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Supply base complexity in times of crisis: moderating the negative impact of the Russia–Ukraine war

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Abstract

Purpose – The Russia–Ukraine war (RUW) has disrupted the operations of global supply chains, highlighting the need to enhance resilience against large-scale disruptions. Building on the dual nature of supply base complexity (SBC), this study examines the extent to which the war has impacted automotive firms and explores how horizontal and vertical SBC differently moderates its negative effects.

Design/methodology/approach – This study conducts an event study to estimate the abnormal stock returns of 837 automotive firms headquartered in 41 countries following the RUW. This is followed by regression modeling to estimate the moderating effect of SBC. Further, a panel regression with fixed effects is used to estimate the effect propagated from automotive firms to their suppliers and customers in other industries.

Findings – Overall, we find that automotive firms experienced a 6.16% (4.73%) reduction in mean (median) market value following the outbreak of the war, with this effect propagating to their customers and, to a lesser extent, their suppliers. The study further reveals that the negative impact is exacerbated for firms with high horizontal SBC but alleviated for those with high vertical complexity.

Originality/value – This study provides evidence of the negative financial impact of the RUW and contributes to the supply chain literature on large-scale exogenous disruptive events. It further expands the boundary conditions of SBC by demonstrating that SBC can serve both as a cost burden and as a source of resilience in times of crisis, depending on whether its structure is more horizontally focused or vertically oriented.

Keywords Russia–Ukraine war, Supply base complexity, Automotive industry, Financial impact, Propagation effects

Paper type Research article

1. Introduction

Supply chains, often understood as the set of entities engaged in the upstream and downstream flows of goods, finances, or information from a source to a customer (Mentzer *et al.*, 2001), play a pivotal role in modern global business operations. However, supply chains are constantly challenged by disruptions and unexpected events that hinder the normal flows of goods and expose them to operational and financial risks. The Russia–Ukraine war (RUW) has acted as a reminder of such vulnerabilities in global supply chains, simultaneously triggering a series of disruptions affecting critical materials, commodities, and equipment (Kilpatrick, 2022; White *et al.*, 2022). Most automotive plants in the affected areas suspended their operations, while many automakers and component manufacturers outside the affected regions ceased importing and exporting automotive products due to trade-related sanctions against Russia (Silberg, 2022).

The RUW has prompted scholarly efforts to explore its potential impact on firms and their supply chains. Accordingly, several studies have attempted to examine the effects of such rare,



large-scale events with far-reaching global consequences, or “mega-disruptions” (Flynn *et al.*, 2021). However, the literature remains limited in several ways: it tends to be conceptual in nature (e.g. Kim *et al.*, 2022; Silberg, 2022; Srai *et al.*, 2023), adopts a macro-level perspective rather than focusing on the firm level (e.g. Boungou and Yatié, 2022), or concentrates on strategic aspects of the RUW, such as sanctions (e.g. Gaur *et al.*, 2023) rather than the war as a whole. Most importantly, to our knowledge, the impact of the RUW has received limited attention from a supply chain perspective.

The potential for negative impacts caused by such disruptive events motivates practitioners to understand efficient strategies to mitigate supply chain disruptions. Recently, supply base complexity (SBC) has been discussed as a potential source of resilience to disruption-related events (Choudhury *et al.*, 2022; Wang *et al.*, 2024; Wiedmer *et al.*, 2021). The basic idea of this perspective is that greater SBC inherently involves a large number of suppliers, which helps diversify the supply base and thereby enhance crisis resilience. However, in the supply chain literature, SBC is viewed with some caution. A common argument is that complex supply bases are harder to manage, which could even make them more prone to the risks of supply chain disruptions (Bode and Wagner, 2015; Brandon-Jones *et al.*, 2015; Choi and Hong, 2002). Moreover, SBC could lead to reduced efficiency mainly due to higher transaction costs (Choi and Krause, 2006; Chopra and Sodhi, 2014). The potential benefits of a larger supply base during a mega-disruption event like the war in Ukraine remain unclear and thereby more research is needed.

Against this background, we aim to examine the following questions: *How and to what extent has the RUW financially affected companies? Does SBC moderate the impact of the event, and if so, how?* We address the research questions by utilizing an event study. Specifically, we assess the financial impact of the RUW by analyzing stock price changes, focusing on 837 publicly listed automotive firms headquartered in 41 countries. Analyzing stock price movements around an event provides a robust estimate of a company’s financial losses and has been widely used in prior operations and supply chain management studies (e.g. Fan *et al.*, 2022; Hendricks *et al.*, 2020; Jacobs *et al.*, 2022).

The automotive industry offers an interesting context for study for the following reasons. First, the automotive industry is considered one of the most complex supply chains, with an average vehicle consisting of between 15,000 and 25,000 components (Legett, 2024). The large number of components needed for an average vehicle contributes to the SBC. Second, the automotive industry comprises a vast and intricate global sourcing network (Legett, 2024), which makes it vulnerable to RUW-driven disruptions in different parts of the globe. For example, both Ukraine and Russia are major suppliers of key raw materials for auto parts, such as neon gas and palladium. Since the military operations began in the conflict regions, these raw material suppliers shut down their operations, impacting vehicle production around the globe (Goldberg, 2023; Harrison, 2022; Silberg, 2022). Third, the automotive industry has become increasingly reliant on direct suppliers (Veloso and Kumar, 2002). The emergence of large direct suppliers, who construct ready-to-install modules, demonstrates the importance of the supply base for automotive operations.

Our analysis results show that, overall, automotive companies experienced a 6.16% (4.73%) reduction in mean (median) market value following the RUW. This negative impact extends not only to the automotive companies, but also to their customers and suppliers in other industries, suggesting a propagation effect across the supply chain due to the war. Indeed, as a type of mega-disruption, the war in Ukraine causes a negative financial effect for companies in the automotive industry and beyond. We further find that the negative effect associated with the RUW is moderated by SBC in contrasting ways. Specifically, horizontal complexity in the supply base amplifies the overall negative impact of the war, while vertical complexity mitigates it. Our findings indicate that the magnitude of the negative market impact caused by the RUW event depends on the structural characteristics of the supply base, particularly its horizontal and vertical complexity.

This study contributes to the literature in the following ways. First, our study provides evidence on the financial effect of the RUW. There has been ongoing discussion regarding how and to what extent the war affects firm performance (Silberg, 2022; Simchi-Levi and Haren, 2022; White *et al.*, 2022), but these discussions are mostly conceptual in nature or limited to the macro-level impact of the event. This study expands the existing literature by revealing the financial impact of the war on automotive companies, as well as its propagation effects on both customers and suppliers in other industries. Second, our study contributes to the recent stream of supply chain research that examines large-scale and long-term disruptions (e.g. Fan *et al.*, 2022; Polyviou *et al.*, 2023; Wang *et al.*, 2024). Like the COVID-19 pandemic or other geopolitical events, the war in Ukraine is an exogenous source of supply chain disruptions that differs from those during normal times in terms of the scale and duration of the disruption (Flynn *et al.*, 2021). Following this, our study contributes additional insight to the supply chain disruption literature by focusing on the war in Ukraine as a case of mega-disruption. Finally, SBC is often discussed in the supply chain literature as having a negative impact on operations (Choi and Krause, 2006). Our study offers a more nuanced perspective by expanding the boundary conditions of SBC's role in moderating the negative impact. Depending on the nature of its structure, SBC can serve as both a potential cost burden and a source of resilience for companies during times of crisis.

2. Literature review

2.1 Disruptions due to the Russia-Ukraine war

The Russia-Ukraine conflict began as early as early 2014, when Russia annexed Crimea from Ukraine (Kirby, 2025). On February 24, 2022, a full-scale war between the countries began, which marked the beginning of a large-scale military conflict. Since its beginning, the RUW has contributed to the growth of general market uncertainty, impacting economic investment and consumption activity and has further destabilized global value chains due to material shortages and rising production costs (Celi *et al.*, 2022). The war has severely disrupted global supply chains as both Ukraine and Russia are major producers of key global commodities (Hamilton, 2023; Kammer *et al.*, 2022; White *et al.*, 2022). Following the outbreak of the war, prices for metals, grains, and energy surged. In particular, the supply of basic commodities such as platinum, titanium, and nickel was disrupted.

In responding to the war, the US and the EU, and several other countries have imposed significant trade-related sanctions on Russia, affecting several industries and targeting various products and raw materials, such as steel, iron, and other raw-materials (European Council, 2023). The trade-related sanctions have restricted the material and component flow from the war areas, further contributing to the supply disruptions and price peaks. Furthermore, the delivery of raw materials and goods from the war areas has been disrupted as the war has restricted shipping in the Black Sea region, a trade bridge between Europe and other continents (Faucon and Parkinson, 2022).

