Vertical Integration, Supply Chain Disruptions, and Corporate Yield Spreads

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July 24, 2024

Abstract

Vertical integration can reduce transaction costs and increase a firm's control along the supply chain, thereby mitigating supply chain risk and leading to lower yield spreads. However, vertically integrated firms may suffer from asset specificity, which can create investment uncertainty and rent extraction, thus resulting in higher yield spreads. We find that firms with greater vertical integration (VI) exhibit lower bond yield spreads. Specifically, a one-standard-deviation increase in VI correlates with an 17 basis points decrease in yield spreads without control variables, and a 4 basis points decrease in yield spreads when accounting for a set of yield spread determinants. This effect is more pronounced for companies facing elevated supply chain risk, supporting the supply chain risk channel. Amid global supply chain disruptions such as the COVID-19 pandemic and the U.S.-China trade war, vertical integration takes on an even more important role in reducing credit spreads. Our findings suggest that firm-level vertical integration can effectively hedge supply chain risk, representing a novel mechanism not previously considered in bond pricing studies.

Keywords: Vertical integration, global supply chain risk, corporate bond markets, yield spreads, supply chain disruptions.

JEL Codes: F15, G12, G32, L22

"*What the current situation exposes is that the risks associated with supply chain fragmentation and globalization have been unpriced and largely ignored. For many companies, the combination of lean production and global multistage supply networks is leading to crises. This should be a wake-up call for managers who need to understand their supply chain's strategic vulnerabilities.*"

— *Willy Shih (2020)* [1]

1 Introduction

In recent decades, the business landscape has witnessed a notable surge in the significance of global supply chains,[2] which have evolved into fully developed networks comprising a complex web of suppliers, manufacturers, and distributors.[3] As firms increasingly rely on effective supply chain management, the global economy has encountered disruptions from events like the Covid-19 pandemic and the U.S.-China trade war, posing challenges for companies in managing supply chain risk. The study of vertical integration within firms offers valuable insights into comprehending corporate organizational structures. More importantly, vertical integration emerges as a noteworthy tool for effectively mitigating supply chain risk (Garfinkel and Hankins, 2011; Ahern and Harford, 2014; Ersahin et al., 2024). Several studies have examined the impact of vertical integration on equity prices (e.g. Helfat and Teece, 1987; Fan and Goyal, 2006; Hendricks et al., 2009);[4] however, its impact on bond pricing has received little attention. In this paper, we investigate the effect of vertical integration on corporate bond yield spreads.

We test the vertical integration effect in the bond market because corporate bonds, while generally considered as safe investments in normal circumstances, are vulnerable to downside risk such as severe disruptions in global supply chains. This risk is factored into the corporate bond

[1] *Is It Time to Rethink Globalized Supply Chains?* by Willy Shih, March 19, 2020, *MIT Sloan Management Review*

[2] In 2020, the combined value of imports and exports of goods and services in the United States amounted to $3.88 trillion, accounting for approximately 18% of the U.S. GDP.

[3] For example, Apple's global supply chain includes more than 200 suppliers, located in 43 countries and more than 800 production locations, as per the 2022 Apple supplier list.

[4] Researchers have broadly investigated the effect of vertical-related integration from the perspective of shareholders. For instance, Helfat and Teece (1987) suggest that vertical mergers may reduce a firm's systematic risk. Fan and Goyal (2006) find that vertical mergers generate significantly greater positive wealth effects than vertically unrelated mergers. According to Hendricks et al. (2009), companies with a high level of vertical relatedness encounter a less adverse stock market reaction to supply chain disruptions.

risk premium, which includes compensation for bearing "tail risk" (Gourio, 2013).[5] As a result, the effects of supply chain risk may be more readily reflected in firms' bond yield spreads than in their equity prices. Moreover, we focus on yield spreads in the secondary market as they can capture real-time variations in supply chain risk, whereas the firm-level features of vertical integration are typically accounted for by rating agencies at the time of bond issuance.

The classic theoretical literature in finance has extensively documented the concept of vertical integration (Coase, 1937; Williamson, 1971, 1979; Klein et al., 1978; Grossman and Hart, 1986; Hart and Moore, 1990), showing that the coordination of production occurs within a firm rather than in the market, especially when transaction costs and hold-up problems are considerable (Holmström and Roberts, 1998).[6] At the same time, modern products frequently integrate essential components or sophisticated materials, demanding specialized technological expertise for their production. Therefore, it is a very challenging task for a single company to encompass the extensive capabilities needed to independently manufacture everything (Shih, 2020). Due to this reason, over the past two decades, we have witnessed a wave of global supply chains being established, which simultaneously highlights the fragility of these systems. This phenomenon naturally leads to intriguing research questions: Should companies strategically choose vertical integration as a corporate policy to address increased supply chain risk? And if so, would this advantage be recognized by financial markets?

To evaluate these questions, we begin by considering the trade-offs between the *benefits* and *costs* of vertical integration. With vertical integration, firms have different stages of production along the supply chain under greater control, implement better management in both quantity and quality and from inputs to outputs, and reduce their exposure to external risks. According to transaction cost theory, firms choose vertical integration when the expenses associated with arm's length transactions surpass those of coordinating activities within a single firm (Williamson, 1971, 1979). Firms with higher degrees of vertical integration are posited to gain advantages in reducing transaction costs and improving information flow along the supply chain (Mahoney, 1992;

[5] "Tail risk" refers to low-probability events with catastrophic consequences, which is precisely what the major global supply chain disruption events addressed in the paper resemble.

[6] Holmström and Roberts (1998) demonstrates that when a supply relationship encounters more extensive hold-up problems, the optimal solution may involve vertical integration. In such cases, all components of the operation are sourced internally rather than externally. The organization and governance structure of a firm are thus considered as mechanisms for addressing hold-up problems.

Pishchulov et al., 2023), thereby lowering the firm's risk. A more vertically integrated company, through control of critical elements in the supply chain, not only reduces its dependence on external suppliers and allows the company to adapt more quickly to changes in supply and demand, but also establishes a buffer against supply chain disruptions. As a result, the benefit of vertical integration predicts a negative relationship between vertical integration and corporate yield spreads, indicative of reduced supply chain risk premiums.

On the other hand, there is a potential downside of asset specificity linked with vertical integration. By investing in assets uniquely customized for their internal operation processes and supply chain requirements, vertically integrated firms increase their asset specificity. High levels of asset specificity can result in reduced liquidation value on these assets and magnify the impact of uncertainty on investment decisions (Kedia et al., 2009; Kermani and Ma, 2023).[7] Additionally, the risk of post-contractual opportunistic behavior, driven by the specificity of investments (Klein et al., 1978; Anderson and Weitz, 1992; Coase, 2006), could result in higher risks borne by firms with increased levels of vertical integration.[8] Therefore, the cost of vertical integration could posit a positive relationship between vertical integration and corporate yield spreads, reflecting the potential costs of asset specificity. Considering both the benefits and the costs of vertical integration, the relationship between vertical integration and corporate yield spreads remains an open question.

