	Pre-disruption	Post-disruption
Mean	2,02%	2,01%	5,93%	1,49%
Median	1,78%	1,55%	4,89%	0,81%
Min	-3,41%	-0,04%	-23,29%	-2,22%
Max	7,82%	4,95%	34,17%	6,25%
Std dev.	0,043	0,020	0,127	0,031

Descriptive statistics for the sales growth observed in the treatment and control groups. These observations span the pre- and post-disruption period. Sales growth for the pre-and post-disruption period are calculated as the average of quarterly sales growth over a number of quarters as detailed below.

	Treatment group		Control group	
Nr of observations	Pre-disruption	Post-disruption	Pre-disruption	Post-disruption
Quarters in each period	2	4	2	4
Quarterly firm observations	170	340	170	340

Specification of the number of quarters designated as the pre- and post-disruption periods, and the total number of quarterly firm observations

iii) The Covid-19

Table 5: Descriptive statistics - Sales growth, Covid-19

	Treatment group		Control group	
Sales growth	Pre-disruption	Post-disruption	Pre-disruption	Post-disruption
Mean	2,89%	-4,29%	8,81%	-6,44%
Median	2,70%	-5,60%	3,29%	-3,81%
Min	-0,90%	-18,63%	-8,56%	-26,14%
Max	7,04%	9,24%	47,38%	11,52%
Std dev.	0,031	0,105	0,157	0,145

Descriptive statistics for the sales growth observed in the treatment and control groups. These observations span the pre- and post-disruption period. Sales growth for the pre-and post-disruption period are calculated as the average of quarterly sales growth over a number of quarters as detailed below.

	Treatment group		Control group	
Nr of observations	Pre-disruption	Post-disruption	Pre-disruption	Post-disruption
Quarters in each period	3	1	3	1
Quarterly firm observations	255	85	255	85

Specification of the number of quarters designated as the pre- and post-disruption periods, and the total number of quarterly firm observations

Table 3, 4 and 5 presents the descriptive statistics for pre-and post-disruption sales growth in the treatment and control group for each of the three analyses. There are some noteworthy observations common in all three. Firstly, the sales growth mean and median decline from the pre-disruption to the post-disruption period for both the treatment and control group across all observed disruptions. This suggests that the supply chain disruptions that followed the Tohoku Earthquake and Tsunami, US-China Trade War and the Covid-19 adversely affected both the treatment and control group in terms of sales growth. Secondly, the decrease in sales growth between the pre and post-disruption periods is more pronounced for the control group in each of the three analyses, as evident when comparing the mean, implying that the treatment group experienced a lesser negative impact on their sales growth following the disruptions. Moreover, the control group exhibits a higher pre-disruption sales growth than the treatment group, for all observed disruptions, revealing that the group of non-resilient firms are on average characterised by high growth. This aligns with the observation that the control group consists of younger firms, which, according to the literature, tend to experience higher growth (Delmar et al., 2003).

8.2. Does financial flexibility enhance resilience?

To test the second hypothesis, a cross-sectional Ordinary Least Squares (hereafter referred to as OLS) regression was performed. This regression involved regressing the individual resilience indices of firms, calculated based on the Covid-19 supply chain disruption, against the financial flexibility characteristics of each respective firm. Furthermore, to conclude whether their financial policies impact resilience as well as the damping and recovery abilities in a similar manner, essentially testing the third hypothesis, separate OLS regression analyses were conducted on all three indices.

Model 2a:

$$Resilience_i = \beta_0 + \beta_1 \times Size_i + \beta_2 \times Lev.ratio_i + \beta_3 \times Cash_i + \beta_4 \times CCC_i + \beta_5 \times (Size_i \times Cash_i)$$

Model 2b:

$$Damping_i = \beta_0 + \beta_1 \times Size_i + \beta_2 \times Lev.ratio_i + \beta_3 \times Cash_i + \beta_4 \times CCC_i + \beta_5 \times (Size_i \times Cash_i)$$

Model 2c:

$$Recovery_i = \beta_0 + \beta_1 \times Size_i + \beta_2 \times Lev.ratio_i + \beta_3 \times Cash_i + \beta_4 \times CCC_i + \beta_5 \times (Size_i \times Cash_i)$$

8.2.1. Underlying assumptions of Ordinary Least Square Regression and their validation

The OLS regression relies on two fundamental assumptions. Firstly, it assumes the absence of multicollinearity in the model, meaning that the regression variables are not expected to be correlated to each other. Secondly, OLS regressions assume the presence of homoscedasticity in the model. Homoscedasticity implies that the variances in the error terms are consistent, or similar. If a model violates either of these two assumptions, the robustness of the results diminishes. (Newbold and Carlson, 2012)

To explore if the model exhibits multicollinearity, a Variance Inflation Factors (hereafter referred to as VIF) test was conducted on the three OLS models. The results, presented in Appendix tables 1-3 confirm that the models report no multicollinearity, as none of the VIF values exceed 5 (Judge, Hill, Griffiths, Lütkepohl and Leem, 1988). Appendix tables 1-3 further confirms that the correlation among the included independent variables in the models are weak. To assess homoscedasticity in the data, a Breush-Pagan test was performed. The results in Appendix table 4 reveal the rejection of the homoscedasticity hypothesis, indicating that the data is heteroskedastic. In order to maintain the models' quality as a linear unbiased estimator, robust standard errors are applied, accounting for the heteroscedasticity (Newbold and Carlson, 2012).

8.2.2. Regression variables

8.2.2.1. Dependent variable

Analysis 2a: Resilience index
The firm-specific resilience index is the dependent variable and was computed following the theoretical framework outlined by Barroso et al. (2015), as presented in Equation 1 in section 6. In the computation of the resilience indices the disruption time frame spans between Q4 2019 until Q2 2023. Q4 2019 corresponds to the time period of firms' normal sales levels prior to the supply chain disruption in Q1 2020 (Benigno et al., 2022).

The disruption time frame concludes at Q2 2023, chosen to coincide with the latest available public data as it offers the most extensive time period as of the paper's creation. This extended time frame makes it possible to calculate the resilience index for firms facing prolonged adverse performance effects, given the recognition of the pandemic as a supply chain disruption with an unusually prolonged impact (Ivanov and Das, 2020). This also aligns with the declining GSCPI, which began decreasing in November 2021 after reaching its highest levels since 1997 (Benigno et al., 2022).

Analysis 2b: Damping index
The damping index was computed in accordance with Equation 2 as outlined in section 6. The period prior to the disruption, corresponding to Q4 2019 constitutes the lower limit of which the index is based on. The upper limit of the damping index aligns with the

severity point, denoting the period when the performance level has reached its lowest point relative to pre-disruption levels in Q4 2019 until the point in time of recovery.

Analysis 2c: Recovery index
The recovery index was calculated following Equation 3, as outlined in Section 6. The time of the firm specific severity point constitutes the lower limit of which the index is based on. The upper boundary of the recovery index corresponds to the recovery point for each firm, indicating the period during which the performance level is fully recovered to pre-disruption levels, more specifically reflecting sales levels observed in Q4 2019.