While the impacts of the war have been felt across various industries through price increases and supply disruptions of commodities, these disruptive effects have been somewhat geographically asymmetric (Borrell, 2022; Celi *et al.*, 2022). Economists have referred to the RUW as the third asymmetric shock, particularly affecting the Euro area over the past two decades, implying greater disruption in some Euro area countries than in others. Furthermore, the sanctions against Russia appear to have especially impacted sanction-imposing countries themselves, which have committed to refraining from sourcing Russian supplies, whereas other countries, such as China, have strengthened economic ties with Russia following the escalation (Lawless, 2023). However, the war's potential impact on firms and their supply chains remains insufficiently examined. Moreover, in an environment characterized by such geographically uneven impacts, SBC structures may play a pivotal role in responding to supply chain disruptions, such as delivery disruptions or economic sanctions, and thereby moderating the negative financial impacts of the war. Yet, this potential has received limited attention in the current literature.

The RUW may have negatively affected the automotive industry mainly due to disruptions in vehicle production and the supply of key materials and components (Silberg, 2022). This potential disruptive impact may stem from the position of Russia and Ukraine as key raw material and component manufacturers in the automotive industry. For example, in 2022, Ukraine supplied more than 70% of the global neon gas, while Russia was the world's largest producer of palladium and one of the world's largest producers of nickel (Frost and Sullivan, 2022). Supply disruptions of these raw materials could have challenged the global supply of semiconductor chips, electric vehicle (EV) batteries, and catalytic converters, among others (Frost and Sullivan, 2022; Silberg, 2022). Indeed, the automotive industry can be considered particularly vulnerable to supply chain disruptions involving such specific materials and goods from within Russia and Ukraine.

2.2 Dual nature of supply base complexity

The literature suggests a dual nature of SBC in terms of its implications for firms' risks and performance. On one hand, scholars primarily discuss the negative side of complexity in the supply base. A common argument is that complex supply bases are harder to manage (Choi and Hong, 2002), making them more prone to the risks of supply chain disruptions (Craighead *et al.*, 2007). Indeed, Bode and Wagner (2015) empirically find that complexities in upstream supply chains increase firms' risk by amplifying disruption frequency. Moreover, SBC could lead to overall reduced efficiency due to higher transaction costs, higher unit costs, and decreased supplier responsibility (Choi and Krause, 2006; Chopra and Sodhi, 2014; Tang, 2006). In sum, this stream of research suggests that SBC could make supply chain operations more prone to the risk of disruptions, as well as increase in operational disadvantages such as cost-inefficiencies and management challenges.

On the other hand, several scholars, particularly in the recent literature, suggest that SBC can offer diversification benefits in times of crisis. Evidence from recent studies shows that supply complexity and diversification can mitigate the negative impact of disruptions caused by COVID-19 (Choudhury *et al.*, 2022; Lin *et al.*, 2021; Wang *et al.*, 2024). Furthermore, supply complexity has been found to be beneficial for buying firms seeking to recover from the disruptions caused by the 2011 Japanese earthquake (Wiedmer *et al.*, 2021). Although there are some negative views (e.g. Fan *et al.*, 2022), the consensus is that companies with a large number of suppliers across the globe were able to manage disruptions better than their competitors due to their diverse supply networks, which may help moderate the impact of the disruptive events. This perspective is also in line with operational flexibility built through supply base diversification, which can help mitigate the negative impact of disruptions (Hendricks *et al.*, 2009). Overall, this diversification view of SBC is related to resilience in supply chains, which indicates a firm's ability to prepare for, mitigate, and respond to unexpected events.

Complexity in the supply base has gained special attention from supply chain scholars, leading to its conceptualization through diverse theoretical lenses (e.g. Choi and Krause, 2006; Kim *et al.*, 2015; Lu and Shang, 2017). Despite the various perspectives, the structural SBC consistently exhibits multidimensional characteristics that hinge on two fundamental distinguishing dimensions: multiplicity and diversity (Ates and Luzzini, 2024). Multiplicity refers to the large number of elements in the supply network, which can be observed through horizontal and vertical complexity. Diversity, however, refers to supplier heterogeneity in terms of geographical location, size, industry, or capabilities. While the two dimensions may not be perfectly correlated, multiplicity is a prerequisite for and pivotal to the diversity dimensions (Jacobs and Swink, 2011). This is particularly relevant in our context, as we focus on the automotive supply chain, an inherently complex network characterized by a vast number of suppliers, which in turn necessitates spatially diverse sourcing across global regions (Legett, 2024). Thus, while controlling for potential diversity effects, we narrow our focus to the multiplicity dimension of SBC by examining horizontal and vertical complexity, which

together more effectively capture the structural characteristics of the upstream automotive supply chain under the disruptive context of the RUW.

2.3 Diversification view of supply base complexity

The diversification view of SBC can be traced to modern portfolio theory (MPT). MPT was introduced by Henry Markowitz (Markowitz, 1952, 1991, 2010). It suggests that investors aim to simultaneously maximize returns and minimize risk, seeking the lowest level of risk at which a given return target can be achieved. The key message of MPT is that assets in a portfolio should not be selected simply based on their individual characteristics. Instead, investors must consider how each asset co-moves with others in the portfolio (Elton and Gruber, 1997). This approach allows investors to balance out the idiosyncratic, asset-specific risks of individual investments and to construct a portfolio with the same expected return but lower risk than one built without accounting for asset interactions.

While MPT was developed for investment purposes, it is widely applicable across different disciplines (Fabozzi *et al.*, 2002). In particular, scholars have applied MPT to supply chain disruption research (Azadegan *et al.*, 2021; Kleindorfer and Saad, 2005; Wiedmer *et al.*, 2021). For example, Azadegan *et al.* (2021) investigated sudden-onset (surprising) disruptions using MPT as a theoretical lens, suggesting that redundancy strategy plays an important role in diversifying supply chain risk. Furthermore, they propose that by having operational slack and supply redundancy across supply chains, firms can better mitigate risks arising from surprising supply chain disruptions. This stream of literature recognizes the risks associated with growing corporate efforts to streamline the supply base. However, it also highlights that from the MPT perspective, more assets are not necessarily better, because an increase in assets can add to asset management complexity and trading costs.

Like the assets in a portfolio, a company's suppliers possess some diverse characteristics such as organizational, cultural, or technological profiles. Thus, a company could manage potential supply chain risks by diversifying its supplier base, similar to how portfolio risk can be mitigated through asset diversification. This means that having more suppliers, or a less concentrated supplier base, and thus increasing SBC could potentially help reduce overall supply chain risk. However, the benefits of complexity should be weighed against its associated costs (Fabozzi *et al.*, 2002), because managing a complex supply base introduces significant operational challenges (Choi and Krause, 2006). Financial advantages would be realized only when the risk diversification benefits outweigh the costs of managing a larger and more complex supplier base.

3. Hypothesis development

3.1 Effects of the Russia-Ukraine war outbreak

The RUW event has negatively affected the global automotive sector via supply and production disruptions (Noble, 2022; Simchi-Levi and Haren, 2022; White *et al.*, 2022; Zhang *et al.*, 2023). A key factor behind the supply disruptions has been the importance of Russia and Ukraine as global producers of automotive-related commodities and components (Silberg, 2022). The automotive industry is particularly sensitive to supply disruptions of specific materials and intermediate goods from both countries (Celi *et al.*, 2022). At the same time, the decision of automotive OEMs and component producers, such as Volkswagen, BMW, Ford, Hyundai, and Toyota, to discontinue operations in the conflict areas has created production disruptions (Harrison, 2022; Oostvoorne, 2022; Silberg, 2022). Moreover, the trade-related sanctions imposed on Russia by major economies, including the EU, the US, and the UK, along with the shipping restrictions in the Black Sea region, have further hindered the flow of goods to and from the conflict zone, thereby intensifying disruptions in supply and production (Faucon and Parkinson, 2022).

These supply and production disruptions caused by the RUW have likely been reflected in reduced sales and profitability among automotive industry players. The inability to access

critical raw materials or components, caused by the direct effect of the war as well as retaliatory sanctions, has led to delays in production schedules, decreased overall automobile and component output, and created challenges in realizing sales on the anticipated timeline and scale (Celi *et al.*, 2022; Frost and Sullivan, 2022; Silberg, 2022). Indeed, global new vehicle sales dropped by 2% year-on-year in 2022, a decline driven especially by supply chain disruptions, semiconductor shortages, and weakening sales in the major automotive market of China (Roberts, 2023). At the same time, the rising costs of key materials and components have impacted the automotive industry. Precious metal prices increased by 10%–30%, and oil prices saw a significant rise following the outbreak of the war impacting the costs of tires, plastics, and paints among others (Silberg, 2022). These kinds of price increases can negatively affect the profitability of the industry unless compensated by increased sales prices. Therefore, keeping other factors constant, the disrupted sales of new vehicles and rising production costs provide evidence to assume a negative financial impact on the automotive industry following the outbreak of the war.