Our main finding demonstrates a negative relationship between vertical integration and corporate yield spreads. The result of a reduction in risk premium indicates that the benefits of vertical integration in mitigating supply chain risk outweigh the potential costs. To explore how bond investors value production coordination by demanding a diminished risk premium from highly vertically integrated firms, we employ firm-year-specific vertical integration scores as introduced by Frésard et al. (2020) to gauge the extent of vertical integration within firms. The vertical integration (VI) score indicates the potential of the given firm's products to be vertically related to the other products sold by the same firm. Intuitively, if this score is higher, the firm is more vertically integrated. Empirical results of our study show that vertical integration plays a significant role in explaining corporate bond yield spreads when controlling for well-established bond yield deter-

[7] Due to the fear of future renegotiation or expropriation involving high-specificity assets, firms might hesitate to invest, leading to underinvestment that could otherwise enhance efficiency and competitiveness.

[8] Asset specificity can reduce a firm's versatility and make its assets difficult to reconfigure for external markets. This can lead to opportunistic behavior, as these assets may lose substantial value if repurposed for other uses.

minant variables in the literature.[9] Specifically, we observe that a firm with a higher degree of vertical integration is associated with lower credit spreads. A one-standard-deviation increase in VI correlates with an 17 basis points decrease in bond yield spreads without control variables, and a 4 basis points decrease in yield spreads when accounting for a set of yield spread determinants.

Next, we explore the underlying mechanism by which vertical integration is associated with lower corporate yield spreads. Vertical integration is recognized as a potent strategy for mitigating supply chain risk (e.g., Ersahin et al., 2024), allowing a company enhanced control over its supply chain and diminishing reliance on external suppliers and logistics providers. Consequently, the supply chain risk channel emerges as a plausible mechanism for understanding the influence of vertical integration on corporate credit spreads. To test our conjecture, we classify the sample into three groups each year, based on both firm-level and industry supply chain risk, and perform the baseline regressions for each subsample. Our findings reveal a heightened vertical integration effect within the subgroup characterized by high supply chain risk. Given that vertical integration exhibits a more pronounced impact on firms facing elevated supply chain risk, our findings suggest that the reduction in yield spreads attributable to vertical integration likely stems from its role in managing supply chain risk, thereby further diminishing the associated risk premium.

The preceding analysis does not rule out the possibility of other risk channels that might intersect with the vertical integration effect on supply chain risk. For instance, the impact of vertical integration on the reduction of supply chain risk could also lead to lower credit risk and liquidity risk. To provide further insight into these potential risk channels introduced by vertical integration, we undertake supplementary tests to investigate its effects within different credit risk and liquidity risk subgroups.[10] Regarding credit risk, our findings reveal a heightened vertical integration effect within the medium credit risk group, with no significant impact observed for the high and low credit risk groups. In terms of bond liquidity risk, we observe a more pronounced effect within the high liquidity risk group, contrasting with weaker effects for both the medium

[9]These control variables include credit ratings, bond illiquidity, maturity in years, issue size, coupon, pretax interest coverage, operating income to sales, long-term debt to assets and equity volatility. Section 4 provides more details.

[10]Specifically, bonds are classified into three credit risk groups according to their credit rating: high credit risk with credit ratings of BB+ or below, medium credit risk with ratings between BBB- to A+, and low credit risk with ratings of AA- or above. Alternatively, bonds are sorted into three illiquidity groups based on Roll (1984)'s bond illiquidity measure: high if it exceeds 75%, medium if it falls between 25% and 75%, and low if it is below 25%. Section 4 provides details on sample construction.

and low liquidity risk groups. Our results suggest that the negative effect of vertical integration on credit spreads could be interacted with a reduction in bond liquidity risk, while the effect dissipates for bond facing high or low credit risk.

We further examine the effect of vertical integration on credit spreads during supply chain disruptions. Recent supply chain disruptions have led to significant costs for firms relying on global supply chains. Therefore, it is crucial to investigate the role of vertical integration amid these disruptions. In addition, by employing recent global supply chain disruptions as exogenous industry-wide shocks, we can address endogeneity concerns in assessing the link between firm vertical integration and credit spreads. Prior studies show that supply chain risk drives vertical integration (Ersahin et al., 2024). However, the exact nature and timing of supply chain disruptions are often unpredictable, making it difficult for firms to adjust their vertical integration structure in response to these disruptions. In our paper, we empirically consider two major events: the Covid-19 pandemic and the U.S.-China trade war, both of which have caused significant disruptions to supply chains for U.S. firms.

In particular, we examine how the effect of vertical integration on corporate yield spreads varies with the onset of these two events. First, our findings show a notable association between vertical integration and substantially reduced yield spreads during the pandemic period. Specifically, a one-standard-deviation increase in vertical integration results in a significant decrease of 7 basis points in yield spreads during this challenging period. This effect becomes even more pronounced for firms exposed to greater Covid-19-related uncertainties and those facing heightened supply chain risk. Second, we observe a comparable impact of vertical integration during the U.S.-China trade war. Vertical integration assumes a more significant role with the onset of the trade war, particularly for firms reliant on imported Chinese goods. Collectively, our findings illustrate that vertical integration mitigates the risks amplified by global supply chain disruptions, thereby resulting in lower bond yield spreads for these firms.

We also explore the interaction between vertical integration and firm inventory on corporate yield spreads, and analyze this interaction amidst supply chain disruptions. Our findings show that vertical integration plays a more prominent role for firms with low inventory levels estimated from the previous quarter. During supply chain disruptions, the marginal impact of vertical integration on firms with low inventory levels diverges, with a positive effect during the pandemic period, while a negative effect emerges during the U.S.-China trade war. This divergent effect is likely attributed to the distinct features of these two events. Moreover, we also examine whether a firm's level of vertical integration interact with its product market power in determining yield spreads. We find that vertical integration has a more pronounced impact on reducing yield spreads for firms with higher product pricing power, as these firms derive greater benefits from vertical integration.

Our research makes three contributions to the existing literature. First, our paper contributes to the ongoing discussion on the implications of organizational structure, specifically examining the strain of literature on vertical integration. While existing studies examine the risk reduction and value enhancement of vertical integration mainly from the perspective of shareholders (e.g., Spiller, 1985; Helfat and Teece, 1987; Fan and Goyal, 2006; Kedia et al., 2009), to our knowledge, we are the first to explore if and how creditors value the firms' vertical integration. For instance, we differ from Fan and Goyal (2006) by providing new evidence from the perspective of bondholders.[11] In addition, our study is novel in several aspects: Firstly, we take advantage of the newly developed construct of firm-level vertical integration by Frésard et al. (2020), allowing us to examine the issue across a broader sample rather than being limited to firm-level events. Secondly, we utilize the macroeconomic events such as U.S.-China Trade War and Covid-19 Pandemic as exogenous shocks, thereby demonstrating the amplified impact of vertical integration during times of significant shock and uncertainty. In a nutshell, our study examines the effect of vertical integration in the corporate bonds markets, and finds that bond investors demand lower risk premiums, as indicated by lower credit spreads, for more vertically integrated firms.

Second, we enhance the burgeoning body of work emphasizing the significance of global supply chain shocks. Building on the theoretical work of Long and Plosser (1983), a pioneering study to explore production network shocks, subsequent studies have shown that the propagation of these shocks through supply chain linkages can result in significant aggregate fluctuations.[12] For instance, Acemoglu and Tahbaz-Salehi (2020) reveal that firm failures and the resulting disruptions to supply chains can amplify negative shocks. In light of the recent global supply chain disruptions, Carvalho et al. (2021) study the disruption caused by the Great East Japan Earthquake, showing

[11] Fan and Goyal (2006) examine the value creation effects of firms' decisions on vertical integration by analyzing stock returns around the announcement of vertical mergers from 1962 to 1996, representing one of the earlier empirical investigations into the equity valuation of vertical integration.