8.2.2.2. Independent variables

Cash holdings
Consistent with prior research, we define cash holding as cash and cash equivalents scaled by total assets (Faulkender and Wang, 2006; Pinkowitz and Williamson, 2006);

$$Cash_i = \frac{\text{Cash and } Cash\ equivalents_i}{Total\ assets_i} \quad (7)$$

Leverage
Consistent with literature, in this study we define leverage as total debt as a percentage of assets (Lins et al., 2010; Campello et al., 2010);

$$Leverage_i = \frac{Debt_i}{Total\ assets_i} \quad (8)$$

Cash Conversion Cycle
To mirror the dynamic influence of CCC, the variable was calculated as the average CCC over the specific time period analysed in the three models (2a, 2b, and 2c), as detailed below;

a) In regression 2a, CCC represents the average CCC from the onset of the disruption to the point of full recovery, as represented in equation 9.

b) In regression 2b, CCC represents the average CCC from the disruption time to when the firm reaches the severity point, as represented in equation 10.

c) In regression 2c, CCC represents the average CCC from the point in time at which the firm reaches the severity point to the point in time of full recovery, as represented in equation 11.

$$CCC_i = \frac{\sum_{t=t_0}^{t_2} CCC_t}{t_2 - t_0 + 1} \quad (9)$$

$$CCC_i = \frac{\sum_{t=t_1}^{t_2} CCC_t}{t_2 - t_1 + 1} \quad (10)$$

$$CCC_i = \frac{\sum_{t=t_0}^{t_1} CCC_t}{t_1 - t_0 + 1} \quad (11)$$

t_0 is the point in time when the disruption occurs
t_1 is the time point when the firm has reached its severity point
t_2 is the time point when the firm has reached full recovery to normal levels
CCC_t is the Cash conversion cycle in time t

CCC at time t was computed based on the Days of Sales Outstanding (DSO), Days of Inventory Outstanding and (DIO) and Days of Payables Outstanding (DPO), compliant with existing literature (Ding et al., 2013);

$$CCC_t = DSO_t + DIO_t - DPO_t \quad (12)$$

Where;

$$DSO_t = \frac{Average(Acc.rec._{t-1} + Acc.rec._t)}{Revenue_t} \times \text{Days in quarter} \quad (13)$$

$$DIO_t = \frac{Average(Inv._{t-1} + Inv._t)}{COGS_t} \times \text{Days in quarter} \quad (14)$$

$$DPO_t = \frac{Average(Acc.pay._{t-1} + Acc.pay._t)}{COGS_t} \times \text{Days in quarter} \quad (15)$$

8.2.2.3. Control variables

Size
Earlier research demonstrates that the extent of firms' susceptibility to the impacts of supply chain disruptions varies with their size (Singahl and Hendricks, 2005; Baghersad and Zobel, 2020), suggesting that size is an explanatory factor for resilience. Therefore, size is incorporated as a control variable in the regression analysis. Baghersad and Zobel (2020) explores differences in resilience among groups of firms categorised according to their size. Their finding that size enhances resilience thus stems from the analysis of the characteristic of being small or large, rather than from the actual size of the firm. Compliantly, our variable size is formed as a binary dummy variable, categorising firms with total assets surpassing the median of the sample group as 1, and those with assets below the median as 0.

Industry
While the analysed dataset solely contains manufacturing firms, there are firms from 151 sub industries included, allowing for the presence of some industry characteristics of

influencing nature. To control for unobserved heterogeneity across industries, the pooled OLS controls for industry fixed effects, using the four-digit SIC codes as determinants of industry.

8.2.3. Descriptive statistics

Table 6: Descriptive statistics analysis 2a

Variable	Observations	Mean	Median	Std. Dev	Min	Max
Resilience index	602	0.900	0.918	0.077	0.735	0.991
Size	602	6.742	6.995	2.305	2.333	10.621
Leverage ratio	602	29.59%	29.84%	19.05%	1.82%	69.63%
Cash	602	13.41%	9.07%	12.38%	0.86%	45.87%
CCC	602	109	98	90	-50	316

The total sample consists of 602 firms with observations on five fundamentals. Resilience is expressed as an index ranging from 0-1, size as the ln(assets), leverage ratio and cash in % of total assets and CCC is number of days

Table 7: Descriptive statistics analysis 2b

Variable	Observations	Mean	Median	Std. Dev	Min	Max
Damping index	602	0.819	0.845	0.130	0.524	0.983
Size	602	6.742	6.995	2.305	2.333	10.621
Leverage ratio	602	29.59%	29.84%	19.05%	1.82%	69.63%
Cash	602	13.41%	9.07%	12.38%	0.86%	45.87%
CCC	602	125	109	114	-77	418

The total sample consists of 602 firms with observations on five fundamentals. Damping is expressed as an index ranging from 0-1, size as the ln(assets), leverage ratio and cash in % of total assets and CCC is number of days

Table 8: Descriptive statistics analysis 2c

Variable	Observations	Mean	Median	Std. Dev	Min	Max
Recovery index	602	0.849	0.881	0.113	0.570	0.984
Size	602	6.742	6.995	2.305	2.333	10.621
Leverage ratio	602	29.59%	29.84%	19.05%	1.82%	69.63%
Cash	602	13.41%	9.07%	12.38%	0.86%	45.87%
CCC	602	120	103	106	-50	395

The total sample consists of 602 firms with observations on five fundamentals. Recovery is expressed as an index, size as the ln(assets), leverage ratio and cash in % of total assets and CCC is number of days

As indicated by the mean and the standard deviation in Table 6, the average resilience demonstrated in the sample group is high and the variability across firms is low. The same pattern emerges for the damping and resilience index as evident in table 7 and table 8. This suggests that the conducted analysis is performed on a group of firms that are concentrated in the upper levels of the resilience, damping and recovery indices. Furthermore, as evident in table 7 in comparison to table 8, the damping index mean is somewhat higher than the recovery index mean. This indicates that on average, the firms within the sample group were better at recovering from the adverse effects of the Covid-19 supply chain disruption, than they were at damping the initial effect. Interestingly, as apparent when comparing table 6, 7 and 8, the mean resilience index is higher than the mean damping and recovery index respectively, indicating that the overall ability to endure the adverse effects of a disruption was higher than the individual abilities to mitigate and recover from it.

In contrast to the resilience, damping and recovery indices, the independent variables vary considerably among the firms within the sample group, as shown by the differences between the minimum and maximum values, as well as the standard deviation. This reveals a large variation in financial policies amongst the firms, despite being concentrated around a relatively small variation in resilience and ability to dampen respectively recovery.

9. Results

9.1. Do more resilient firms outperform relatively less resilient firms in the face of a supply chain disruption?

i) The Tohoku Earthquake and Tsunami

Table 9: Do resilient firms cope better with a disruption, evidence from the Tohoku Earthquake and Tsunami

Sales Growth	Regression 1
Period	-0.0539
	(-3.2070)***
Treatment	-0.0804
	(-6.4100)***
Size	-0.0057
	(-2.010)**
Age	-0.0002
	(-1.7000)*
DiD	0.0488
	(2.5330)**
Number of observations	340
R-squared	0.1721
Adjusted R-squared	0.1597

All regressions are performed using robust standard errors. The dependent variable is Sales growth (%). The t-stat for the respective variable is presented in parenthesis under each coefficient.

*Note; *p < 0.1 ; **p < 0.05 ; ***p < 0.01*

The results of the diff-in-diff model performed on the supply chain disruption following the Tohoku Earthquake and Tsunami are shown in table 9. Across both the treatment and control group the average sales growth during the post-disruption period was 5 percentage points lower than pre-disruption levels, significant at the 1% level, indicating adverse effects of the disruption across firms. The diff-in-diff variable shows that the treatment group had a 5 percentage points smaller sales growth reduction during the post-disruption period compared to the control group, significant at the 5% level. The result from the analysis thus supports the hypothesis that firms demonstrating resilience possess an enhanced ability to withstand subsequent supply chain disruptions.

Considering the control variables, the negative correlation between sales growth and size was significant at the 5% level while the negative correlation between sales growth and age was significant at the 10% level. This indicates that larger and older firms experienced lower sales growth across both the treatment and control group.

ii) US-China Trade War

Table 10: Do resilient firms cope better with a disruption, evidence from the US-China Trade War

Sales Growth	Regression 1
Period	-0.0385
	(-2.8240)***
Treatment	-0.0255
	(-1.6360)
Size	-0.0047
	(-1.7990)*
Age	-0.0001
	(-1.3520)
DiD	0.0301
	(1.6980)*
Number of observations	340
R-squared	0.0620
Adjusted R-squared	0.0480

All regressions are performed using robust standard errors. The dependent variable is Sales growth (%). The t-stat for the respective variable is presented in parenthesis under each coefficient.

*Note; *p < 0.1 ; **p < 0.05 ; ***p < 0.01*

The results from the diff-in-diff analysis on the supply chain disruption that followed the US-China Trade War are reported in table 10 and show outcomes similar to those observed in the diff-in-diff analysis conducted on the Tohoku Earthquake and Tsunami. Average sales growth across both the treatment and control group dropped by 4 percentage points post-disruption as compared to pre-disruption levels, with results being significant at the 1% level. The diff-in-diff variable shows that the treatment group had a 3 percentage points smaller reduction in sales growth compared to the control group, with results being significant at the 10% level. These results support the hypothesis that firms that have exhibited resilience possess an enhanced ability to withstand subsequent supply chain disruptions.