This negative financial impact stemming from lower sales and higher costs after the outbreak of the war is likely to have been reflected in the market value of the automotive companies. A firm's value is determined by the level and risk of its expected future cash flows (Bodenhorn, 1964). Thus, the decline in sales and rise in costs due to the war are expected to negatively affect the cash flow expectations of automotive companies (Srivastava *et al.*, 1998), thereby reducing their share prices. In short, imminent supply chain disruptions triggered by the RUW are likely to lead to increased uncertainty and diminished cash flow potential, which in turn can negatively impact the market value of automotive companies. Therefore, we develop the following hypothesis:

- H1. The outbreak of the RUW will have a negative effect on the market value of automotive companies.

3.2 Roles of horizontal and vertical complexities

The existing literature suggests that SBC could help companies mitigate the negative impact of disruptions in the supply chain (Choudhury *et al.*, 2022; Kleindorfer and Saad, 2005; Tang, 2006). The benefits of a larger supply base are argued to follow from the ability to turn away from single-sourcing and seek diversification through a versatile supply base during the disruptions. This diversification, arising from a more complex supply base, could have benefited companies during the RUW by providing greater access to alternative suppliers. Such access to alternative suppliers can provide automotive companies with resilience against supply and production disruptions (Kim *et al.*, 2015), as well as price increase in raw materials and components in the industry. Moreover, it provides opportunities to access to additional resources and learn from alternative sources, thereby mitigating the risks of future disruptions in the supply base (Fan *et al.*, 2022; Wang *et al.*, 2024). Consequently, automotive companies that maintained supply and production continuity through alternative supply sources after the outbreak of the war could differentiate themselves from competitors by achieving greater sales and operating at lower costs.

The MPT supports this view of diversification (Elton and Gruber, 1997; Francis and Kim, 2013). Under the assumption that suppliers face idiosyncratic risks arising from their different characteristics, such as geographic location and organizational policy, constructing a supply base with suppliers of diverse characteristics could allow a company to balance supplier-specific risks and achieve a lower overall supply risk. Given that a company with a larger number of suppliers typically has a more diversified supply base than a company relying on only a few key suppliers (Borgatti and Li, 2009; Kim and Davis, 2016; Wang *et al.*, 2024), increasing SBC would help automotive companies realize these diversification benefits during times of crisis.

However, the benefits of building a diverse supply base should be weighed against the costs associated with managing its complexity (Fabozzi *et al.*, 2002; Markowitz, 1952, 2010). In

other words, the benefits of supply base diversification may not be fully realized if the inherent complexity results in higher transaction costs and increased management overhead (Choi and Krause, 2006; Lu and Shang, 2017; Sharma *et al.*, 2020). Moreover, increasing SBC tends to introduce management challenges, such as communication breakdowns, monitoring inefficiencies, and difficulties in resource allocation, all of which contribute to disruption risks in the supply chain (Bode and Wagner, 2015). These disruption risks may further diminish the potential benefits of diversification.

During the RUW, having a large number of direct (first-tier) suppliers can expose automotive companies to substantial management challenges for two main reasons. First, horizontal SBC is widely known to increase transaction costs. Choi and Krause (2006) argue that an increase in the number of suppliers leads to higher transaction costs due to “frictions” arising from managing complex relationships with suppliers. This challenge could have become more pronounced during the RUW, as companies faced heightened difficulties in maintaining stable and efficient communication with a large number of direct suppliers operating in a disrupted global environment (Frost and Sullivan, 2022; Harrison, 2022). Thus, automotive companies with a more horizontally complex supply base are likely to incur greater management overhead during RUW-driven disruptions.

Second, upstream horizontal complexity increases the risk of supply chain disruptions (Bode and Wagner, 2015; Brandon-Jones *et al.*, 2015). Amid the RUW, the probability of supply and production disruptions rose significantly (Silberg, 2022), and automotive companies with a more horizontal SBC could have faced a higher likelihood of encountering disruption due to their exposure to affected or risky suppliers. Furthermore, coordination difficulties, an inherent challenge in managing a complex network of direct suppliers (Kim and Davis, 2016), were exacerbated under the uncertain conditions of the war. Taken together, the direct management of large first-tier suppliers may lead to higher transaction and management costs, as well as a high likelihood of disruption risks, thereby diminishing or even negating the intended benefits of supply base diversification. Given the discussion, we posit that:

H2. The negative market value effect caused by the RUW will be amplified by higher horizontal SBC.

By contrast, companies with high vertical SBC are more likely to achieve the benefits of diversification within the supply base. Vertical complexity refers to the hierarchy of suppliers (Lu and Shang, 2017), meaning that focal buying firms do not work directly with second- and lower-tier suppliers. Instead, modern supply chain operations are managed in a cascading manner, with a few first-tier suppliers overseeing a large number of lower-tier suppliers. Cousins (1999) referred to this approach as “delegated sourcing”. First pioneered in the automotive industry, delegated sourcing allows “a firm to reduce the number of direct suppliers without necessarily reducing the total amount of supply” (Cousins *et al.*, 2008, p. 55). A recent study by Grossman *et al.* (2023) shows that such supply base structure enables firms to access alternative suppliers more effectively during disruptions while reducing management costs. Thus, it may have helped automotive companies to find alternatives at lower management costs during the Ukraine war, where they struggled to replace auto suppliers in the affected areas, mainly due to the lack of available suppliers (Amann and Carey, 2022).

Furthermore, while supply chain disruptions may increase with upstream vertical complexity, the frequency of supply chain disruptions caused by vertical complexity is significantly lower compared to that caused by upstream horizontal complexity (Bode and Wagner, 2015). This reduced disruption risk could be attributed to the resilient nature of the vertically oriented supply base structure. Specifically, the multi-tiered hierarchical nature is more robust against potential supply disruptions because it decentralizes risks across tiers, thereby increasing resilience (Kim *et al.*, 2015).

Consequently, during the RUW, automotive firms with high vertical SBC may be better able to retain the benefits of diversification while minimizing management burdens. This more

vertically oriented structure may help automotive firms access alternative sources in times of crisis, as well as mitigate and respond more effectively to supply disruptions caused by the conflict. Hence, we develop the following hypothesis:

- H3. The negative market value effect caused by the RUW will be mitigated by higher vertical SBC.

4. Research design

4.1 Sample construction and description

The main context of our study is the global automotive industry. Accordingly, we selected the “Automobiles” and “Automobile Components” categories from the Global Industry Classification Standard (GICS) taxonomy and identified publicly listed companies from Refinitiv Workspace. This process resulted in a sample of 1,032 automobile and component producers, compiled as of March 2024. However, 195 of these companies lacked sufficient data on stock returns around the year of the war outbreak. After excluding these firms, we obtained a final sample of 837 automotive companies across 41 countries, which was used for the estimation of abnormal returns (H1) surrounding the war event.

The supply base data were collected from FactSet Supply Chain Relationships, which is commonly used in recent supply chain risk studies (e.g. Son *et al.*, 2021; Wang *et al.*, 2021). We focused on the first- and second-tier suppliers of the 837 automotive companies. First-tier suppliers are the direct suppliers of the automotive companies, while second-tier suppliers are the direct suppliers of the first-tier suppliers. Second-tier suppliers were defined as firms indirectly linked to automotive companies through a two-step relationship, in which they supply to a first-tier supplier who then supplies the automaker, with the condition that no firm could appear as its own second tier supplier (Wang *et al.*, 2021). Because supplier relationship data were missing for some sample companies for the year immediately preceding the war outbreak (i.e. year 2021), the initial sample was reduced to 517 automotive companies. Finally, after excluding companies with no financial data in Refinitiv Workspace, we used a final sample of 495 companies for examining the role of SBC during the RUW (H2). We note that our results remain consistent even when the analysis is restricted to buyer-supplier relationships that persisted throughout the entire 2021 sample period ($n = 370$), demonstrating robustness to relationship continuity (Wang *et al.*, 2021).

Table 1 presents the descriptive statistics of the sample used in the analyses. Panel A shows the diverse regional background of our sample firms. About 25% of the sample firms are headquartered in China, followed by South Korea (14.10%), Japan (13.14%), and India (13.02%). There are also samples headquartered in the US (5.50%) and Germany (1.91%). Panel B shows the percentage representation of automobile and component manufacturers. About 15% of the sample firms are automobile manufacturers, while component manufacturers account for over 85% of the sample. As noted in Table 1, many of the automobile companies are headquartered in China (26.23%) or the US (13.93%), while component manufacturers are primarily headquartered in the Asia-Pacific region, such as China (25.45%), South Korea (16.08%) and Japan (13.99%).