[12] Studies, including those by Carvalho (2014), Baqaee and Farhi (2019), Liu (2019), and Bigio and La'O (2020), explore the role of supply chain linkages in propagating shocks and distortions.

how it propagated upstream and downstream along supply chains. Fajgelbaum et al. (2020) find the negative externality of protectionism on the U.S. economy, demonstrating that import and retaliatory tariffs caused substantial declines in imports and exports. Additionally, Hassan et al. (2023) observe the effects of Covid-19 as a simultaneous shock to demand and supply, both of which impact firms' market valuations. Our research further examines the effect of vertical integration on corporate credit spreads amid supply chain disruptions and provides empirical evidence that the vertical integration plays a more prominent role in reducing yield spreads during these periods.

Third, our study enriches the current research on the determinants of credit spreads and their implications for financial markets. Standard bond pricing models, including both structural and reduced-form models, have encountered limitations in explaining observed bond yield spreads. Empirical applications of these bond-pricing models find that credit risk explains only a fraction of yield spreads (Collin-Dufresn et al., 2001; Elton et al., 2001; Huang and Huang, 2012). Recent studies suggest that some of the variations could be driven by the effect of equity volatility (Campbell and Taksler, 2003), bond illiquidity (Chen et al., 2007; Bao et al., 2011), and rollover risk (Nagler, 2020), among others. While these factors might account for the determinants of yield spreads, they are unlikely to be the sole explanation. Our study contributes to the literature by demonstrating that vertical integration can effectively manage a firm's supply chain risk, which represents an additional source of risk not previously considered in bond pricing models.

The remainder of this paper is organized as follows. Section 2 offers an exploration of the institutional background and hypothesis development. The subsequent Section 3 delves into the details of the data and methodology, while Section 4 presents our primary findings. We then explore how firm vertical integration responds to diverse global supply chain shocks in Section 5. Section 6 presents additional analyses. Finally, Section 7 concludes.

2 Institutional Background

2.1 Global Supply Chains

For decades, global supply chains have been a prevalent feature of the international business arena. The advent of globalization has ignited a new phase of international competition, leading to a transformation in global production and trade, consequently reshaping the organizational structure of industries (Gereffi et al., 2005; Gereffi and Lee, 2012).[13]

Since the mid-1960s, U.S. manufacturing firms have been fragmenting their supply chains in pursuit of cost-effective and capable offshore suppliers. The 1970s and 1980s witnessed the inclusion of U.S. retailers and brand-name companies in the quest for offshore suppliers across various consumer goods categories.[14] The 1990s and 2000s marked a substantial expansion of global supply chains, encompassing not just finished goods but also components and subassemblies. This expansion not only impacted manufacturing industries but also extended its influence to sectors such as energy, food production, and a diverse range of services, ranging from call centers and accounting to medical procedures and the core research and development (R&D) activities of the world's leading multinational corporations (Engardio et al., 2005; Gereffi et al., 2005).

Entering the 21st century, fully developed global supply chains were established, setting the stage for significant events capable of profoundly impacting their flow. A notable illustration is the Great East Japan Earthquake of 2011, marked by its exogenous and regional nature, which underscores the vulnerable state of global supply chains. The subsequent disruptions spread both upstream and downstream along the supply chains, affecting the direct and indirect suppliers and customers of the disaster-stricken firms (Carvalho et al., 2021). The limitations of *putting all their eggs with one supplier* strategies become evident when considering that not all manufacturers, with their intricate networks of suppliers, share the same level of experience or possess extensive backup plans. This realization leads to a chaotic scramble, unveiling the disadvantages and resulting in production delays, product shortages, and increased prices (Fisher, 2011).[15] In the wake of the unforeseen and disastrous interruption caused by the Japanese earthquake, numerous offshore firms now have the opportunity to assess the cost and benefit trade-offs of implementing measures such

[13]According to the survey literature by Antràs and Yeaple (2014), data from the U.S. Bureau of Economic Analysis shows that sales of domestically produced goods to foreign customers constituted only 25% of the total sales of large American firms. The remaining 75% was attributed to the sales of foreign affiliates of American multinational corporations (Yeaple, 2013). Additionally, information from the U.S. Census Bureau indicates that approximately 90% of both U.S. exports and imports are facilitated through multinational firms. Almost half of U.S. imports occur within the operations of multinational firms rather than between unaffiliated parties (Bernard et al., 2009).

[14]In the 1960s, the concept of "global outsourcing" primarily concentrated on the basic assembly of parts provided by U.S. manufacturers, exemplified by initiatives like the U.S. production-sharing or "twin plant" program with Mexico. Transitioning to the 1970s and 1980s, these chains evolved from regional production-sharing arrangements to comprehensive global supply chains, with an increasing focus on East Asia (Gereffi, 1996; Dicken, 2007).

[15]For instance, approximately 22% of the global 300 mm silicon wafer supply can be traced back to the Shin-Etsu Handotai's Shirakawa plant in Fukushima prefecture, with 60% of crucial automotive components originating from the same region. Moreover, this area assumes a pivotal role as a supplier of lithium battery chemicals, flash memory, and anisotropic conductive film used in LCD flat panel displays.

as increasing supplier or geographic diversity.

In the wake of the 2008 financial crisis, a trend towards international trade protectionism was set in motion, impacting global supply chains (Zahoor et al., 2023). Numerous economically developed governments have implemented populist policies and measures that endorse the local sourcing of supplies, with the goal of safeguarding their local industries and jobs (Constantinescu et al., 2020). These policy interventions have attracted considerable attention, prompted by the efforts of the 45th President of the United States, Donald Trump, to reestablish U.S. global leadership with a more inward-looking and fortress-like mentality.[16] The shift ultimately led to the commencement of the U.S.-China trade war, a phenomenon contrasting with the original inception of the global supply chain.

Over the past decade, in addition to the 2011 Great East Japan earthquake and the U.S.-China trade war, another significant occurrence has become part of the series of black swan events: the Covid-19 pandemic. After the 2011 earthquake, certain companies, especially in the semiconductor industry, made gradual adjustments by creating alternative sources (Okada and Shirahada, 2022). Despite the lessons drawn from the trade war, a substantial number of businesses returned to the status quo, deeming it nearly impossible to replace key suppliers in China (Hass and Denmark, 2020). However, the Covid-19 pandemic stands out as it has highlighted country risk on an unprecedented scale. The global disruption resulting from the world's second-largest economy going offline and cutting external logistics connections was unforeseeable. Many firms are now recognizing the extent of their dependencies, prompting the necessity to reassess supply chain risks and enhance their networks for greater resilience (Shih, 2020).