While the impact was slightly more pronounced compared to the analysis of the Tohoku Earthquake and Tsunami, a similar pattern emerged in the examination of the effect of firm size and age on sales growth. Across both the treatment and control group, age and size exhibited a negative influence on sales growth, significant at the 5% respectively 1% level.

iii) Covid-19

Table 11: Do resilient firms cope better with a disruption, evidence from Covid-19

Sales Growth	Regression 1
Period	-0.1096
	(-3.4990)***
Treatment	-0.0288
	(-1.8770)*
Size	-0.0044
	(-0.6710)
Age	-0.0005
	(-2.0750)**
DiD	0.0515
	(1.2750)
Number of observations	340
R-squared	0.0746
Adjusted R-squared	0.0608

All regressions are performed using robust standard errors. The dependent variable is Sales growth (%). The t-stat for the respective variable is presented in parenthesis under each coefficient.

*Note; *p < 0.1 ; **p < 0.05 ; ***p < 0.01*

Table 11 displays the outcomes of the diff-in-diff analysis for the Covid-19 supply chain disruption. The findings from the diff-in-diff analysis indicate a decline in sales growth of 11 percentage points post-disruption across both the treatment and control group, significant at the 1% level. This suggests that the Covid-19 induced a supply chain disruption had a negative impact on firms' sales growth. Furthermore, the results suggest that age had a small but negative impact on sales growth across the treatment and control group, significant at the 5% level. While the coefficient for the diff-in-diff variable suggests that the treatment group experienced a reduction in sales growth which was five percentage points smaller compared to the control group, the lack of significance on the coefficient implies that historically exhibited resilience did not have a statistically significant impact on a firm's ability to withstand the adverse effects induced by Covid-19.

The categorisation of firms into treatment and control groups in the diff-in-diff analysis presented in table 11 is rooted in the resilience exhibited during the disruption induced by the 2008 financial crisis. The grouping into treatment and control groups, anchored in a non-recent disruption, prompts an interest in exploring whether the lack of significance in the diff-in-diff variable arises from changes in firms' resilience over time or whether the supply chain disruption caused by Covid-19 was markedly different from historical disruptions.

To explore this question further, an additional diff-in-diff analysis on the same pre-and post-period was conducted, incorporating two treatment groups sourced from the same sample of firms. Firstly, the firms were categorised into the treatment and control groups based on their resilience index exhibited during the 2008 financial crisis, spanning from Q4 2008 until Q1 2012 with Q3 2008 representing normal levels. Secondly, the firms were categorised into treatment or control group based on their resilience index exhibited during the US-China Trade War, spanning from Q3 2018 to Q4 2019 with Q2 2018 representing normal levels.

Table 12: Do firms who exhibited resilience during 2008 financial crises and 2018 Tradewar cope better with a disruption, evidence from Covid-19

Sales Growth	Regression 1
Period	-0.0594
	(-1.8080)*
Treatment_Trade War	-0.2017
	(-1.1510)
Treatment_Financial crisis	-0.0167
	(-0.9035)
Size	-0.0012
	(-0.1874)
Age	0.0001
	(0.3628)
DiD_Trade War	-0.0379
	(-1.0450)
DiD_Financial crisis	0.0225
	(0.6210)
Number of observations	124
R-squared	0.1408
Adjusted R-squared	0.0890

All regressions are performed using robust standard errors. The dependent variable is Sales growth (%). In the table. The t-stat for the respective variable is presented in parenthesis under each coefficient.

*Note; *p < 0.1 ; **p < 0.05 ; ***p < 0.01*

The results from the second diff-in-diff analysis on Covid-19 are presented in table 12. They suggest that the treatment and control group's sales growth were negatively impacted by 6 percentage points post the supply chain disruption. When categorised based on resilience during the 2008 financial crisis, the treatment group did not exhibit a statistically significant difference in sales growth reduction compared to the control group. Similarly, the coefficient on the diff-in-diff variable for the group, when categorised based on their resilience in the supply chain disruption caused by the US-China Trade War, was not statistically significant. The continued absence of significance in the diff-in-diff variable for resilience exhibited in 2008 and the lack of significance in the diff-in-diff variable for resilience exhibited during 2018 indicate that the historically exhibited resilience did not enhance a firm's ability to withstand the Covid-19 supply chain disruption.

To conclude on the first hypothesis, firms that demonstrated resilience possessed an enhanced ability to withstand the subsequent supply chain disruptions that followed the Tohoku Earthquake and Tsunami and the US-China trade war. However, we find no empirical evidence that supports this notion for the Covid-19 induced supply chain disruption.

9.2. Does financial flexibility enhance resilience?

With regards to the limited sample size, the magnitude of below discussed coefficients might not be representable for the population. The results are thus presented with regards to the direction of the coefficients and not to its magnitude.

i) Resilience

Table 13: Does financial flexibility enhance a firm's resilience?

Resilience	Regression 1a	Regression 2a	Regression 3a	Regression 4a
Size	0.0326	0.0346	0.0336	0.0214
	(5.3390)***	(5.2920)***	(5.1730)***	(2.2670)**
Leverage ratio	-0.0231	-0.0372	-0.0380	-0.0368
	(-1.4260)	(-2.2450)**	(-2.3370)**	(-2.2760)**
Cash	-0.0668	-0.0874	-0.0875	-0.1085
	(-2.5420)**	(-3.1280)***	(-3.1570)***	(-3.4800)***
Cash Conversion Cycle			-0.0001	-0.0001
			(-1.9170)*	(-1.9370)*
Cash : Size				0.0997
				1.8540)*
Industry fixed effects	No	Yes	Yes	Yes
Number of observations	602	602	602	602
R-squared	0.0722	0.4225	0.4276	0.4308
Adjusted R-squared	0.0675	0.2130	0.2182	0.2208

All regressions are conducted using robust standard errors. The dependent variable is Resilience, and the independent variables of interest are Leverage ratio, Cash, Cash conversion cycle and the interaction between Size and Cash. The t-stat for the respective variable is presented in parenthesis under each coefficient

*Note; *p < 0.1 ; **p < 0.05 ; ***p < 0.01*

The regression results for hypothesis two are presented in table 13. In the first regression (Regression 1a), the dependent variable resilience is regressed against leverage ratio, cash and the control variable size. The negative coefficient on cash indicates that larger cash holdings have a negative impact on a firm's resilience, significant at the 5% level. Furthermore, the coefficient on the control variable size is positive at a 1% significance level which reveals that the size of a firm influences its resilience and that larger firms are more resilient than smaller firms, if all else equal. Leverage ratio reports no significant coefficient, suggesting that it lacks explanatory value for the resilience demonstrated by firms during Covid-19. Notably, the R2 reported for Regression 1a is low, signalling that the independent variables included do not explain much in the variation of resilience.

In the second regression (Regression 2a), industry fixed effects are added to the model. As a result, the R2 increases significantly, suggesting a better fit of the model. Moreover, the observed increase in magnitude of coefficients on all included variables suggests that the results are partly driven by unobservable industry factors. Consistent with Regression 1a, the coefficient on size and cash remains positive respectively negative. The significance of the coefficient on cash increases to the 1% level after controlling for industry fixed effects, suggesting that cash has a consistent and meaningful negative impact on resilience that holds across industries. Consistent with Regression 1a, the size coefficient remains positively significant at the 1% level, with a slight increase in magnitude.

In Regression 2a the negative coefficient on leverage ratio becomes significant at the 5% level. When compared to Regression 1a, it becomes evident that the inclusion of industry fixed effects influences the statistical significance of leverage ratio. The change in significance suggests that industry-specific factors have a moderating influence on the relationship between leverage ratio and resilience. Hence, when removing the influence of unobservable heterogeneity across industries, an increase in leverage ratio decreases the resilience of a firm.