4.2 Analysis of market value effect

To test H1, we compute the sample companies’ abnormal returns around the war event. The abnormal returns are calculated as the difference between a company’s actual returns and its expected returns as shown in Equation (1) (Brown and Warner, 1985):

$$AR_{it} = R_{it} - (\hat{\alpha} + \hat{\beta}R_{mt}) \quad (1)$$

Table 1. Descriptive summary

Panel A: headquarter countries of sample firms ^a				
Country	%	Country	%	
China	25.57	Thailand	2.15	
South Korea	14.10	Hong Kong	2.03	
Japan	13.14	Germany	1.91	
India	13.02	Turkey	1.55	
Taiwan	6.69	Rest of the world	15.05	
United States	5.50			
Panel B: industry representation ^a				
GICS industry name	%			
Automobiles ^b	14.83			
Automobile components ^b	85.17			
Panel C: sample statistics ^c (year 2021)				
Variable	Mean	SD	Min	Max
Market value (\$M)	199643.1	3,949,886	8.9	89,700,000
Sales (\$M)	40620.5	195,508	0.06	3,049,000
Total assets (\$M)	51973.9	253036.3	4.0	4,081,000
Net income (\$M)	1626.6	12867.9	−36020.0	201,000
Employees (000s)	21.0	55.5	0.01	672.8
Note(s): , ^a <i>n</i> = 837;, ^b Mainly headquartered in China (26.23%) and the US (13.93%) for automobiles and in China (25.45%), South Korea (16.08%) and Japan (13.99%) for automobile components;, ^c <i>n</i> = 495 eligible for regression analysis				
Source(s): Authors’ own creation				

where AR_{it} indicates the abnormal return of firm i on day t , R_{it} denotes the actual return of firm i on day t , and the terms in parenthesis represent the market model's expected return for the firm. $R_{m,t}$ is the market return on day t , measured through the relevant market index corresponding to the stock exchange in which firm i is traded. For the market index, we use the FTSE China A50 for Chinese firms, the KOSPI 200 for Korean firms, the TOPIX for Japanese firms, the Nasdaq Composite for US firms, the FTSE 100 for UK firms, and comparable indices for other countries. In general, we used the market index data available through Refinitiv Workspace. In a few cases where the major market index returns were not available, we used index proxies compiled by Thomson Reuters. For example, Brazil's Bovespa index data were unavailable and were replaced with a similar index compiled by Thomson Reuters (RIC: TRXFLDBRP).

To calculate the parameters $\hat{\alpha}$ and $\hat{\beta}$, we use an ordinary least squares (OLS) regression over a defined estimation window. The length of an estimation window has no definite rule. Hence, following common practice (e.g. Hendricks and Singhal, 2003), we use the estimation window as 200 days with a 10-day offset period before the actual event, which in our case began on 24.02.2022. Thus, our estimation window runs from 29.07.2021 to 13.02.2022. The cumulative abnormal returns (CAR) for an event window $[t_1, t_2]$ are calculated as indicated in Equation (2):

$$CAR[t_1, t_2] = \sum_{t_1}^{t_2} \frac{\sum_{i=1}^n AR_{i,t}}{n} \tag{2}$$

The literature does not offer any strict rules for determining the event window. The assumption of an efficient market implies that information should be incorporated into stock prices immediately, leaving no time for opportunistic trading. This holds particularly true for information that is straightforward to interpret, such as earnings or dividend events. However, for information without prior precedent, the stock market may require additional time to assess its broader impact on prices. This need for a longer adjustment period is emphasized in recent event studies in the literature (Child *et al.*, 2021; Hendricks *et al.*, 2020; Jacobs *et al.*, 2022; Silvers, 2016). For example, Jacobs *et al.* (2022) used a [0, 6] event window for analyzing the market value effect of the US-China trade war focusing on ZTE. Thus, while a very short window may be effective, it carries the risk of missing the true effect if the market incorporates the information gradually.

In our context, the price impact of the war is likely driven not only by the direct effect of the invasion itself, but also by other indirect consequences, such as retaliatory sanctions and fluctuations in energy prices. Thus, for the event window, we consider Day 0 to be Thursday, 24 February 2022, when Russia announced a “special military operation” in Ukraine during the early hours. Subsequently, a series of sanctions were imposed on Russia’s investments, trade, and individuals by major economies, including the EU, the US, the UK, Japan, South Korea, Australia, and Canada. For example, the EU announced sanctions on 25 February, 28 February, 1 March, 9 March and 15 March, particularly aiming to restrict the import and export of goods and technology and to limit trade in raw materials such as iron and steel (European Union, 2024). While several new and repeated sanctions were announced throughout 2022 and up to the present, we observe that the majority of trade-related sanctions by major economies were announced between 24 February and 15 March 2022. Additionally, we note that the war remained in the news headlines for months following the initial invasion. However, new information for the stock market was largely absent after the initial weeks. To further explore this, we examined Google Trends data for the keyword “Russia Ukraine war” to check for any surprises. As shown in Figure 1, the popularity of the keyword steadily declined over time, further indicating the absence of new information. Based on these observations, we select a 14-day event window [0, 13] as our primary focus, while also reporting results for alternative intervals to ensure robustness.

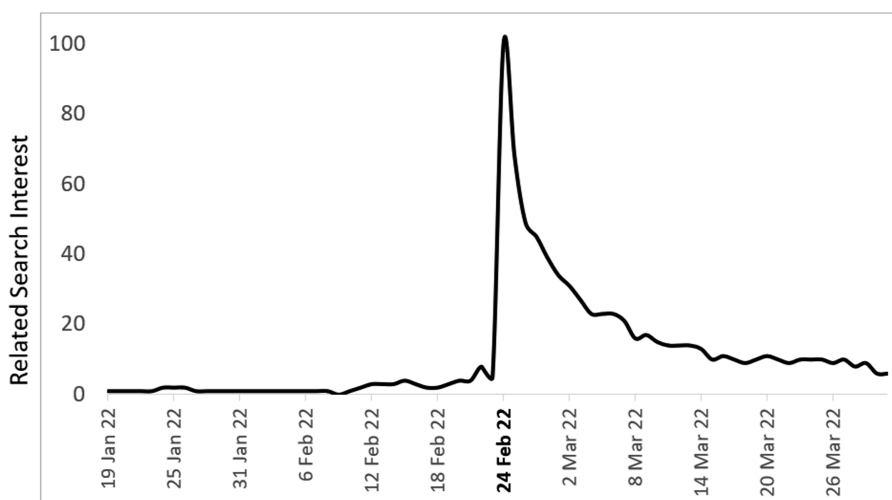


Figure 1. Google Trends popularity of “Russia Ukraine war”. **Note(s):** The RUW broke out on 24 February 2022; A score of 100 relative search interest indicates peak popularity. **Source(s):** Authors’ own creation

Because we estimate CARs for multiple firms on the same event date(s), there may be high chances of samples being clustered. To avoid this potential bias, we follow [Brown and Warner \(1985\)](#) and test the statistical significance of CARs:

$$t.stat_{t_2-t_1} = \frac{\sum_{t_1}^{t_2} \bar{A}_t}{s\sqrt{t_2 - t_1}} \quad (3)$$

where $\bar{A}_t$ represents the mean abnormal returns of the sample firms on days $t = t_1, \dots, t_2$ during the event window and s is the standard deviation calculated as:

$$s = \sqrt{\frac{\sum_{t_{e1}}^{t_{e2}} \left(\bar{A}_t - \bar{A}_e \right)^2}{(t_{e2} - t_{e1}) - 1}} \quad (4)$$

where $\bar{A}_t$ represents the mean abnormal returns of the sample firms on days $t = t_{e1}, \dots, t_{e2}$ during the estimation window, while $\bar{A}_e = \frac{\sum_{t_{e1}}^{t_{e2}} \bar{A}_t}{t_{e2} - t_{e1}}$. For our calculation, we use $e_1 = -11$ (11th day prior to the first day of event), and $e_2 = -210$.

4.3 Regression specification

To test [H2](#) that estimates the moderating effect of SBC, we construct an OLS regression model as follows:

$$CAR_i = \alpha + \beta_1 \times Horizontal_complexity_i + \beta_2 \times Vertical_complexity_i + \sum \beta_k \times Control_variables_i + \varepsilon_i \quad (5)$$

where CAR_i indicates the cumulative abnormal returns [0, 13] of firm i , and the coefficients β_1 and β_2 indicates the SBC of firm i , which estimate the market value effect of *horizontal complexity* and *vertical complexity*, respectively.

To measure horizontal complexity, we follow common practice and use the total number of first-tier suppliers in a firm's supply base ([Bode and Wagner, 2015](#); [Fan et al., 2022](#); [Sharma et al., 2020](#)). In our data, the average number of first-tier suppliers is 24.5 (SD = 75.4). We also follow common practice and measure vertical complexity by the average number of second-tier suppliers per first-tier supplier (e.g. [Lu and Shang, 2017](#)). In our data, the mean vertical complexity is 20.01 (SD = 39.8), which means that for each first-tier supplier of automotive companies, there are approximately 20 second-tier suppliers connected to it.