In summary, Figure 1 illustrates the development of global supply chains, highlighting key events that have shaped their trajectory, including major disruptive shocks. Drawing on the concept of "renationalization" as discussed in Bonadio et al. (2021) which entails the reestablishment of economic activities or production processes within a country, particularly in response to global disruptions like the Covid-19 pandemic, we delve deeper into the role of vertical integration strategies

[16]Prasad, R. (2021). *U.S. historians on what Donald Trump's legacy will be.* BBC News. January 1, 2021, https:// www. bbc. co. uk/ news/ world- us- canada- 55640 427

in mitigating supply chain risk.[17]

2.2 Firm Vertical Integration

The exploration of vertical integration within firms provides invaluable insights into understanding corporate organizational structures. Building on the pioneering work of Coase (1937) regarding the boundaries of firms, a substantial body of literature has laid the theoretical groundwork for vertical integration (e.g. Williamson, 1971, 1979; Klein et al., 1978; Grossman and Hart, 1986; Hart and Moore, 1990). These studies emphasize that production is coordinated within a firm, rather than in the market, particularly when transaction costs and hold-up problems are significant. Furthermore, vertically integrated firms, facilitated by technical dialogues between upstream and downstream units, are more inclined to possess internal access to extensive knowledge base of firm-specific information compared to vertically specialized firms (Monteverde, 1995). Subsequently, the adoption of vertical integration is a prudent approach that aids in optimizing a firm's product portfolio and attaining product success. This contribution to a firm's competitive advantage, in turn, enhances overall firm performance (Rothaermel et al., 2006; Lahiri and Narayanan, 2013).[18]

To effectively illustrate the concept of vertical integration, which involves owning or controlling various stages of an industry's value chain, we use the automobile industry as a live example. Specifically, we highlight Tesla's leadership role by examining how its vertical integration and operational efficiency contribute to its prominence in the industry.[19]

First, it's important to clarify that the idea of vertical integration is far from new. We can trace its origins back to the very beginnings of the moving assembly line in the old playbook of automobile manufacturing. Take Ford Motors, for instance. Back in the 1920s, the company engaged in mining

[17] Prior research indicates that the "renationalization" of global supply chains doesn't necessarily enhance a country's resilience to pandemic-induced contractions. This is because, in the context of a labor-supply shock, reducing reliance on foreign inputs merely shifts the emphasis to domestic inputs. If domestic inputs are also susceptible to lockdowns, renationalization fails to mitigate contraction. Resilience through renationalization is contingent on the country's lockdown stringency compared to its trading partners; a less stringent lockdown or vice versa would contribute to increased economic resilience (Bonadio et al., 2021).

[18] The benefits of pursuing vertical integration have been underscored in numerous prior studies, as exemplified by Hill and Hoskisson (1987); Jones and Hill (1988); Dyer (1996); Dyer and Singh (1998); Stuart (2000); Ireland et al. (2002).

[19] *Tesla's Vertical Integration and Efficiency Show Why They're the Leader in EVs*, August 1, 2022, https://www.notateslaapp.com/tesla-reference/867/tesla-s-vertical-integration-and-efficiency-show-why-they-re-the-leader-in-evs

the iron ore required to manufacture the steel used in its cars. Ford pursued vertical integration extensively, connecting operations from a mine in Minnesota to a factory floor that produced tires, glass, and power near Detroit. This comprehensive approach aimed to ensure necessary components, especially during periods of surging demand that challenged supplies.[20] Applying a similar rationale, Tesla has adopted a strategy that dismisses the traditional approach of supply chain diversification or outsourcing, aiming to minimize dependencies on external entities. Tesla has embraced vertical integration across various production phases, spanning from battery production to electric powertrain manufacturing and the development of self-driving software. Described by Tesla CEO Elon Musk as a *"chain of startups,"* this strategic approach has enabled Tesla to navigate around battery shortages, a hurdle that has hindered traditional automakers in scaling up the production of electric vehicles.[21]

The automotive sector has faced considerable challenges due to the recent supply chain disruptions caused by the Covid-19 pandemic. A global shortage of chips, coupled with various supply chain shocks, has significantly impacted the entire industry (Ramani et al., 2022). In navigating these challenges, Tesla's vertically integrated strategy has demonstrated to be particularly advantageous, allowing the company to better withstand and adapt to the complexities of the disrupted supply chain. Organized into three main divisions - Auto, Energy, and Information Technology, Figure 2 outlines Tesla's vertical integration strategy and its corresponding competitors in each sector.

As supply chain uncertainty escalates and the likelihood of bottlenecks increases, the challenges associated with hold-up problems between a company and its suppliers become more pronounced, leading to a heightened preference for vertical integration (Grossman and Hart, 1986; Ersahin et al., 2024). Viewing this issue from an alternative perspective, if firm vertical integration demonstrates itself as a better alternative for mitigating supply chain disruptions, then it follows that vertical integration is a strategic approach for firms to navigate the adverse impacts of supply chain risk. Consider the case of Tesla, where in every crucial aspect of its operations, the company is self-sufficient and does not depend on external sources for vital components like chips, software, or

[20] *Tesla Is Dusting Off a Strategy From Henry Ford to Navigate an Uncertain Market*, by Al Root, February 22, 2023, https://www.barrons.com/articles/tesla-stock-price-ev-vertical-integration-70da8f0b

[21] Prior to traditional automakers entering the electric vehicle manufacturing arena, Tesla collaborated with Panasonic to establish its gigafactory for battery production in 2014. This facility plays a crucial role in guaranteeing a consistent and dependable supply of batteries. https://en.wikipedia.org/wiki/Gigafactory_Nevada

batteries. In this context, vertical integration should be acknowledged as an effective strategy to move away from *"catalogue engineering"* and is reflected as a meaningful corporate strategy.[22]

2.3 Main Hypothesis

In this paper, we propose hypotheses with respect to the pricing of firm-level vertical integration within financial markets, with a particular emphasis on the perspective of bond investors. On the positive side, vertical integration can benefit firms from two distinct perspectives.

Firstly, vertical integration may reduce transaction costs and alleviate hold-up problems. Expanding upon Coase (1937), market transactions between independently operated vertically related firms may suffer significant costs. This line of literature, exemplified by seminal works like Williamson (1971, 1979), posits that transactions should occur within a firm (vertical integration) when the expenses associated with arm's length transactions between specialized firms exceed those of coordinating multiple activities within a single firm. Moreover, vertical integration can facilitate information flow and enhance transparency between upstream and downstream entities along the supply chain (Mahoney, 1992; Pishchulov et al., 2023). Therefore, firms with a high degree of vertical integration benefit by reducing transaction costs and mitigating information asymmetry.

Secondly, from the risk management perspective, vertical integration emerges as a strategic tool to mitigate risks associated with the supply chain. By controlling critical elements along the supply chain, a more vertically integrated company lessens its reliance on external suppliers (Grossman and Hart, 1986) and allows for better coordination of the production process (Alfaro et al., 2019). Beyond the traditional approaches such as fostering relationships with nearby and domestic suppliers, as well as with industry-leading suppliers, firms use vertical integration to navigate supply chain complexities, improve operational efficiency, and stay ahead of the competition (Ersahin et al., 2024).

In addition, firms establish vertical integration as a buffer against supply chain disruptions, enabling them to respond more swiftly to fluctuations in supply and demand. While earlier studies focus on cash-flow uncertainty (Garfinkel and Hankins, 2011) and industry shocks (Ahern and Harford, 2014) as factors motivating firms to integrate different stages of production, recent disruption

[22]In a 2020 earnings call, Elon Musk stated, "We're designing and building much more of the car than other OEMs, who primarily resort to the traditional supply base and, as I refer to it, engage in what I call catalog engineering." https://insideevs.com/news/580977/tesla-vertical-integration-automakers-copy/

events have further revealed the vulnerabilities of global supply chains. These disruptions result in production delays, product shortages, increased costs, and changes in firms' resourcing strategies. Vertical integration stands out as a strategy to provide firms with greater resilience and flexibility to mitigate risks associated with global supply chain disruptions (Arora et al., 2024).