In the third regression (Regression 3a), the inclusion of the CCC as an independent variable enhances both R2 and adjusted R2, indicating that the CCC variable contributes with explanatory value to the variations in resilience. When compared to Regression 2a, it is evident that the significance levels of the coefficients on cash, size, and leverage ratio remain unchanged and that there is only a slight change in the magnitudes. The negative and statistically significant coefficient on CCC at the 10% significance level indicates that a prolonged CCC has a negative effect on a firm's resilience.

Regression 4a tests whether size has a moderating impact on cash reserves through the utilisation of an interaction variable. The coefficients on leverage ratio, cash, and CCC maintain their significance levels, whereas the significance of the size coefficient decreases to the 5% level. The magnitude of the size and leverage ratio coefficients decreases slightly, while the cash coefficient experiences an increase in magnitude and the CCC coefficient remains unchanged. The coefficient on the interaction variable is positive and significant at the 10% level, implying that the partial effect of cash reserves on resilience is contingent on the size of the firm. Considering that the coefficient on cash remains negative also in Regression 4a, the findings suggest that, all else equal, an increase in cash prior to the disruption leads to a smaller reduction in resilience for large firms compared to small firms.

According to the findings presented in table 13, there is evidence that partially supports hypothesis two. Specifically, the results support our hypothesis that low leverage enhances resilience. However, our hypotheses that cash reserves and a long CCC increase resilience are both rejected.

ii) Damping

Table 14: Does financial flexibility enhance a firm's damping ability?

Damping	Regression 1b	Regression 2b	Regression 3b	Regression 4b
Size	0.0587	0.0591	0.0553	0.0306
	(5.4180)***	(5.2210)***	(4.9380)***	(1.8900)*
Leverage ratio	-0.0622	-0.0812	-0.0870	-0.0846
	(-2.1530)**	(-2.7050)***	(-2.9930)***	(-2.9320)***
Cash	-0.1245	-0.1493	-0.1468	-0.1890
	(-2.6770)***	(-3.0100)***	(-2.9820)***	(-3.4500)***
Cash Conversion Cycle			-0.0002	-0.0002
			(-3.1610)***	(-3.2160)***
Cash : Size				0.2010
				(2.2460)**
Industry fixed effects	No	Yes	Yes	Yes
Number of observations	602	602	602	602
R-squared	0.0765	0.4389	0.4544	0.4586
Adjusted R-squared	0.0719	0.2353	0.2548	0.2589

All regressions are conducted using robust standard errors. The dependent variable is Damping, and the independent variables of interest are Leverage ratio, Cash, Cash conversion cycle and the interaction between Size and Cash. The t-stat for the respective variable is presented in parenthesis under each coefficient

*Note; *p < 0.1 ; **p < 0.05 ; ***p < 0.01*

Regression 1b, is performed on the independent variables leverage ratio and cash and relevant control variables. Compliant with Regression 1a, the coefficient on cash is negative, although significant even at the 1% level, indicating that larger cash holdings have a negative impact on a firm's ability to dampen the adverse effects of a supply chain disruption. Moreover, the coefficient on the control variable size is positively significant at the 1% level, aligning with the findings in Regression 1a. This suggests that, all else being equal, larger firms demonstrate greater ability in mitigating the adverse effects of a supply chain disruption. Compared to Regression 1a, leverage ratio reports a significant negative coefficient already before controlling for industry fixed effects. It suggests that, when not considering industry-specific variations, a higher leverage ratio negatively affects a firm’s ability to dampen. The low R2 value in Regression 1b suggests that the included independent variables have limited explanatory power in accounting for the variation in resilience.

Regression 2b includes industry fixed effects to control for unobservable heterogeneity across industries. All coefficients increase slightly in magnitude. While the significance level of the coefficients on size and cash remains the same, the significance of the coefficient on leverage ratio increases to the 1% level. This proves that size, leverage ratio and cash reserves influence the ability to dampen, even when accounting for industry-specific factors. Consistent with the finding in Regression 2a, the increase in R2 suggests an improved model fit when industry fixed effects are included.

Regression 3b, which incorporates CCC, produces results in line with those of Regression 2b. The coefficients retain their significance and direction, with only minor changes in magnitude. In compliance with Regression 3a, the coefficient on CCC is negative, although higher in magnitude and significant at the 1% level. This indicates that a prolonged CCC has a negative impact on a firm’s ability to dampen the effects of a supply chain disruption. Evidently, the negative effect of a prolonged CCC is larger on a firm’s ability to dampen the adverse effects of a supply chain disruption, than it is on a firm's overall resilience.

Regression 4b, examining the moderating influence of size on cash reserves, mirrors the patterns observed in Regression 4a. While the significance of leverage ratio, cash reserves and CCC remains the same as Regression 3b, the significance of the coefficient on size decreases to the 10% level. The coefficient on the interaction variable is positive and somewhat larger in terms of magnitude compared to Regression 4a, significant at the 5% level. This suggests that all else equal, an increase in cash prior to the disruption leads to a smaller reduction in ability to dampen the adverse effects of the disruption for large firms compared to small firms.

iii) Recovery

Table 15: Does financial flexibility enhance a firm's recovery ability?

Recovery	Regression 1c	Regression 2c	Regression 3c	Regression 4c
Size	0.0526	0.0516	0.0474	0.0272
	(5.5850)***	(5.0310)***	(4.6310)***	(1.7570)*
Leverage ratio	-0.0457	-0.0610	-0.0640	-0.0620
	(-1.7540)*	(-2.1950)**	(-2.3790)**	(-2.3120)**
Cash	-0.0985	-0.1269	-0.1241	-0.1587
	(-2.3740)**	(-2.8020)***	(-2.7780)***	(-3.0670)***
Cash Conversion Cycle			-0.0002	-0.0002
			(-3.2540)***	(-3.2910)***
Cash : Size				0.1646
				(2.0230)**
Industry fixed effects	No	Yes	Yes	Yes
Number of observations	602	602	602	602
R-squared	0.0764	0.3806	0.3999	0.4036
Adjusted R-squared	0.0718	0.1559	0.1803	0.1835

All regressions are conducted using robust standard errors. The dependent variable is Recovery, and the independent variables of interest are Leverage ratio, Cash, Cash conversion cycle and the interaction between Size and Cash. The t-stat for the respective variable is presented in parenthesis under each coefficient

*Note; *p < 0.1 ; **p < 0.05 ; ***p < 0.01*

Similar to the previously analysed regressions for resilience and damping, Regression 1c reports a positive coefficient on size, significant at the 1% level. The coefficient on cash is negative as well and is significant at the 5% level. Similar to Regression 1b, the negative coefficient on leverage ratio is significant already before controlling for industry fixed effects. It suggests that a higher leverage ratio negatively affects a firm's ability to recover from the adverse effects of a supply chain disruption.

Regression 2c shows that, when industry-fixed effects are added to the regression, the positive and significant coefficients on size and the negative and significant coefficients on leverage ratio and cash prevails, proving that larger firms, firms with less leverage respectively firms with less cash exhibit improved abilities to recover from a disruption, independent of industry-specific factors. The significance of the coefficient on leverage ratio and cash increases to the 5%, respectively 1% significance level. The change in significance of leverage ratio and cash reserve suggests that industry-specific factors influence the relationship between a firm's leverage ratio and its recovery ability respectively between a firm's cash reserves and its recovery ability. Similar to Regression

2a and Regression 2b, R^2 increases significantly when controlling for industry fixed effects suggesting a better fit of the model.

In Regression 3c, CCC is included as a variable. The coefficient is significant at the 1% level and, similar to Regression 3a respectively Regression 3b, the coefficient is negative, suggesting that firms with longer CCC exhibit a lower ability to recover from a supply chain disruption. The significance on size, cash and leverage ratio remains the same as in Regression 2c while magnitude of the coefficient on size and cash decreases slightly, and the coefficient on leverage ratio increases.

In Regression 4c, the interaction term between size and cash reserves is included. The coefficient on size, leverage ratio, cash and CCC remains the same in terms of direction compared to Regression 3c. While there is a drop in significance on size to the 10% level, all other coefficients remain at the same significance level as compared to Regression 3c. In alignment with the findings in Regression 4a and Regression 4b, the coefficient on the interaction term is positive at the 5% significance level. This indicates that, holding all else equal, higher cash reserves prior to the disruption leads to a lower reduction in the ability to recover for large firms.