We control for firm-level factors that are known to affect firm's market value during times of crisis ([Lins et al., 2017](#); [Srinivasan et al., 2023](#)). These include firm size (the natural logarithm of total assets), prior performance (the ratio of net income to total assets), financial leverage (the ratio of long-term debt to the book value of equity), short-term debt (the ratio of short-term debt to total assets), cash holdings (the ratio of cash equivalents to total assets), inventory turnover (the ratio of sales to total inventories), and capital intensity (the ratio of capital expenditure to sales). All variables are measured based on the latest fiscal year before the outbreak of the RUW.

We also control for sector- and location-level factors, as automotive firms may experience varying market value effects depending on their sector, geographical location, and whether their suppliers are based in affected regions (i.e. the EU). We include a binary variable for the firm's sector (1 = automobile components, 0 = automobiles). To account for geographical location, we use dummy variables for Europe, North America, and Other regions, with Asia as the reference category. For supplier location, we use the ratio of a sample firm's all first- and

second-tier suppliers that are located in the EU. Table 2 presents the statistical summary statistics of the variables used in regression analysis.

5. Results

5.1 Market reaction for the Russia-Ukraine war

The results of the event study analysis are presented in Table 3. Panel A reports the CARs for all sample firms ($n = 837$) during the event window (for daily ARs, see Table A1). Specifically, the mean (median) CAR over the $[0, 13]$ window is -6.16% (-4.73%), which is significant at the 1% level. The percentage of firms with negative CARs during this window is also high, exceeding 70%. The subcategories of automobiles ($n = 123$) and automobile components ($n = 714$) are also presented in Panel A. The mean (median) CAR for both automobiles and automobile components are -4.92% (-5.67%) and -6.38% (-4.32%), respectively, which are similar to those of all sample firms. The percentage of firms with negative CARs is also comparable to that of the full sample. It is evident that both subcategories experienced negative market reactions to the war in Ukraine during the event window.

Overall, the empirical findings suggest that the companies in the automotive industry experienced negative stock market returns following the outbreak of the RUW. This evidence provides support for H1.

5.2 Moderating effects of supply base complexity

The results of regression analyses are presented in this section. First, we check the Pearson correlation coefficients among the variables in Table 2. We observe no strong correlation among other variables. Indeed, the maximum variance inflation factor (VIF) value across all regression models was 1.63, with an average VIF value of 1.24.

The regression results are reported in Table 4. As shown in Model 2, horizontal complexity has a significant negative coefficient for the mean CAR ($b = -0.012$, $p = 0.031$). Thus, for each additional first-tier supplier, the firm's CAR decreases by 0.012%. This result is consistent in the full regression model (Model 4), thus supporting H2. By contrast, we find a significant positive coefficient of vertical complexity for the mean CAR ($b = 0.026$, $p = 0.028$). Thus, for each additional second-tier supplier per first-tier supplier, the firm's mean CAR increases by 0.026%. The significance also holds in the full regression model (Model 4), thus supporting H3.

Overall, we find evidence of a differential impact of SBC on firm market value following the outbreak of the war. Automotive companies with higher horizontal complexity experienced more negative market reactions to the RUW, whereas firms with higher vertical complexity exhibited the opposite effect.

5.3 Robustness checks

5.3.1 Alternatives for event study results. Alternative event windows were considered, as shown in Panel B of Table 3. We find no significant market value impact associated with the RUW during the $[0, 1]$ window. However, we observe a marginally significant negative impact during the $[0, 5]$ window. The overall market value impact of the war tends to increase over longer event windows $[0, 10]$ and $[0, 20]$. This suggests that the market perceives the war as an evolving disruption, with its impact intensifying over trading days, consistent with the dynamics captured in our main event window. A similar increasing pattern is also observed for the median CARs. Overall, these results support our main event study findings.

As an additional measure of robustness, we also consider alternative models in Panel C of Table 3. First, to account for potential war-related distortions in market index returns in Equation (1), we replaced the event-day market returns with the index's average return over the ten days preceding the war (i.e. Day -11 to Day -1). Next, we estimate the CARs using the

Table 2. Variable statistics and correlation matrix

Variables	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. CAR [0, 13] (%)	−6.66	11.3											
2. Horizontal complexity	24.5	75.4	−0.10										
3. Vertical complexity	20.01	39.8	0.09	−0.07									
4. Auto components	0.82	0.38	0.01	−0.47	−0.09								
5. Supplier location	0.13	0.16	−0.07	0.06	0.07	−0.02							
7. Firm size	21.7	2.29	−0.11	0.40	−0.04	−0.15	−0.11						
8. Prior performance	0.03	0.09	−0.13	0.005	0.002	0.14	0.07	0.09					
9. Financial leverage	0.61	4.77	0.05	0.007	−0.01	−0.10	0.001	−0.09	−0.29				
10. Short-term debt	0.13	0.11	0.003	0.01	0.03	0.01	−0.05	0.08	−0.08	−0.03			
11. Cash holding	0.13	0.12	0.05	0.002	0.07	−0.24	−0.001	−0.03	−0.26	0.10	−0.24		
12. Inventory turnover	6.97	6.99	−0.07	0.02	−0.03	−0.10	−0.02	0.05	0.02	−0.03	−0.12	0.13	
13. Capital intensity	0.09	0.78	−0.04	−0.003	0.03	−0.07	0.04	0.01	−0.05	−0.02	−0.04	0.15	−0.06

Note(s): $n = 495$; coefficient (absolute) values greater than 0.09 are statistically significant at $p < 0.05$

Source(s): Authors' own creation

Table 3. CARs for sample firms affected by the RUW

	<i>n</i>	Mean (%)	<i>t</i> -statistic	Median (%)	<i>Z</i> -statistic	AR < 0 (%)
<i>Panel A: total sample for CAR [0, 13]</i>						
All sample firms	837	−6.16***	−4.07	−4.73***	−15.42	72.75
Automobiles	123	−4.92**	−2.37	−5.67***	−6.05	73.77
Automobile components	714	−6.38***	−3.98	−4.32***	−14.17	72.58
<i>Panel B: alternative event windows</i>						
CAR [0, 1]	837	−0.76	−1.33	−0.76***	−8.50	64.76
CAR [0, 5]	837	−1.90*	−1.92	−1.18***	−8.82	63.34
CAR [0, 10]	837	−4.77***	−3.55	−4.44***	−14.56	72.24
CAR [0, 20]	837	−4.57***	−2.46	−4.51***	−12.44	68.33
<i>Panel C: alternative models for CAR [0, 13]</i>						
Prior-10-day ^a	837	−5.21***	−3.44	−3.63***	−11.28	65.11
Mean-adjusted model	837	−7.77***	−4.03	−6.06***	−16.97	74.79
Four factor model ^b	837	−4.21***	−2.79	−3.81***	−12.48	68.65
GARCH model	837	−4.13***	−9.00	−2.75***	−9.60	60.93
<i>Panel D: CAR [0, 13] based on regions^c</i>						
Asia	619	−6.48***	−3.39	−4.8***	−13.24	72.73
Europe	68	−9.05***	−3.89	−8.04***	−5.85	80.88
North America	50	1.31	0.27	−1.57	−0.78	56.00
Others	100	−5.91***	−3.21	−4.03***	−6.78	82.00

Note(s): The *z*-statistics are obtained from Wilcoxon signed rank tests; AR < 0 (%) presents negative abnormal returns; ^aWe used prior-10-day average market returns from Equation (1), ^bDue to lack of availability of country-wide Fama-French factors, we use the developed markets' factors for size, value and momentum from the Kenneth French data library; ^cScheffé test shows no significant difference in CARs among Europe, Asia, and Other regions, but a significant difference between North America and the other three regions ($p < 0.01$); * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source(s): Authors' own creation

mean-adjusted model (Brown and Warner, 1985). This model may be appropriate in the context of the RUW, as it does not rely on market index returns. We also employ the four-factor model to control for systematic risks beyond the market factor including size, value, and momentum (Fam and French, 2012). Lastly, we re-estimate the CARs using the GARCH model to account for potential volatility clustering around the war event (Bollerslev, 1986). The results are presented in Panel C, showing that estimated CARs are nearly identical to the results obtained using the market model.

We examine whether there is a location-specific effect associated with the war event. As shown in Panel D, among the four continent groups, automotive firms located in Europe experienced the strongest negative market reaction (−9.05%, $p < 0.01$), followed by those in Asia (−6.48%, $p < 0.01$) and other regions (−5.91%, $p < 0.01$). Firms in North America did not experience a significant negative market reaction (1.31%, $p > 0.10$). The daily ARs reported in Figure 2 also support the regional variation in market reactions to the RUW. A Scheffé test further shows that the differences in CARs among Europe, Asia, and other regions are not statistically significant. However, a significant difference is observed between North America and the other three regions at the 1% level, suggesting that geographic proximity to the conflict zone may have amplified the negative impact.