Taken together, vertical integration could decrease a firm's risk (Helfat and Teece, 1987), thereby reducing the *ex ante* bond risk premium and associated bond yield spreads. Hence, we anticipate lower corporate yield spreads for more vertically integrated firms, thereby forming the main hypothesis of the paper.

Hypothesis 1a: There is a *negative* relationship between vertical integration and corporate yield spreads.

On the flip side, vertical integration introduces the potential pitfall of asset specificity. By investing in assets that are uniquely tailored to their internal production processes and supply chain needs, vertically integrated firms become more asset-specific. This asset specificity can incur additional costs for these firms for two main reasons.

Firstly, when assets are specific to a particular use, their liquidation values are limited; correspondingly, investments cannot be easily reversed (Kermani and Ma, 2023). This irreversibility creates a "reluctance to invest" situation, as a forward-looking firm hesitates to invest today due to the possibility that it may wish to sell capital in the uncertain future but will be able to reclaim little, if any, of the undepreciated asset value (Chirinko and Schaller, 2009). Thus, high asset specificity can reduce the value of existing investments and amplify the effects of uncertainty on investment activities.

Secondly, asset specificity can be associated with post contractual opportunistic behavior, prompting other involved parties to extract rents *ex post* (Klein et al., 1978; Williamson, 1985; Coase, 2006). Once a specific investment is undertaken, the prospect of opportunistic behavior emerges,[23]and the resulting asset loses substantial value if repurposed for another use (Anderson and Weitz, 1992; Gulati et al., 1994; Hwang, 2006). Under this assumption, the assets of vertically integrated firms become highly specific to their internal operations, making them less versatile and

[23]When assets are specific, firms face the risk of being expropriated by the counterpart through opportunistic renegotiation. This can happen when the transaction partner realizes that the firm has few or no alternatives and can threaten to exit or impose new terms to capture a larger share of these quasi-rents.

more challenging to reconfigure for external markets. This specialization can lead to a substantial loss in asset value if the firm attempts to use or sell these assets for purposes other than their original intended use within the integrated production process. This cost can incentive other transacting parties to generate rents post-transaction.

If asset specificity risk is considered by the market, we anticipate higher credit spreads for more vertically integrated firms in bond markets, thereby proposing the competing hypothesis.

Hypothesis 1b: There is a *positive* relationship between vertical integration and corporate yield spreads.

3 Data and Sample

3.1 Text-based Vertical Integration Data

The sample used in this study consists of non-financial firms from July 2002 to June 2020.[24] The data of the firm-level score of vertical integration is constructed and validated by Frésard et al. (2020). The score provides the degree which a firm's products to be vertically related to the other products sold by the same firm in a year. In Frésard et al. (2020), the establishment of vertical relatedness between pairs of commodities is based on the 2002 BEA input-output (IO) tables. The annually updated information regarding the products offered by firms, sourced from 10-K annual firm business descriptions in the SEC Edgar database, is utilized to identify vertical relatedness among products within firms by combining the vocabulary found in firm 10-Ks with the terminology defining the BEA IO commodities. By the construct, the score of vertical integration will be higher if a firm's business description contains many word pairs that are vertically related. In another word, a firm has higher score of vertical integration when its product vocabulary spans vertically related markets.[25]

To begin the process of applying Frésard et al. (2020)'s text-based measure of vertical integration, the 10-K annual firm business descriptions are first identified and extracted from the SEC Edgar Database following the same process as in Hoberg and Phillips (2016). Then, use the 2002 BEA input-output (IO) tables, which provide dollar flows between producers and purchasers in the

[24]We start the sample in 2002 as this coincides with the availability of data from the TRACE Enhanced database.
[25]We thank Frésard, Hoberg, and Phillips (2020) for the data.

U.S. economy, and the *Detailed Item Output* table, which verbally describes each commodity and its subcommodities to assist in identifying vertical relatedness. Note that, in this step, only nouns and proper nouns are included, and additional screens are put in place to ensure the identification of vertical links is accurate.[26]

The next step involves merging the vocabulary from firms' 10-K reports with the vocabulary that defines BEA IO commodities to determine vertical relatedness between firms. The detailed process consists of three primary stages. First, Frésard et al. (2020) connect each firm-year in the Compustat/Edgar universe to BEA IO commodities by calculating the similarity between the firm's business description and the textual description of each BEA commodity. Second, the vocabularies of both firms and BEA commodities are represented as vectors, with lengths equal to the number of nouns and proper nouns found in the 10-K business descriptions for each year. Each element of these vectors corresponds to an individual word. The third step involves computing the "firms to IO commodity correspondence matrix," B, which has dimensions $M \times C$, where C represents the number of IO commodities and M represents the number of firms. An entry $B_{m,c}$ (row m, column c) is the cosine similarity between the text of the given IO commodity c and the text in firm m's business description.[27]

To measure the extent to which firm i is located upstream relative to firm j, use the following triple product: $\text{UP}_{i,j} = [B \cdot V \cdot B']_{i,j}$, where V is a sparse square matrix based on the extent to which a given commodity is vertically linked (upstream or downstream) to another commodity.[28] This step yields an $M \times M$ matrix of upstream-to-downstream relatedness between firms i and j. Downstream relatedness is simply the mirror image of upstream relatedness, $\text{DOWN}_{ij} = \text{UP}_{ij}$.

[26] As stated in Frésard et al. (2020), the filtering process includes manually discarding expressions indicating a vertical relation, removing expressions indicating exceptions, discarding common words from commodity vocabularies, and removing any words that do not frequently co-appear with other words in a given commodity's vocabulary.

[27] In calculating cosine similarity, the weights of commodity word vectors are assigned based on the economic importance of each word from the commodity-word correspondence matrix (CW). The CW matrix is structured with three columns: a commodity, a commodity word, and the corresponding economic importance. The firm word vectors are equally weighted, following Hoberg and Phillips (2016).

[28] According to Frésard et al. (2020), the matrix V is obtained by first constructing the SHARE matrix, an $I \times C$ matrix (Industry $\times$ Commodity) that contains the percentage of commodity c produced by a given industry i. The USE matrix is a $C \times I$ matrix that records the dollar value of industry i's purchase of commodity c as input. The CFLOW matrix is then given by USE $\times$ SHARE, resulting in a $C \times C$ matrix of dollar flows from an upstream commodity c to a downstream commodity d. In line with Fan and Goyal (2006), the SUPP matrix is defined as CFLOW divided by the total production of the downstream commodity d. SUPP records the fraction of commodity c that is used as an input to produce commodity d. Likewise, the CUST matrix is given by CFLOW divided by the total production of the upstream commodity c, recording the fraction of commodity c's total production that is used to produce commodity d. The V matrix is then calculated as the average of SUPP and CUST. A higher value in V indicates a stronger vertical relationship between commodities c and d.

Frésard et al. (2020) then repeat this procedure for each year, creating a time-varying network of firm-pairwise vertical integration (VI) measure.

3.2 Corporate Bond Data

Corporate bond data come from the Trade Reporting and Compliance Engine (TRACE) and Mergent's Fixed Investment Securities Database (FISD). The enhanced TRACE database contains the transactions for all publicly traded corporate bonds beginning in July 2002. The FISD database includes issuance information for all fixed-income securities. It contains issue- and issuer-specific information, such as coupon rates, issue date, maturity date, issue size, ratings, and other characteristics. Bond yields and trade data for corporate bonds are sourced from the first database, while ratings and bond-specific characteristics are obtained from the FISD. The primary variable in this study is *Yield Spread*, which is defined as the difference between corporate bond yield and the corresponding treasury bond yield with a comparable maturity.