Concluding from the results presented in table 14 and 15, when related to those in table 13, we find empirical support for the third hypothesis. This implies that damping and recovery are equally influenced by the observed financial policies as resilience is.

10. Discussion

In the backdrop of a dynamic business landscape characterised by global interconnectivity, geopolitical uncertainties and a rising frequency of environmental disasters, this thesis has demonstrated that developing resilience is crucial for enhancing a firm's ability to endure disruptions. Moreover, it reports findings that, within the current business landscape, certain financial strategies can be leveraged by companies to enhance their resilience and proactively address the potential of supply chain disruptions. The following section will evaluate our findings in relation to existing literature, ultimately concluding upon the thesis' contributions and implications.

Global pressure: widespread adverse effects of supply chain disruptions

Our empirical results reveal a consistent, and significant, negative impact of supply chain disruptions on firms operating performance, as evident in the reduction of sales growth identified in the diff-in-diff analyses across all observed firms and disruptions. The results resonate with prior studies that have observed a decline in firms' sales subsequent to the announcement of a supply chain disruption (Hendricks and Singhal, 2005; Baghersad and Zobel, 2020). The focus in existing literature on supply chain disruptions' adverse effects on operating performance, revolves around disruptions confined to specific supply chains (Hendricks and Singhal, 2005; Baghersad and Zobel, 2020). Hendricks and Singhal (2005), and Baghersad and Zobel (2020) study the impact on firms who have announced disruptions that have occurred within their supply chain and already have had negative implications for their operations. In contrast, our study takes a broader perspective on supply chain disruptions.

Similar to previous literature, our study also addresses the implications of disruptions on firms. However, it also provides insights into how heightened global supply chain pressure, resulting from disruptive events in one supply chain, can affect companies across various supply chains. Our study, in comparison to Hendricks and Singhal (2005), and Baghersad and Zobel (2020), thus sheds light on a wider spectrum of challenges faced by firms within the global interconnected systems. Together with the existing literature, our findings suggest that firms should not only consider the potential of disruptions within their specific supply chain but also contemplate the heightened global pressure stemming from disruptive events occurring in the global interconnected systems.

Revealing vulnerabilities: unpreparedness of firms and supply chains for disruptions unfolding in the current global dynamic environment

As indicated by the results in the diff-in-diff analyses on the supply chain disruptions following the Tohoku Earthquake and Tsunami 2011 and the US-China Trade War 2018, firms deemed resilient based on historical performance during 2008 exhibited enhanced ability to withstand the adverse effects of the two disruptions. Consistent with the prevailing literature suggesting that firms exhibit varied ability to cope with the adverse effects of a supply chain disruption based on their characteristics (Hendricks and Singhal, 2005; Baghersad and Zobel 2020), our findings confirm the existence of such differences. Specifically, our results imply that these differences are attributable to firm resilience, indicating that resilience strengthens a firm's ability to endure supply chain disruptions.

Our findings suggest that resilience exhibited prior to a disruption enhances a firm's ability to maintain sales growth during the disruption. The thesis thus offers empirical evidence to the prevalent notion in the literature that resilient firms can more effectively respond to adverse consequences of unexpected events, maintain growth patterns and promptly return to its original state (Christopher and Peck 2004; Carvalho and Areal, 2016; Ma et al., 2018). Our findings support that resilience, quantified using the resilience index introduced by Barroso et al. (2015), comply with the conceptualisation of resilience in previous literature. We therefore validate the resilience index as a framework for predicting a company's resilience towards supply chain disruption. However, it should be noted that the resilience of a firm and its maintenance of sales growth are not exhibited within the same disruption in our study. Therefore, we cannot with certainty conclude that firms who were resilient before the disruption, and maintained growth during the disruption, are deemed resilient according to the index when measured for that disruption. This reasoning holds true as the observation of maintained sales growth in a disruption does not, with certainty, indicate that the firm will have a high resilience index.

However, the results also show that the difference between resilient and non-resilient firms in sustaining sales growth post disruption, subsided between the disruption that followed Tohoku Earthquake and Tsunami in 2011 and the one that followed US-China Trade War in 2018. It prompts the question of whether it is the resilience of firms to supply chain disruptions that diminishes or if the subsiding effect stems from differences in the consequences that followed the two disruptions.

Reviewing the results from the analysis on resilience in relation to Covid-19, it becomes evident that the effect of exhibiting resilience in 2008 on the ability to withstand supply chain disruptions, is absent. This finding indicates that the resilience demonstrated in 2008 does not guarantee a lasting ability to endure the adverse consequences caused by all subsequent supply chain disruptions. The lack of significance persists in the second regression on Covid-19, when resilience is instead determined based on the performance during the US-China Trade War. Since we confirm the results using a disruption closer in time to the pandemic, it suggests that the absent effect does not stem from a change in firms' resilience between when it is measured to when the disruption occurs. Instead, it proposes that the absent effect arises from the distinct consequences of Covid-19, as opposed to historical disruptions. However, it leaves the question of whether this is due to differences in the origins of the disruptions or to changes in the global business environment influencing supply chains.

Despite being considered as a black swan event, Covid-19 shares similarities with historical supply chain disruptions in terms of risk and propagation. While the Tohoku Earthquake and Tsunami in 2011 occurred locally, and the US-China Trade Tar in 2018 initially disrupted the flow of goods between two specific countries, they both originate from environmental risks and had global repercussions through ripple effects, similar to the Covid-19 disruption. This suggests that the absent ability of firms deemed resilient in 2008 to better withstand the Covid-19 supply chain disruption does not stem from differences in the origins of the analysed disruptions.

The remaining explanation for the absent influence of historical resilience on a firm's ability to withstand Covid-19, is that the pandemic unfolded in a global environment distinct from the setting of historical disruptions. The distinguishing factor of the supply chain disruption resulting from Covid-19 lies in its rapid global scalability, causing an immediate impact on global trade, given that multiple countries were affected simultaneously (Ivanov and Dolgui, 2021). In an ever-more globalised world with rising prevalence of trans manufacturing (Ferdows, 1997), coupled with a tendency of firms to neglect supply chain resilience in strategic decisions (Christopher and Peck, 2004), the literature discusses that supply chains are more vulnerable than ever to the occurrence of a disruption. Our finding, that historical resilience did not matter during Covid-19, indicates that the capabilities previously considered crucial for building resilience were possibly neither effective nor sufficient in the globally interconnected world in which Covid-19 unfolded. The findings thus resonate with the literature, specifically Ivanov and Das (2020), in the suggestion that firms and supply chains are not prepared for tackling disruptions in this global dynamic environment.

Navigating disruptions: how to build resilience in the current global environment

Within the unique setting of Covid-19, our study explores the anticipated relationship between financial flexibility and resilience exhibited during the Covid-19 supply chain disruption. Beyond studying the overall resilience of a firm, our study deconstructs resilience into its two core components, with the objective of determining whether resilience enhancing strategies related to financial policies differ during the damping phase respectively the recovery phase. Our findings suggest that during Covid-19, the influence of financial flexibility on a firm's ability to mitigate, respectively recover from the adverse effects of a disruption, closely mirrors how financial flexibility influenced the overall resilience of firms. Therefore, the following analysis of financial policies in relation to the overall resilience of a firm, is also applicable to firms' capabilities to mitigate and recover from disruptions.

Navigating disruptions: resilience in the current global environment can be enhanced through low leverage policies

The first testable component of our hypothesis, that a low-leverage policy enhances resilience, is supported by the empirical results. The results imply that firms with low leverage-policies prior to the Covid-19 induced supply chain disruption demonstrated greater resilience on average in the face of the disruption. These findings relate to the study of Nguyen et al. (2023) who observe that companies maintaining lower debt levels are better at navigating financial uncertainties during periods of economic instability. Our finding contributes to the conclusion of Nguyen et al. (2023) and the broader literature body on leverage policies, with new insights on how leverage should be optimised in the context of a disruption.