Finally, during the outbreak of the war, some of our sample firms may have been affected by other financially relevant information such as new product introductions, earnings announcements, or executive appointments. To verify this possibility, we manually checked major newspapers (e.g. *The Wall Street Journal*, *Financial Times*), and identified 22 such

Table 4. Regression results

	Model 1	Model 2	Model 3	Model 4
Horizontal complexity		−0.012** (0.006)		−0.010* (0.006)
Vertical complexity			0.026** (0.012)	0.024** (0.012)
Auto components	0.159 (1.283)	−0.888 (1.437)	0.431 (1.273)	−0.486 (1.438)
Supplier location	−4.125 (3.866)	−3.985 (3.861)	−4.789 (3.956)	−4.625 (3.951)
Firm size	−0.484** (0.231)	−0.348 (0.249)	−0.459** (0.229)	−0.344 (0.249)
Prior performance	−11.639 (9.944)	−11.747 (9.768)	−12.183 (9.919)	−12.240 (9.774)
Financial leverage	0.018 (0.058)	0.017 (0.057)	0.022 (0.057)	0.021 (0.057)
Short-term debt	0.893 (4.761)	0.810 (4.725)	0.480 (4.694)	0.436 (4.667)
Cash holding	2.891 (5.594)	2.113 (5.503)	2.227 (5.377)	1.602 (5.319)
Inventory turnover	−0.110* (0.057)	−0.114** (0.058)	−0.105* (0.056)	−0.108* (0.057)
Capital intensity	−0.848 (0.554)	−0.890* (0.532)	−0.865 (0.529)	−0.900* (0.512)
Focal firm location ^a	Included	Included	Included	Included
Constant	4.983 (5.556)	3.258 (5.655)	3.862 (5.547)	2.453 (5.657)
Observations	495	495	495	495
F-value	7.42***	7.65***	7.53***	7.86***
R-squared (%)	4.88	5.30	5.71	6.01

Note(s): Robust standard errors in parentheses; ^aFocal firm’s regional location dummies are included, representing Europe, North America, and other regions, with Asia as the referent category; the maximum VIF value for all models is 1.60; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source(s): Authors’ own creation

cases. In non-tabulated results, we re-estimate the CAR after excluding these firms and found results that are nearly identical to the main results shown in Panel A.

5.3.2 Alternatives for regression results. We conduct several robustness tests for the moderating effect of SBC. First, we conduct a placebo test to examine whether the moderating effect of SBC on stock price changes can be attributable to the war event. We re-estimate the regression model using CAR over an 11-day window prior to the outbreak of the war; that is, $[-11, -1]$. As shown in Table 5, we find statistically insignificant coefficients for both horizontal and vertical complexities. We also find a similar pattern when using CAR $[-6, -1]$. This result supports our inference that the observed market value effects are indeed driven by the war event, rather than by any pre-existing trends unrelated to the war.

We next re-run the regression model using alternative event windows. As shown in Model 3 to Model 5, we find that our main results remain consistent for CAR $[0, 5]$, CAR $[0, 10]$, and CAR $[0, 20]$. However, in non-tabulated results, they become less significant when using CAR $[0, 1]$, with an insignificant coefficient for horizontal SBC ($b = -0.002$, $p = 0.119$) and a marginally significant coefficient for vertical SBC ($b = 0.006$, $p = 0.053$), consistent with our event study findings as shown in Table 3. Overall, these results indicate that our main findings are robust across different event windows.

Moreover, SBC, often associated with diversification, can also be measured using the Herfindahl-Hirschman Index (HHI) (Lam, 2018). Thus, following common practice (e.g.

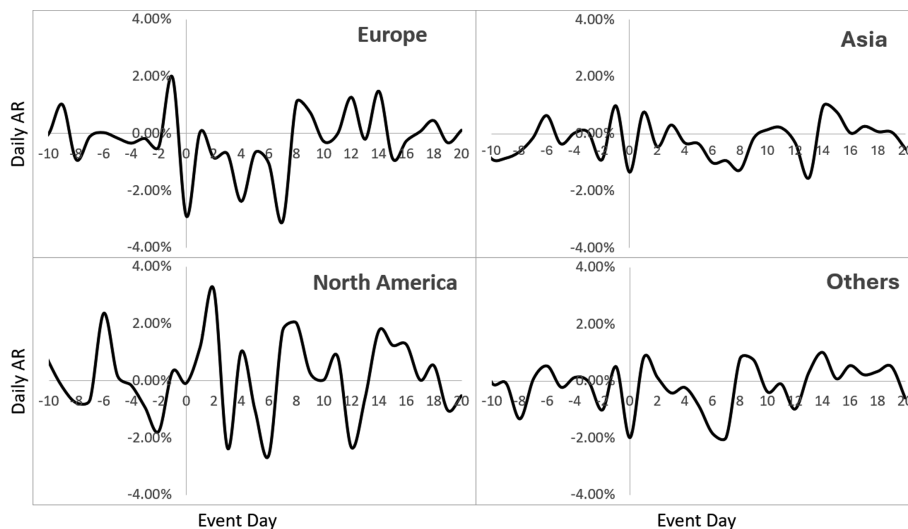


Figure 2. Daily ARs by region before and after the RUW. **Note(s):** Daily ARs are presented for automotive companies located in the major regions of our sample including Europe, Asia, North America, the rest of the world (as “Others”); Event day 0 represents the outbreak of the RUW on 24 February 2022. **Source(s):** Authors’ own creation

Hendrick *et al.*, 2009), we use 1 minus the HHI, calculated based on the number of suppliers by country, as a proxy for SBC. As shown in Model 6 of Table 5, the results are consistent with our main findings reported in Table 4. This suggests that our main findings are not driven by the choice of measurement.

Similarly, spatial complexity, often measured by the number of countries represented by first-tier suppliers (Fan *et al.*, 2022; Lu and Shang, 2017), is also considered as a sub-dimension of diversity complexity (Ates and Luzzini, 2024). In the context of our study, however, this dimension is closely associated with horizontal complexity, as it reflects the type of complexity commonly observed in the automotive industry (Legett, 2024). Indeed, we found a very high correlation coefficient ($r = 0.87$, $p < 0.05$) between the two dimensions. Therefore, as shown in Model 7 of Table 5, we substitute spatial complexity for horizontal complexity and confirm that the result ($b = -0.285$, $p < 0.01$) is consistent with the main finding.

Finally, one could argue that automotive firms with publicly available supply chain relationship data are more likely to exhibit a negative market reaction. To account for this potential self-selection bias, we apply Heckman’s two-stage estimation method (Heckman, 1979). In the first step, we run a probit regression using data from 837 initially selected firms to estimate how likely each firm was to be included in our final sample. This inclusion depended on whether the firm had supply chain relationship data (dummy variable) available in the FactSet database. The estimation was based on firm-specific characteristics, such as size, past performance, financial leverage, short-term debt, cash holdings, inventory turnover, capital intensity, and industry classification. This produced an inverse Mills ratio (λ), which we included in the full regression model (Model 4 in Table 4). The results of this analysis are reported in Model 8 of Table 5, which shows consistent findings with our main results.

5.4 Propagation effects on supply chain partners

The RUW represents an exogenous shock to supply chains, with its negative effects on automobile companies potentially propagating to their supply chain partners, particularly

Table 5. Robustness checks

	Model 1 CAR [−11, −1]	Model 2 CAR [−6, −1]	Model 3 CAR [0, 5]	Model 4 CAR [0, 10]	Model 5 CAR [0, 20]	Model 6 1-HHI	Model 7 Spatial	Model 8 Heckman
Horizontal complexity	0.002 (0.005)	−0.001 (0.003)	−0.011*** (0.004)	−0.014*** (0.005)	−0.020*** (0.007)	−3.118* (1.797)	−0.285*** (0.086)	−0.010* (0.005)
Vertical complexity	0.006 (0.007)	−0.005 (0.005)	0.011* (0.006)	0.018* (0.010)	0.038* (0.019)	0.029** (0.012)	0.023* (0.012)	0.024** (0.012)
Sector-level controls	Included	Included	Included	Included	Included	Included	Included	Included
Firm-level controls	Included	Included	Included	Included	Included	Included	Included	Included
Location-level controls	Included	Included	Included	Included	Included	Included	Included	Included
Observations	495	495	495	495	495	495	495	495
F-value	3.83***	2.86***	9.08***	11.74***	8.87***	6.64***	7.73***	7.81***
R-squared (%)	5.57	3.22	2.12	15.41	15.35	6.31	7.34	10.83

Note(s): Robust standard errors in parentheses; the maximum VIF value for all models is 1.63; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source(s): Authors' own creation

downstream customers in other industries. To examine this potential, we use a panel regression with fixed-effects approach (Agca *et al.*, 2022; Carvalho *et al.*, 2021; Crosignani *et al.*, 2023). To do this, we first collected a list of publicly listed customers and suppliers of our sample automotive firms from FactSet database. As a result, 1,029 customers (see Table A2) were linked to 348 automotive firms, while 1,723 suppliers (see Table A3) were linked to 381 automotive firms. We then created a dataset comprising 3,075 “customer–automotive firm” pairs and 5,508 “supplier–automotive firm” pairs and estimated their daily ARs around the war event, as described in Equations (1) and (2).