We first clean the TRACE data by eliminating canceled, corrected, and reversed trades. Then, we follow Bessembinder et al. (2008) and Lin et al. (2011) and remove bonds that are not listed or traded in the U.S. public market such as bonds issued through private placement, bonds issued under the 144A rule, bonds that do not trade in U.S. dollars, and bond issuers outside the jurisdiction of the United States. We also exclude bonds with a maturity of less than 1 year and longer than 30 years, preferred shares, non-U.S. dollar-denominated bonds, and bonds that are mortgage-backed, asset-backed, convertible and exchangeable as well as secured bonds. Finally, we mainly use the Standard & Poor's (S&P) rating from the FISD, but, if it is not available, we use the Moody's or Fitch rating when possible and drop bonds whose ratings we cannot identify.

We then match the sample with Compustat database to obtain accounting data. The final dataset includes 393,379 bond-month observations spanning from July 2002 to June 2020. Appendix A provides variable definitions.

3.3 Summary Statistics

Table 1 presents summary statistics of vertical integration as well as firm and bond characteristics. To minimize the influence of extreme values, we winsorize all continuous variables at their 1^{st} and 99^{th} percentiles. Vertical integration assesses the extent to which a firm provides products or services that are vertically connected. A higher value signifies a greater degree of vertical integration. The average of vertical integration is 0.0141 with a standard deviation of 0.0115 ranging from 0.0025 to 0.0296 between the 10^{th} to 90^{th} percentiles.

The main variable of interest is the bond yield spread, which has a mean of 1.60% and a standard deviation of 2.11%. Roll (1984)'s bond illiquidity (*Illiquidity*) measure estimates the percentage bid-asks spread, with an average bond illiquidity at 1.44%. To facilitate empirical analysis, we translate bond credit ratings into numerical values using a rating conversion scheme: AAA=1, AA+=2, ..., C=21, and D=22. The median credit rating is 8, equivalent to BBB+. Concurrently, the median issue size is $450 million, with a maturity period of 7 years and a coupon rate of 5.38%. In addition, we report the bond sample distribution by year in Table B1. The bond issuers have an average long-term debt to assets ratio of 0.30 and a total debt to capitalization ratio of 0.32. Their average operating income to sales ratio is 0.24, and the pretax interest coverage ratio is 9.17. We also furnish statistics for a list of variables utilized in various analyses, with further elaboration provided in the empirical sections of the paper.

4 Empirical Results

4.1 Vertical Integration and Corporate Yield Spreads

As previously discussed, firms could strategically use vertical integration as an efficient tool for managing supply chain risk. Vertical integration allows a company to have greater control over its entire supply chain, thereby reducing reliance on external suppliers and logistics providers. Thus, we anticipate that a more vertically integrated firm can mitigate the potential supply chain risk, resulting in lower credit spreads. Alternatively, vertical integration comes with the costs of asset specificity, thus may increase the risk and higher bond yield spreads.

To empirically test the impact of vertical integration on bond yield spreads, we employ a panel regression approach to regress yield spreads on vertical integration, along with various control variables.[29] The model is specified as follows:

[29] Petersen (2009) shows that panel regressions with fixed effects enable researchers to enhance the efficiency of estimates and straightforwardly compute standard errors clustered, making the estimated coefficients and standard errors more robust than those obtained using the traditional Fama-MacBeth framework.

$$YS_{i,m,t} = \alpha + \beta VI_{i,t} + \gamma' Controls_{i,t} + \tau_t + \lambda_j + \epsilon_{i,m,t} \quad (1)$$

where i indexes bond, j indexes industry, m indexes month and t indexes year. $YS_{i,m,t}$ denotes bond i's yield spreads in month m of year t. Vertical integration (VI) measures the degree to which a firm provides products or services that are vertically related measured at the beginning of the year t. To account for factors that may affect yield spreads, the analysis includes a set of firm and bond-level variables, consistent with previous research on bond yield spreads (Campbell and Taksler, 2003; Chen et al., 2007). The first set of control variables include bond-specific characteristics, including the bond's illiquidity measure, credit ratings, years to maturity, issue size, and coupon rate.[30] The second set of control variables is related to issuers of the bond: long-term debt to assets (Long-Term Debt/Assets),total debt to capitalization (Total Debt/Capitalization), operating income to sales (Operating Income/Sales), equity volatility, and four variables constructed to measure the incremental influence of the pretax interest coverage (Pretax D1–Pretax D4) using the procedure outlined in Blume et al. (1998).[31] Additionally, time (τ) fixed effects and industry (λ) fixed effects are included in the regression to account for potential time-series trends and other unobserved firm characteristics, with regression standard errors clustered by bond issuer and year.[32]

Table 2 presents empirical results. In Column (1), we exclusively include VI alongside year and industry fixed effects. Consistent with *Hypothesis 1a*, we find a robust and negative coefficient of -14.576 on VI, with a t-statistic of -4.93. Given the standard deviation of VI as 0.0115, a one-standard-deviation increase in VI correlates with an 17 basis points decline in bond yield spreads. Expanding the model to include bond-level control variables, with and without credit ratings in Column (2) and (3), respectively, reveals consistent findings. Bond characteristics exhibit substantial explanatory power for corporate bond yield spreads, evidenced by an increase in adj. R^2 from 20.3% (without bond controls) to 52.5%. The coefficient on VI drops from -14.576 to -3.002, indicating that the influence of VI on credit spreads is, in part, explained by bond-specific

[30] We do not assume that yield spreads are a linear function of credit ratings and use dummy variables as a fixed effect to capture variations across different rating categories.

[31] For each transaction, we consider the equity data for the 252 days prior to (not including) the bond trade and accounting data for the previous calendar year.

[32] Consistent with recent studies that examine the effect of firm characteristics on corporate credit spreads (e.g. Nagler, 2020), we control for industry fixed effects rather than issuer fixed effects because we examine the effect of vertical integration (at the annual frequency) on monthly bond yield spreads.

characteristics. Nonetheless, the coefficient remains negative and highly statistically significant. Coefficients on bond characteristics align with previous literature (Chen et al., 2007; Bao et al., 2011); for instance, higher bond illiquidity and higher coupon correlate with higher credit spreads.

In Column (4), we additionally incorporate firm-level control variables and observe that the explanatory power of VI is not attributable to issuer characteristics. The coefficient on VI is -3.546 with a t-statistic of -2.62. This suggests that even after controlling for both bond and firm-level control variables, a one-standard-deviation increase in VI is still associated with a 4 basis points decline in yield spreads. To address seasonal time effects, we further introduce month fixed effects in Column (5), and the results remain robust. Our findings regarding firm-level control variables align with recent studies such as Campbell and Taksler (2003) and Nanda et al. (2019). In the subsequent analysis, we employ model 5 from Table 2 as the foundational model to delve deeper into the mechanism underlying the relationship and assess the effects of vertical integration across different market conditions.

In summary, we present robust results indicating a negative effect of vertical integration on bond yield spreads. This suggests that a firm with a higher degree of vertical integration is associated with lower yield spreads, supporting our *Hypothesis 1a*.