While no previous literature explores the relationship between leverage and resilience specifically, plausible rationales for why low leverage is resilience enhancing can be formed through insights from the two literature bodies on leverage policies and resilience. Firstly, the maintenance of a low leverage policy allows a firm to access capital markets easier in the event of earnings shortfalls (DeAngelo et al., 2011). This indicates that companies with low leverage prior to the supply chain disruption caused by Covid-19, were in a better position to obtain external financing during the disruption to finance continued operations, potentially explaining their enhanced resilience. Secondly, given that leverage entails a payment obligation, it imposes constraints on a firm's flexibility in resource allocation (McKoen and Dennis, 2012). Hence, leverage introduces a form of resource rigidity. According to Ambulkar et al. (2015), resource rigidity hampers resilience, extending the plausible explanation for our finding that high leverage reduced resilience during the Covid-19 supply chain disruption.

Navigating disruptions: resilience in the current global environment can be enhanced through restricted cash reserves

Our hypothesis that larger cash holdings prior to the Covid-19 disruption enhanced resilience is rejected. Instead, the results indicate that firms with substantial cash reserves, on average, demonstrated lower resilience during the supply chain disruption following Covid-19. This contradicts the assertion made by Carnes et al. (2023) that firms with significant cash holdings are better at adjusting their supply chain to changing market conditions. Furthermore, our findings, in relation to the study of Kulchania and Thomas (2017) raise a pressing concern. While Kulchania and Thomas (2017) provide evidence that firms increase their cash holdings in response to heightened supply chain pressure, our results suggest that this strategy does not enhance resilience: instead, it hampers it. Consequently, our finding presents a crucial extension to the insights of Kulchania and Thomas (2017) by uncovering an inefficiency in the current precautionary measures adopted by firms to confront supply chain disruptions.

Our finding, that larger cash reserves hampered resilience during Covid-19, challenges the conventional perspective that cash holdings provide financial security. However related literature offers a plausible explanation for this contradiction. Ambulkar et al. (2015) emphasise the critical role of resource reconfiguration in enhancing a firm's resilience to supply chain disruptions. This underscores the need for firms to strategically reallocate resources to adapt to unforeseen challenges, a capability that is fundamental for enhancing resilience. Large cash holdings, while often perceived as readily available resources, may act as a limiting factor on flexibility if not utilised efficiently. This perspective aligns with McNeil and Moore (2023) who suggests that accumulating cash holdings indicate inefficiency in resource allocation. Connecting to the reasoning of Ambulkar et al. (2015), it becomes evident that while cash provides a buffer against financial shocks, its impact on resilience is somewhat contingent on the utilisation of these resources, in a way that increases a firm's ability to resource reconfigure.

It is important to highlight that our study does not present empirical evidence supporting the idea that the impact of cash holdings on resilience is contingent on the efficient utilisation of cash during a disruption. Nevertheless, our finding that large cash holdings are resilience hampering reveals that relying solely on cash reserves is an inadequate strategy for coping with disruptions. When contextualising this finding within the existing literature, an intriguing question emerges, namely if the demonstrated negative influence on resilience is a consequence of a firm's inability to effectively employ cash reserves during a disruption. In the light of the literature our finding thus suggests that firms should assess their accumulation of cash with regards to how it is intended to be spent.

Interestingly, our study indicates a nuance in cash holdings' influence on resilience during Covid-19 related to the firm size. While not rejecting the main finding that cash holdings negatively influenced resilience, it shows that larger firms appear to be less negatively impacted by an increase in cash reserves. This finding resonates with Parker and Ameen's

(2018) view that smaller firms, accustomed to financial constraints, have an inherent capability of reconfiguring resources without the reliance on excess cash. Contrary, they argue that larger firms who are less accustomed to facing financial constraints, might more efficiently utilise cash holdings when confronted with the financial instability brought by a supply chain disruption.

Navigating disruptions: resilience in the current global environment can be enhanced through a short cash conversion cycle

Our hypothesis, that a longer CCC increased resilience to the Covid-19 disruption, is rejected. The results indicate that a longer CCC had adverse effects on resilience during the disruptions caused by the Covid-19 pandemic. Interestingly, while our results align with the conventional perspective of efficient working capital management, emphasising a short CCC (Das, 2015), they contradict the prevailing literature on how working capital should be managed during unforeseen events. While Afza and Nazir (2007) identified a positive correlation between corporate profitability and extended inventory periods during production interruptions, our findings present a contrasting perspective. Although our study doesn't break down the CCC making direct comparisons with Afza and Nazir (2007) challenging, longer inventory period effectively implies a longer CCC. This assumption, holding other factors constant, allows us to draw some conclusions. In the light of the contradictory results, we find a plausible explanation. The firms that we study operate within the manufacturing industry with complex supply chains that arguably require larger inventories and longer inventory periods in their normal operations. It is thus reasonable that a longer CCC can be the result of the complexity in the manufacturing industry, rather than signalling a redundancy strategy. In our regression analysis, firms with longer CCC are treated the same, disregarding if this is due to complex manufacturing or redundancy strategies. As a result, our study potentially neglects the specific impact of an extended inventory period, resulting from a redundancy strategy on resilience.

Moreover, Ding et al. (2013) observed that firms with substantial working capital reserves demonstrate enhanced flexibility in adjusting their working capital when confronted with cash flow shocks. While our study indicates that a short CCC, resulting in reduced working capital, is optimal during a supply chain disruption, this doesn’t necessarily contradict their findings. As our study exclusively evaluates CCC during the Covid-19 disruption without accounting for its pre-disruption state, our findings do not offer insights into how firms should manage their CCC before a disruption to enhance resilience during such disruptions. Achieving an optimal state of a short CCC, as suggested by the result from our study, could potentially be contingent on the initial length of a firm’s CCC before the disruption, reasoning with Ding et al. (2013).

Appuhami (2008) contends that effective working capital management is characterised by the ability to promptly and easily respond to unexpected shifts in market conditions. Resilience refers to a firm’s ability to adapt to a changing environment. Applying Appuhami's (2008) perspective, our finding that a shorter CCC improves resilience thus implies that efficient working capital management in disruptive periods involves the maintenance of a short CCC. This insight extends the understanding of how working capital should be managed in times of disruptions, suggesting that firms should shorten their CCC. However, considering Peng and Zhou’s (2019) proposal that a reduced CCC imposes financial strain on suppliers, it should be acknowledged that opting for a shorter CCC could potentially put pressure on global supply chains, heightening their vulnerability.

Navigating disruptions: resilience in the current global environment is influenced by the application of financial flexibility policies

As discussed, the independent results on the three specific financial policies unfold the joint conclusion that firms can partly enhance resilience through the adoption of financial flexibility. More specifically, we provide evidence that, in the face of a supply chain disruption, firms can increase resilience through three financial policies: low leverage, low cash reserves and a short CCC. Our findings, that certain firm characteristics contribute to resilience, aligns with prior research. Barroso et al. (2015) notes the existence of firm specific differences explaining the varying levels of resilience when applying their resilience index while not delving deeper into this aspect. Our finding that specific financial policies enhance resilience, thus provides empirical evidence that partly, while not exhaustively, explain the difference in resilience that they observe.

Additionally, our finding that financial policies can be used as a resilience enhancing strategy extends the existing literature body on supply chain resilience. As presented in section three, there are several existing studies that provide evidence for how firms can build supply chain resilience (Christopher and Peck, 2004; Datta and Christopher, 2011; Pettit et al., 2010; Tang, 2006). However, as indicated earlier in the discussion, we find evidence suggesting that when confronted with a disruption in the current era of unprecedented globalisation, the strategies previously relied upon for resilience enhancement might no longer be sufficient. While we cannot neglect the existing resilience literature, the evident lack of preparedness in global systems, emphasises the necessity to explore resilience enhancing strategies further. The majority of existing literature focuses on building strategies that enhance external resilience (Mohammed et al., 2023). Within the complex and interconnected value chains, disruptions impact supply chains from multiple directions, limiting firms' ability to identify their supply chain vulnerabilities. External resilience is thus argumentatively difficult to achieve as it would require firms to reconsider their entire supply chain network.