Next, we constructed a panel of daily ARs before and during the event days. The customers’ (suppliers’) daily ARs could be affected by their link with automotive firms even before the RUW. Any variation in the customers’ (or suppliers’) daily ARs due to the effect of the war on the automotive firms would be reflected in the difference between the event period and the period just before it, as captured in Equation (6):

$$AR_{jt} = \alpha + \beta_1 \times AR_{it} + \beta_2 \times AR_{it} \times War_t + \beta_3 \times AR_{jt-1} + \gamma_{ij} + \varepsilon_{ij} \quad (6)$$

where AR_{jt} represents the AR of customer j (or supplier j) of sample automotive firm i on day t , and War_t is an RUW event indicator variable that takes the value 1 if day t is February 24, 2022 (i.e. Day 0) or later, and 0 otherwise.

Our main coefficient of interest is β_2 , which captures the interaction between the automotive firm’s daily ARs and War_t . We include one-day lagged values of the dependent variable to control for autocorrelation. For the daily ARs in the pre-event days, we use the daily ARs from the 10 trading days preceding 24 February and examine the propagation effect on different lengths of trading days after the announcement of the war. In Equation (6), we also include γ_{ij} to indicate the customer- or supplier-automotive firm pair fixed effects, which capture the variation within each supply chain pairs, including firm-specific characteristics such as size, leverage, among others.

The results are presented in Tables 6 and 7. For customer firms, the interaction coefficient β_2 is consistently positive and statistically significant ($p < 0.01$) across the days following the outbreak of the war, providing strong evidence of a propagation effect on their stock returns.

Table 6. Propagation effects on customers^a

DV: customer firm AR	Model 1 Till day 13	Model 2 Till day 5	Model 3 Till day 10	Model 4 Till day 20
Automotive firm AR	0.031*** (0.006)	0.028*** (0.007)	0.030*** (0.007)	0.030*** (0.005)
War	−0.000*** (0.000)	0.000 (0.000)	−0.001*** (0.000)	0.000 (0.000)
Automotive firm AR × War	0.049*** (0.009)	0.053*** (0.011)	0.046*** (0.010)	0.043*** (0.009)
Lagged customer AR	−0.012* (0.007)	−0.079*** (0.010)	−0.028*** (0.008)	0.004 (0.006)
Constant	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000*** (0.000)
Pair fixed effects ^a	Yes	Yes	Yes	Yes
Observations	70,176	46,784	61,404	90,644
F-value	45.04***	45.46***	39.59***	41.12***
R-squared (%)	0.5	0.9	0.5	0.4

Note(s): Robust standard errors in parentheses; ^aFixed effects for 3,075 customer-automotive firm pairs;

* $p < 0.10$, *** $p < 0.01$

Source(s): Authors’ own creation

Table 7. Propagation effects on suppliers^a

DV: supplier firm AR	Model 1 Till day 13	Model 2 Till day 5	Model 3 Till day 10	Model 4 Till day 20
Automotive firm AR	0.041 ^{***} (0.005)	0.045 ^{***} (0.005)	0.042 ^{***} (0.005)	0.041 ^{***} (0.005)
War	−0.002 ^{***} (0.000)	0.000 ^{***} (0.000)	−0.000 ^{***} (0.000)	0.000 ^{***} (0.000)
Automotive firm AR × War	0.009 (0.007)	0.005 (0.008)	0.020 ^{***} (0.007)	0.032 ^{***} (0.006)
Lagged supplier AR	−0.017 ^{**} (0.005)	−0.088 ^{***} (0.005)	−0.036 ^{***} (0.006)	−0.013 ^{***} (0.004)
Constant	−0.000 ^{**} (0.000)	0.000 ^{***} (0.000)	0.000 ^{***} (0.000)	−0.000 ^{***} (0.000)
Pair fixed effects ^a	Yes	Yes	Yes	Yes
Observations ^c	126,072	84,048	110,313	162,843
F-value	96.27 ^{***}	85.77 ^{***}	39.59 ^{***}	68.82 ^{***}
R-squared (%)	4.0	0.9	4.0	3.0

Note(s): Robust standard errors in parentheses; ^aFixed effects for 5,508 supplier-automotive firm pairs; ^{*}*p* < 0.05, ^{***}*p* < 0.01

Source(s): Authors' own creation

In contrast, for supplier firms, the interaction coefficient β_2 is positive, but the statistical significance is inconsistent as more post-event days are included. This suggests only limited evidence of a propagation effect on supplier firms.

6. Results

6.1 Theoretical implications

Our findings provide several theoretical implications. First, the results of the study show that automotive companies experience negative abnormal returns following the outbreak of the RUW. Our analysis further shows that such negative financial effects are propagated to supply chain partners in other industries. Several recent studies have documented the impact of the RUW, however, these studies are mainly conceptual in nature (e.g. [Silberg, 2022](#); [Srai et al., 2023](#)), adopt a macro-level perspective by focusing on overall market effects of the war (e.g. [Boungou and Yatié, 2022](#)), or concentrate on specific aspects of the war such as sanctions (e.g. [Gaur et al., 2023](#)). To our knowledge, there is still a significant gap in the literature regarding the examination of the RUW from a supply chain perspective. Drawing on the dual nature of SBC, our study contributes to the literature by revealing how this geopolitical conflict has affected companies in the automotive industry and beyond, within the broader context of global supply chains.

Our findings provide additional evidence for the supply chain disruption literature. While the pioneering studies by Hendricks and colleagues (e.g. [Hendricks and Singhal, 2003](#); [Hendricks et al., 2009](#)) focused on endogenous supply chain disruptions arising from internal operations within the supply chain, our study contributes to the growing body of research examining exogenous mega-disruptive events, such as COVID-19 ([Choudhury et al., 2022](#); [Srinivasan et al., 2023](#); [Wang et al., 2024](#)) and the US-China trade war ([Fan et al., 2022](#); [Jacobs et al., 2022](#)). The magnitude of the market reaction to the RUW is somewhat comparable to that of these other mega-events. For example, among the recent event studies, the average loss in shareholder value was 2.16% for firms facing COVID-19-related supply chain disruptions ([Choudhury et al., 2022](#)), 4.13% for US supplier firms exporting to China during the trade war ([Jacobs et al., 2022](#)), and 0.65% for firms exposed to the Ebola outbreak ([Ichev and Marinč,](#)

2018). Other mega-events such as the 2008 financial crisis reduced non-financial firms' shareholder value by 1.46% (Mio and Fasan, 2012). Thus, we complement prior event-based research and contribute to an understanding of how different types of mega-disruptions affect supply chain dynamics.

Moreover, our study offers a more nuanced perspective to the SBC literature (Choi and Krause, 2006; Bode and Wagner, 2015) by expanding the boundary conditions of its role in moderating the negative effect of external shocks such as the RUW. The mainstream literature has suggested that SBC poses challenges in supply chain management (Choi and Hong, 2002). This negative view mainly stems from the perspective that SBC could lead to reduced efficiency and higher management costs (Choi and Krause, 2006; Chopra and Sodhi, 2014; Tang, 2006), as well as an increase exposure to supply chain disruptions (Bode and Wagner, 2015; Brandon-Jones *et al.*, 2015). Our findings show that horizontal SBC intensifies the severity of such effects, as suggested in the literature (Bode and Wagner, 2015; Fan *et al.*, 2022), whereas vertical SBC alleviates the negative impact. One reason for the mitigative effect is that the transaction costs of managing second-tier suppliers are typically not borne by focal firms, but rather by first-tier suppliers (Ang *et al.*, 2017). In addition, the context of the RUW is particularly relevant for automotive supply chains, as second-tier suppliers, which often serve as providers of components and materials to first-tier suppliers, tend to be more concentrated (Silberg, 2022). Continued access to alternative second-tier suppliers via first-tier suppliers during the RUW signals a smoother flow of supply chain operations. Therefore, our study offers depth to this view by showing that SBC can have opposing moderating effects during times of crisis, depending on whether its structure is more horizontally focused or vertically oriented.

Our findings on the moderating effect of SBC are worth comparing with prior research in the recent literature. Jiang *et al.* (2023) find that supplier concentration, measured using the top five suppliers, increases firm resilience during the disruption stage of the pandemic. Since high supplier concentration may indicate low horizontal SBC, our result regarding the adverse role of horizontal SBC during the war event somewhat aligns with this prior finding. This aspect is also consistent with Wiedmer *et al.* (2021) and Fan *et al.* (2022), which reveal that horizontal SBC amplifies the negative effects caused by the 2011 Japan earthquake and the US-China trade war, respectively. Overall, our study findings contribute to this stream of research by providing new insights in the context of the RUW as a mega-disruption. In particular, we advance our understanding of SBC in times of crisis by being among the first to examine both horizontal and vertical SBC.