4.2 Supply Chain Risk and Vertical Integration

Next, we investigate whether the effect of vertical integration on corporate credit spreads is likely manifesting through the supply risk channel. We posit that if the influence of vertical integration primarily operates via the supply chain risk channel, its significance should be more prominent in companies grappling with heightened supply chain risk. To empirically test this conjecture, we stratify our sample into three groups based on supply chain risks at both the firm and industry levels. To quantify firm-level supply chain risk, we employ textual analysis of earnings conference calls following the methodology outlined by Ersahin et al. (2024). Each year, we categorize the sample into three groups based on the supply chain risk measure: high supply chain risk if it exceeds 75%, medium if it falls between 25% and 75%, and low if it is below 25%. Additionally, we undertake an alternative classification based on industry supply chain risk. We utilize the industry-year average of firms' supply chain risk to rank the industries. Industries ranking within the top 10 in overall supply chain risk are designated as high-risk, while those in the bottom 10 are classified as low-risk.[33] The remaining industries fall into the medium-risk category.

Regression results are reported in Table 3. Columns (1) to (3) present findings sorted by firm-level supply chain risk, while Columns (4) to (6) display results sorted by industry supply chain risk. Notably, we observe a more pronounced vertical integration effect for firms facing elevated supply chain risk. In Column (1), the coefficient on VI stands at -5.365, significant at the 1% level. By contrast, for the medium supply chain risk group, the VI coefficient is -3.248 (t-value = -2.06), and for the low supply chain risk group, it is -3.172 (t-value = -1.94), suggesting a weakened VI effect for firms subject to moderate and lower supply chain risk. These outcomes align with our conjecture, indicating that vertical integration can effectively lower risk premium through the supply chain risk channel. For firms facing higher supply chain risk, vertical integration can be a more efficient strategy to manage and mitigate this risk. In contrast, for firms with relatively low supply chain risk, the role of vertical integration becomes less significant in managing supply chain risk. Thus, the impact of vertical integration on credit spreads is more pronounced when channeled through the supply chain risk. To reinforce our findings, we conduct a further analysis on VI sorted by industry supply chain risk groups. In Columns (4) to (6), we identify negative and significant coefficients on VI for firms in high and medium supply chain risk industries. Conversely, the effect is statistically insignificant for industries characterized by low supply chain risk. This once again substantiates our hypothesis, emphasizing the heightened relevance of vertical integration when supply chain risk is more pronounced.

4.3 Other Potential Risk Channels

The preceding analysis lends support for the supply chain risk channel in explaining the vertical integration effect. However, this might not rule out other potential risk channels could intersect with the vertical integration effect on corporate yield spreads. Specifically, the impact of vertical integration on reduction in supply chain risk could be associated with lower credit risk and liquidity risk. To delve into these alternative risk channels, we focus on two main risk factors: bond credit risk and illiquidity risk. Drawing from the findings of Huang and Huang (2012), which assert that credit risk contributes one third of credit spreads, along with studies by Chen et al. (2007) and Bao

[33] We list the top 10 and bottom 10 industries in terms of our measure of overall supply chain risk in the Appendix Table B2.

et al. (2011) indicating that bond liquidity can explain a comparable portion of credit spreads, we categorize bonds into groups according to their credit and liquidity risk profiles.

The credit risk is proxied by a bond's credit rating, categorizing bonds into groups with high credit risk (ratings of BB+ or below), medium credit risk (ratings between BBB- to A+), and low credit risk (ratings of AA- or above). Alternatively, each month, bonds are classified into three groups based on Roll's bond illiquidity measure: high bond illiquidity risk if it exceeds 75%, medium if it falls between 25% and 75%, and low if it is below 25%.

Columns (1) - (3) of Table 4 show results categorized into three rating groups. Interestingly, the most pronounced effect of VI is observed within the medium credit risk group, with a coefficient of -2.813, significant at the 1% level. Although the coefficient on VI for the high credit risk group has the largest magnitude, it lacks statistical significance. For the low credit risk group, the coefficient is negative at -3.077 but also statistically insignificant. These outcomes suggest that the role of VI is stronger among firms with a medium credit risk profile. In instances where a bond holds a non-investment grade rating, the risk mitigation effect of vertical integration might be overshadowed by heightened credit risk. Conversely, when a firm faces low credit risk, the contribution of vertical integration to further risk reduction appears limited. This observation aligns with Longstaff et al. (2005), illustrating that the risk premium of highly rated investment-grade bonds is predominantly determined by credit risk. Another noteworthy observation is that the medium credit risk group comprises approximately 80% of the entire sample in our dataset, while the low and high credit risk Group each account for about 10%. This distribution suggests that the reduction effect of VI on yield spreads holds both economic and statistical significance for the vast majority of the sample.

Columns (4) to (6) present results sorted into three bond illiquidity groups. We observe the most substantial VI effect within the high bond illiquidity group, with a coefficient of -5.941 (t-value = -3.03). This translates to a 7 bps reduction in credit spreads for a one-standard-deviation increase in VI. In contrast, the coefficient estimates on VI decrease to -2.431 and -2.552 for the medium and low illiquidity groups, respectively. These findings suggest that the VI effect on credit spreads may also operate through the liquidity risk channel, with the most substantial negative VI effect observed in the high illiquidity group. Additionally, statistical significance is observed at the 1% level across all bond illiquidity groups, indicating that the negative VI effect is robust across various levels of bond liquidity risk.

5 Global Supply Chain Disruptions

In this section, we examine the impact of vertical integration on credit spreads during global chain disruptions for two purposes: On the one hand, with the evolution of global supply chains, firms often rely on each other for specific components, technologies, or materials, fostering a highly interconnected global economy. However, such interconnectedness of global supply chains exposes vulnerabilities in production strategies and supply chains (Chopra and Sodhi, 2014), with disruptions potentially leading to significant costs and business standstills. We are interested to test whether a higher degree of vertical integration respond better to market changes or disruptions in the supply chain under such conditions. On the other hand, exogenous global supply chain shocks, like Covid-19 and the U.S.-China trade war, offer a (quasi-)natural experiment to mitigate endogeneity concerns in assessing the link between firm vertical integration and bond yield spreads. These disruptions, beyond the control or influence of individual firms, result in firms not being able to immediately adjust their organizational structures ahead of them, thus enabling us to isolate the impact of vertical integration on bond market perceptions. Applying such events provides a clearer understanding of how vertical integration influences firm risk and bond yields.

5.1 Covid-19 Pandemic Crisis

First, we investigate the role of vertical integration on corporate credit spreads during the Covid-19 pandemic crisis. The pandemic significantly disrupted entire supply chains, with lockdown, quarantine measures, and movement restrictions leading to the closure of numerous factories and production facilities worldwide. To assess the vertical integration effect during the pandemic period, we include the interaction term between VI and Covid-19 pandemic ($Covid$) dummy variable into the Eq. (1). The pandemic period is defined as from February to April of 2020. The main variable of interest is the interaction term between VI and $Covid$.

As shown in Column (1) of Table 5, the coefficient on VI is negative and significant, suggesting that a higher degree of VI is associated with lower yield spreads during non-pandemic period, consistent with our prior findings. More importantly, the coefficient on the interaction term of VI * $Covid$ is -2.786 with a t-value of -2.47. Specifically, a one-standard-deviation increase in VI results in 7 bps lower yield spreads during the pandemic period. Our findings underscore the heightened importance of vertical integration in mitigating credit spreads during supply chain disruptions.