In the contemporary business landscape, with increased geopolitical risks and a heightened likelihood of natural disasters, supply chain disruptions are more likely to occur. It is thus crucial to build internal resilience (Mohammed et al, 2023) that makes firms more responsive to disruptions, irrespective of its risk and origin. Our study offers valuable insights into how firms can build internal resilience in the midst of this new era. More specifically, we identify that companies can build resilience through the application of financial policies, contributing to the relatively unexplored field of internal resilience (Mohammed et al., 2023). Within the literature on internal resilience, Tang and Tomling (2008) suggest that flexibility is the key capability for increased resilience. Resonating with Tang and Tomling (2008), our study reveals that financial policies can establish operational flexibility, facilitating decisions that strengthen firm resilience. Uncovering the influence of financial policies on resilience we therefore also address the rising concern of unifying operational and financial decisions (Birge, 2015).

Compliant with what was suggested by Fahlenbrach et al. (2021), our study demonstrates that firms with financial flexibility, in terms of low leverage, are able to better navigate the adverse effects that followed the Covid-19 supply chain disruption. Similarly, our empirical findings indicate that financial flexibility, in terms of a short CCC, enhances resilience during this specific disruption, aligning with the conventional view on efficient working capital management (Das, 2015). Although conventionally viewed as a policy of financial flexibility, our study does not find evidence supporting the notion that holding cash enhances resilience.

Consequently, the thesis does not find empirical evidence indicating that the joint concept of financial flexibility, when considered conventionally, leads to increased resilience. Nevertheless, shifting away from the traditional perspective that emphasises which policies create financial flexibility, it is reasonable to instead evaluate them based on their effects when implemented in a specific context. Examining financial flexibility as a strategic asset that improves agility and the capacity to navigate unforeseen challenges, compliant with the view of Dennis (2011), we observe that during disruptions, financial flexibility is marked by low leverage, reduced cash holdings, and a shortened cash conversion cycle. Therefore, we contribute with new insights into what could be regarded as financial flexibility, in the specific context of a supply chain disruption, which interestingly does not align with the conventional view.

Additionally, as highlighted in prior research by Ivanov and Dolgui (2021), existing resilience strategies often present a trade-off with contemporary supply chain management paradigms, leading practitioners to neglect their adoption. Our discovery that firms can increase resilience through specific financial policies offers valuable insights, as the implementation of such policies does not directly conflict with the advantages derived from efficient supply chain management.

11. Conclusion

With evidence that individual firms are affected negatively by a disruptive event causing pressure on the global system, we conclude the importance for firms to extend their focus beyond the risks within their individual supply chain. We moreover conclude that the conventional capabilities once deemed essential for building resilience might no longer be sufficient to withstand the adverse effects of supply chain disruptions in today's globally interconnected environment. The unpreparedness of firms and supply chains to effectively tackle disruptions in this globalised and interconnected era highlights the necessity for firms to reassess their resilience strategies.

Considering the proven inefficiency of existing resilience strategies in today's business environment, we address the need for reassessing resilience strategies, offering evidence of how firms can build internal resilience through financial policies. We firstly provide empirical evidence supporting the resilience index (Barroso et al., 2015) as an effective framework for assessing a firm's ability to withstand disruptions, and thereafter use it to explore what financial policies that are resilience enhancing during the supply chain disruption induced by Covid-19. We conclude that during the Covid-19 supply chain disruption, unfolding in an unprecedented, globalised era, low-leverage, restricted cash holdings and a short CCC increased firms' resilience.

In conclusion, our thesis offers a comprehensive answer to the research question: *Did financial flexibility, as conventionally perceived, improve firms' ability to withstand the adverse effects of the Covid-19 supply chain disruption on operating performance?* We present evidence that firms with low leverage or a short CCC, both conventionally perceived as financial flexibility policies, exhibited higher resilience to the Covid-19 supply chain disruption. In contrast, the presence of substantial cash holdings, often considered an indication of financial flexibility, evidently reduced resilience during the same disruption. Consequently, in addressing the research question, we conclude that financial flexibility, when viewed as a joint concept, did not improve firms' ability to withstand the Covid-19 supply chain disruption's adverse effects on operating performance. Nevertheless, if approaching the research question by examining each financial policy individually, the conclusion becomes more precise. Low leverage and a short CCC, as standalone indicators of a firm's financial flexibility, did improve firms' abilities to withstand the adverse effects of the Covid-19 disruption. On the contrary, cash reserves, typically viewed as a signal of financial flexibility, did not contribute to improved ability to withstand the adverse effects of during Covid-19; rather, it reduced it.

11.1. Limitations

The main limitations of this work pertain to the specifics of the available data, the sample and the standardised approach used to measure resilience. Limited data availability results in a relatively small sample size across all regressions in this paper, as indicated by the consistently low R2 values. This suggests that the models examined may not comprehensively capture the variation in the dependent variable. The small sample size raises concerns about the representativeness of the sample in relation to the broader population and increases the risk of greater variability in estimates, potentially leading to less accurate results. Therefore, the observed results cannot definitively be presumed to apply to an alternate dataset.

Additionally, the conducted heteroscedasticity test indicates the presence of some heteroscedasticity among the error terms of the fitted model. In response to this issue, we incorporate heteroskedastic-robust standard errors. It's important to note that this adjustment only impacts the t-stats of the reported results and not the coefficients. Consequently, a limitation of our study is the absence of a more refined regression model to address heteroscedasticity, which slightly diminishes the robustness of our results.

Additionally, the lack of more frequent data on operating performance, than the quarterly that is available, presents a challenge in computing resilience using the resilience index. Ideally, the resilience index (Barroso et al., 2015) should capture the precise times when firms are initially affected by the disruption and when they fully recover. However, due to the standard practice of quarterly reporting, more frequent data is unavailable. This limitation might introduce noise in the measurement of firm-specific resilience indices, potentially influencing both the classification of firms into treatment and control groups in the diff-in-diff analyses and the final regression on financial policies.

The standardised methodology for measuring resilience using the resilience index introduces inherent limitations through the application of empirical rules that may not hold in practical scenarios. Firstly, to classify a firm as fully recovered, a specific rule had to be established, and we opted for the first of two subsequent quarters in which the firm exhibited pre-disruption sales levels. This standardised rule carries the risk of incorrectly categorising a firm as recovered when it has not fully recovered, thereby influencing its resilience index. Secondly, the methodology imposes constraints by necessitating the setting of a disruption time frame, which raises the risk of overlooking firms that have not yet recovered or falsely categorising firms as recovered within that time frame when they have not. Thirdly, for the diff-in-diff analysis a resilience threshold had to be determined to categorise firms as resilient or non-resilient, introducing the risk of random allocation errors. While partially mitigated by using quartiles of the resilience index for the designated treatment and control groups, introducing a resilience threshold is problematic given the nature of the sample, where firms, on average, demonstrate high and similar resilience, as evident from the mean and standard deviation for the full samples group reported in table 1.

Lastly, existing literature proposes several strategic capabilities that they argue are resilience enhancing, while not providing empirical evidence for such relationships. Given the challenge of precisely quantifying qualitative abilities, we refrain from controlling for them, introducing a limitation to this study. This limitation poses the issue that we cannot with statistical accuracy guarantee that the observed relationship in our study between resilience and the studied financial policies, does not stem from other capabilities omitted in our study.

11.2. Future research

As revealed in the discussion, our study sheds light on the impact of possessing cash reserves when confronted by a disruption. When this finding is accompanied with insights from existing literature, it raises a question on whether the association between cash and resilience depends on the efficiency of cash utilisation during disruptions. Consequently, there is an interest in exploring the mediating effect of cash spending on the relationship between cash reserves and resilience.

Furthermore, our findings indicate that a shorter CCC positively affects resilience. However, our study does not explicitly break down the CCC into its three components, thus leaving unexplored how each of the components impact resilience. As highlighted in the discussion, prior literature reveals results suggesting that a longer inventory period is positively linked to a firm’s profitability during periods of production interruptions. It would therefore be interesting to explore if the inventory period, and the other two components of CCC, propose implications on resilience that are i) distinct from each other and ii) distinct from the overall influence of CCC.