Finally, this study also contributes to the diversification perspective of MPT (Markowitz, 1952, 2010) in the context of global supply chains (Azadegan *et al.*, 2021; Kleindorfer and Saad, 2005; Wiedmer *et al.*, 2021). The observed mitigating effect of vertical SBC highlights the importance of supply base strategies for company resilience, suggesting that a vertically oriented supply base may protect companies from the negative shock of crises such as the RUW. This effect may be explained by the delegated-sourcing approach (Cousins, 1999; Cousins *et al.*, 2008), which enables firms to access alternative suppliers at lower management costs and with reduced disruption risks, thereby enhancing resilience. Therefore, our findings provide further insight into the applicability of MPT's diversification view for managing complex supply bases during times of crisis.

6.2 Managerial implications

Our study offers two important managerial implications. Our findings highlight that the war can significantly discount firm's stock price and increase its cost of capital. This adverse stock price effect is not confined to the focal industry but propagates to supply chain partners, particularly downstream customers, in other industries as well. Automotive firms often serve as strategic partners to customer or supplier firms across a wide range of industries (Silberg, 2022). For example, the automaker BYD Company Ltd. supplies Apple Inc., which primarily

operates in the consumer electronics industry. In the event of the RUW, our findings suggest that any disruption in the future cash flows of automobile firms is likely to affect their contractual obligations to customers. Thus, supply chain managers should not underestimate these negative impacts by assuming they are limited to directly involved companies. Instead, potential supply chain risks arising from exogenous, mega-disruptive events should be a key consideration when fostering collaboration with supply chain partners. In this context, automotive firms may benefit from incorporating geopolitical risk clauses or joint contingency planning mechanisms into their agreements, thereby promoting coordinated responses and ensuring continued alignment under crisis conditions.

The automotive industry has been characterized by just-in-time manufacturing with minimal buffers (Legett, 2024; Veloso and Kumar, 2002), along with its global scope and reliance on single-sourcing (Legett, 2024). In the context of the war in Ukraine, these characteristics may exacerbate the industry's exposure to disruption risks. Our findings confirm this vulnerability through the observed negative market reactions. Notably, we find that horizontal SBC amplifies the negative market response, whereas vertical SBC plays a mitigating role. These contrasting effects underscore the nuanced implications of supply base diversification and highlight the importance of strategic supply chain design. The positive effect of vertical SBC suggests that during times of crisis, firms benefit from extended supply networks beyond their first-tier suppliers. This benefit is not necessarily due to direct engagement with lower-tier suppliers, but rather due to the delegated sourcing structure that enables access to alternative sources at lower coordination costs (Ang *et al.*, 2017; Chae *et al.*, 2024; Cousins *et al.*, 2008). Therefore, in the automotive industry, we recommend supply chain managers leverage the resilience potential of vertical SBC by building supply chain structures that can retain delegated control over second-tier suppliers, while ensuring visibility and relational access through their first-tier partners. These efforts can also help streamline horizontal SBC, which amplifies the negative impact in times of crisis.

Overall, our study emphasizes the need for supply chain managers to critically assess the benefits and risks inherent in the traditional automotive industry when pursuing diversification. In particular, it underscores the nuanced role of SBC, which can have opposing effects during times of crisis. This evidence addresses the prevalent issue of “under-diversification,” where managers fail to diversify their supplier base adequately, despite the evident risks posed by current sourcing strategies (Goldschmidt *et al.*, 2021). By integrating these insights, supply chain managers can better prepare for and respond to future disruptions, fostering resilience in their global supply chains.

7. Conclusions

The RUW has acted as a reminders of the vulnerabilities of global supply chains and has called for managerial actions to improve firms' resilience to this kind of mega-disruption. In this study, we explore how and to what extent the war has affected automotive companies and how SBC moderates its negative effect. The results support our arguments on the increased risk in a company's cash flows that negatively affect their market value, which is propagated to customers in other industries. The results further suggest that while it is often viewed as a source of managerial complexity, cost-inefficiencies, and/or additional risk, supply chain complexity can have differential moderating effects during times of crisis, depending on its horizontal and vertical nature.

Although our study offers novel insights into the academic literature, it also has certain limitations and provides avenues for future investigation. First, while we present evidence of the contrasting moderating effects of SBC within the specific RUW context, we caution against generalizing these empirical findings to dissimilar contexts. Therefore, we encourage future researchers to examine the role of SBC in other mega-disruptive events and to compare the findings across different settings.

Second, this study focuses on the short-term impact of the RUW using an event study approach, which is well-suited for analyzing firms' financial responses to external shocks.

However, as an exogenous large-scale event, the war has had prolonged effects on global supply chains. Thus, future research should investigate the longer-term consequences of the RUW, particularly how SBC continues to interact with and influence these extended effects.

Finally, while our analysis provides empirical evidence from the automotive industry, the results might not be directly generalizable to other industries due to potential structural differences in their supply chains. Therefore, further studies are needed to obtain industry-wide or cross-industry evidence of these phenomena. As future research selects industries and examines their supply chain relationships, it should account for the significant structural differences that exist across industries.

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Appendix

Table A1. Daily ARs for sample firms affected by the RUW

Event day	Mean (%)	<i>t</i> -statistic	Median (%)	Z-statistic	AR < 0 (%)
0	−2.00***	−3.99	−1.83***	−6.73	75.75
1	0.84*	1.67	−0.32***	−3.45	34.29
2	0.13	0.27	−0.26	−0.89	61.53
3	−0.43	−0.86	−0.18*	−1.74	49.34
4	−0.23	−0.45	−0.16**	−2.12	56.99
5	−0.86*	−1.70	−0.56***	−4.47	56.99
6	−1.84***	−3.66	−1.49***	−6.51	69.41
7	−1.97***	−3.93	−1.67***	−7.35	69.18
8	0.81	1.62	−0.60***	−3.98	63.68
9	0.74	1.48	−0.31***	−2.56	50.18
10	−0.42	−0.83	−0.45***	−3.47	50.90
11	−0.09	−0.18	−0.06	−0.07	46.71
12	−1.04**	−2.07	−0.68***	−4.03	55.56
13	0.31	0.63	0.09	−1.11	68.10

Note(s): $n = 837$; the z-statistics are obtained from Wilcoxon signed rank tests; AR < 0 (%) presents negative abnormal returns; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source(s): Authors' own creation

Table A2. Descriptive statistics of customers

Panel A: headquarter countries				
Country	%		Country	%
Japan	18.82		Germany	2.75
United States	17.50		France	2.64
China	12.21		United Kingdom	2.24
South Korea	10.38		Indonesia	2.03
India	6.10		Hong Kong	1.73
Taiwan	4.27		Rest of the world	19.33
Panel B: industry (GICS) representation				
Industry	%		Industry	%
Machinery	19.18		Electrical equipment	4.12
Specialty retail	12.37		Household durables	3.76
Ground transportation	5.73		Distributors	3.41
Trading companies and distributors	5.38		Construction and engineering	3.23
Electronic equipment, instruments and components	4.30		Aerospace and defense	3.05
Industrial conglomerates	4.30		Others	31.18
Panel C: sample statistics				
Variable	Mean	SD	Min	Max
Market value (\$M)	2.22E+06	2.10E+07	0.03	5.03E+08
Sales (\$M)	1.95E+06	1.27E+07	0.10	2.79E+08
Total assets (\$M)	5.94E+06	4.48E+07	6.61	6.63E+08
Net income (\$M)	1.84E+05	1.98E+06	−1.63E+06	5.33E+07
Note(s): $n = 1,029$ publicly traded customer firms				
Source(s): Authors' own creation				

Table A3. Descriptive statistics of supplier

Panel A: headquarter countries				
Country	%	Country	%	
China	18.87	Germany	4.18	
United States	16.96	United Kingdom	4.06	
Japan	14.26	Taiwan	3.56	
South Korea	9.10	France	3.38	
India	5.29	Hong Kong	2.09	
Rest of the world	18.25			
Panel B: industry (GICS) representation				
Industry	%	Industry	%	
Machinery	12.17	Electrical Equipment	6.15	
Electronic Equipment	9.22	IT Services	4.98	
Chemicals	9.04	Semiconductors and Equipment	3.81	
Software	8.67	Media	3.32	
Metals and Mining	6.21	Construction and Engineering	2.58	
Others	33.87			
Panel C: Sample statistics				
Variable	Mean	SD	Min	Max
Market value (\$M)	17837.63	1.29E+05	0.02	2.75E+06
Sales (\$M)	6538.04	27241.63	−347.01	4.70E+05
Total assets (\$M)	16429.58	1.35E+05	0.64	4.31E+06
Net income (\$M)	872.45	5859.41	−6823.67	1.09E+05
Note(s): $n = 1,723$ publicly traded supplier firms				
Source(s): Authors' own creation				

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