Lastly, given that we present novel evidence suggesting that firms can leverage their financial policies to develop resilience, there is a need for additional empirical validation of the study. As a recommendation for future research, we propose a similar analysis applied to a different sample group, preferably one distinct from manufacturing, to investigate if similar patterns emerge in other industries. Additionally, it would be interesting to anchor our findings in the context of another global event that disrupts supply chains. In the same business environment as Covid-19, the Russian Invasion of Ukraine has caused multiple disruptions to global systems. While the supply chain pressure is still notable as of the publication of this study, it provides a compelling context to conduct a similar analysis at a later point in time.

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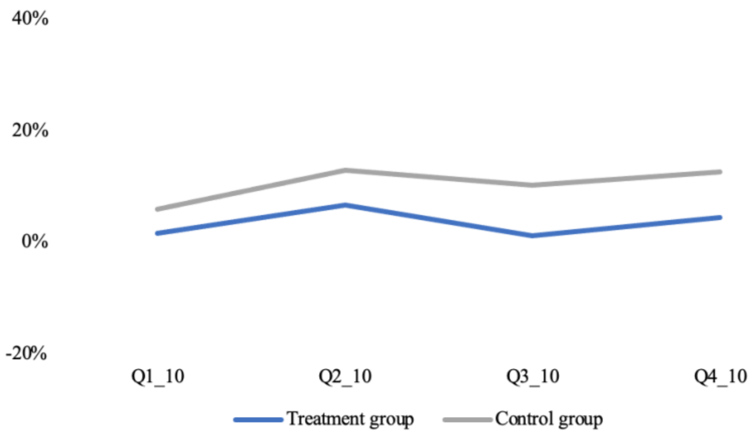
13. Appendix

Appendix figure 1: Parallel pre-intervention trend assumption 2011

Sales growth

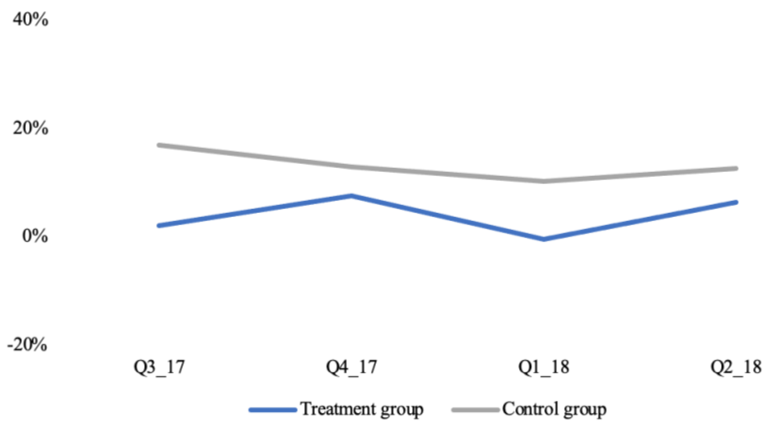


Average sales growth for the treatment and control group in the four quarters prior to the supply chain disruption caused by the Tohoku Earthquake and Tsunami in 2011.

Appendix figure 1: Validate parallel pre-intervention trend assumption for the treatment and control group; Tohoku Earthquake and Tsunami in 2011

Appendix figure 2: Parallel pre-intervention trend assumption 2018

Sales growth

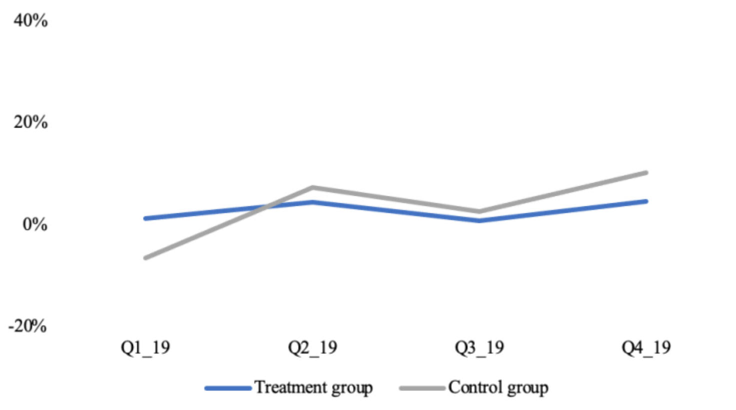


Average sales growth for the treatment and control group in the four quarters prior to the supply chain disruption caused by the US-China Trade War in 2018.

Appendix figure 2: Validate parallel pre-intervention trend assumption for the treatment and control group; US-China Trade War in 2018

Appendix figure 3: Parallel pre-intervention trend assumption 2020

Sales growth

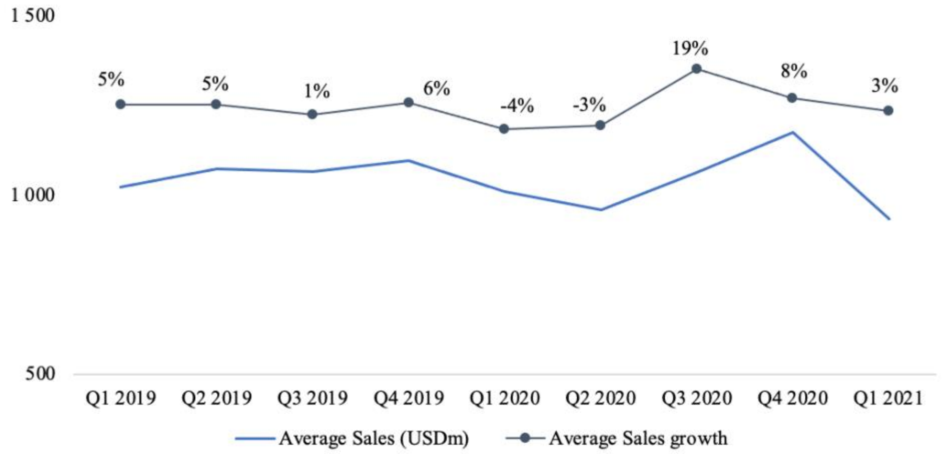


Average sales growth for the treatment and control group in the four quarters prior to the supply chain disruption caused by the Covid-19 pandemic in 2020.

Appendix figure 3: Validate parallel pre-intervention trend assumption for the treatment and control group; Covid-19 pandemic in 2020

Appendix figure 4: Trend in quarterly sales and sales growth

Sales and Sales growth



Quarterly sales and sales growth trend over the period Q1 2019 to Q1 2021, for full sample, including both the treatment and control group

Appendix figure 4: Quarterly sales data and sales growth data for the treatment and control group, Q1 2019 to Q1 2021

Appendix table 1: Correlation matrix and VIF-test for independent variables in analysis 2a

Variables	1	2	3	4	VIF
(1) Size	1				1.165
(2) Leverage ratio	0.211	1			1.083
(3) Cash	-0.312	-0.225	1		1.149
(4) Cash Conversion Cycle	-0.210	-0.122	0.150	1	1.060

Correlation matrix and VIF-test for the independent variables included in model 2a

Appendix table 1: Correlation and VIF-test for model 2a

Appendix table 2: Correlation matrix and VIF-test for independent variables in analysis 2b

Variables	1	2	3	4	VIF
(1) Size	1				1.70
(2) Leverage ratio	0.211	1			1.087
(3) Cash	-0.312	-0.225	1		1.149
(4) Cash Conversion Cycle	-0.229	-0.149	0.162	1	1.075

Correlation matrix and VIF-test for the independent variables included in model 2b

Appendix table 2: Correlation and VIF-test for model 2b

Appendix table 3: Correlation matrix and VIF-test for independent variables in analysis 2c

Variables	1	2	3	4	VIF
(1) Size	1				1.177
(2) Leverage ratio	0.211	1			1.084
(3) Cash	-0.312	-0.225	1		1.151
(4) Cash Conversion Cycle	-0.243	-0.136	0.171	1	1.080

Correlation matrix and VIF-test for the independent variables included in model 2c

Appendix table 3: Correlation and VIF-test for model 2c

Appendix table 4: BP-test for heteroscedasticity in model 2a-2c

Model	Resilience model (2a)	Damping model (2b)	Recovery model (2c)
BP value	13	15	10
P-value	(0.01)***	(0.005)***	(0.04)**

The table reports the results from the performed Breusch-Pagan heteroscedasticity test for the models. Significant results imply the regression of the null hypothesis of homoscedasticity

Appendix table 4: Breusch-pagan test for model 2a-2c