We extend our analysis to investigate the impact of VI under different levels of firm-level Covid-19 risk. Following the methodology of Hassan et al. (2023), we measure firm-level Covid-19 risk using earnings conference call (quarterly) from February to April of 2020. This approach allows us to explore whether the effect of vertical integration varies for firms with higher Covid risk exposure during the pandemic. Our sample comprises 686 firms, 334 of which can be identified with Covid risk. We then perform a panel regression, including the interaction term between Covid risk and VI in the baseline regression. The results are reported in Column (2). Consistent with the previous findings, we observe a stronger VI effect for firms subject to higher Covid risk. When both VI and Covid risk increase by one-standard-deviation, the yield spreads decease by an additional 8 bps (-35.19 * 0.0115 * 0.19).

The Covid-19 pandemic caused simultaneous disruptions in demand, supply, and logistic infrastructure, setting it apart from classical disruption risks that typically affect either supply or demand but not both. To explore whether the impact of VI is more pronounced for firms confronted with heightened supply chain risk during the pandemic, we use the triple-interaction term involving vertical integration, a $Covid$ pandemic dummy, and firm supply chain risk in Column (3). The key finding is that the coefficient on this triple-interaction term is negative and significant, suggesting that vertical integration plays a more crucial role for firms with higher supply chain risk in reducing yield spreads during the pandemic period. Additionally, the coefficient on the interaction between $Covid$ and supply chain risk is positive, indicating that investors demand a higher risk premium for firms subject to greater supply chain risk. Consistent with the findings presented in Table 3, we find that a higher level of VI is associated with lower yield spreads for firms facing higher supply chain risk during non-pandemic periods.

5.2 U.S.-China Trade War

Next, we explore the impact of vertical integration on corporate credit spreads during the U.S.-China trade war. Global supply chains are typically established in anticipation of free trade. However, the U.S. government's imposition of input tariffs surprised the industries heavily reliant on imported goods, resulting in additional cost such as renegotiation with existing suppliers or searching for alternative suppliers (Grossman et al., 2024). In this section, we investigate whether the U.S.-China trade war disproportionately affect more vertically integrated U.S. firms, especially those that depend significantly on imports from China.

Since 2018, the U.S. government has been engaged in an unprecedented trade war, characterized by widespread tariffs imposed on its trading partners, particularly China.[34] This event of considerable magnitude is unparalleled in the post-war era and has a significant impact for the global supply chain (Fajgelbaum et al., 2020; Benguria and Saffie, 2023; Huang et al., 2023). To examine the role of vertical integration on corporate credit spreads during the U.S.-China trade war, we introduce the interaction term between VI and trade war indicator variables into the Eq. (1). Specifically, we examine two distinct phases of the U.S.-China trade war. In the initial phase, the Trump administration issued a presidential memorandum on March 22, 2018, proposing significant tariffs on over \$50 billion of Chinese imports.[35] The scope and value of targeted Chinese products expanded with subsequent tariff waves implemented in July and September, targeting \$200 billion Chinese products.[36] In this study, the initial phase (TW Phase 1) spans from March to June 2018, while the second phase (TW Phase 2) ranges from July to October 2018.

We examine the interaction effect between VI and these two phases separately in Column (1) and Column (2) of Table 6. First, we find that the coefficients on VI in both columns are negative and statistically significant at the 5% level, confirming that a higher degree of VI is associated with lower spreads. Second, the coefficient on the interaction term VI * $TW\ Phase$ 1 is negative at -2.801, with a t-statistic of -2.22. This suggests that, during the initial phase of the U.S.-China trade war, the reduction in yield spreads for firms with a higher degree of vertical integration is more pronounced. By contrast, the coefficient on VI * $TW\ Phase$ 2 is neither economically nor statistically significant. This implies that the impact of the trade war on bond pricing is primarily concentrated during the first phase. Subsequent analyses will consequently center on the interaction effect between VI and $TW\ Phase$ 1 under various scenarios.

Since the U.S. government imposed higher tariffs on certain imported goods from China, we

[34] In response, China and other U.S. trading partners have imposed retaliatory tariffs on U.S. exports. For instance, between April and September of 2018, China implemented retaliatory tariffs on U.S. goods, collectively covering over \$92 billion (6% of annual U.S. exports) across 7,474 products.

[35] Huang et al. (2023) focus on a significant event: the March 22, 2018 announcement of U.S. tariffs on a substantial portion of Chinese imports. Their findings show that U.S. firms with higher dependencies on exports to and imports from China experience larger declines in market value.

[36] As shown in Fajgelbaum et al. (2020), tariffs on China targeted 11,207 imported products worth \$247 billion, and increased tariffs, on average, from 3.0% to 15.5%. A total of 48.8% of imports from China were targeted with tariff increases.

anticipate a more pronounced interaction effect between vertical integration and the trade war for U.S. firms that depend on imports from China. As such, we use the the proportion of imported input from China as a proxy for firms' exposure to the U.S.-China trade war. Previous studies (e.g. Huang et al., 2023) have shown that the tariffs imposed by the U.S. government directly impact firms with a greater reliance on imported goods from China.[37] Additionally, the trade war's effect is particularly concentrated among U.S. firms that outsource to Chinese suppliers for differentiated inputs.

To assess a firm's exposure to the trade war, we follow Huang et al. (2023) and estimate the percentage of imported products from China using U.S. bill of lading and USA Trade Online datasets. Specifically, we calculate the ratio of a firm's inputs from China to its total imported input for the year 2017, which precedes the onset of the trade war.[38] Next, we analyze the triple interaction between VI, TW Phase 1, and $Input\ China$, with the results reported in Column (3).[39] The coefficient of our main variable of interest is -27.257, significant at the 5% level. As expected, a high degree of vertical integration is associated with lower yield spreads for firms with a higher reliance on imported Chinese goods during the trade war. In addition, the interaction term between VI and *TW Phase 1* becomes insignificant, indicating that the negative interaction effect shown in Column (1) is primarily driven by U.S. firms that depend on imports from China. Moreover, the positive coefficient on TW Phase 1 $*$ $Input\ China$ indicates that bond investors require higher risk premium for firms relying on Chinese inputs during the trade war period.

As a robustness check, we further investigate U.S. firms that have purchased differentiated products from China. Using the detailed product categories in the lading database and the definition of product differentiation introduced by Rauch (1999), we follow Huang et al. (2023) to construct the measure of $Input\ China\ (Diff)$. This measure, defined as the average exposure to inputs from China across suppliers with differentiated product inputs, captures the share of a U.S. firm's differentiated goods imported from China in 2017. Consistent with the results observed in Column(3), the coefficient of the triple interaction term escalates to -36.14 (t-stat = 2.28), indicating that the

[37]Our focus is specifically on the offshoring of capital goods and intermediate goods, excluding any imported final goods.

[38]As of 2017, 38% of the sample firms reported positive imports from China, with these imports accounting for an average of 19% of their total imported inputs.

[39]Considering that the input from China is estimated from the year 2017, we focus on the effect of $Input\ China$ conditional on the trade war period.

negative VI effect on bond yield spreads is more pronounced for firms that import differentiated goods from China.

6 Extended Analyses

6.1 Vertical Integration and Firm Inventory

Vertical integration plays a crucial role in inventory management within a supply chain by transforming inter-firm information sharing into intra-firm information sharing. By ensuring internal knowledge access (Monteverde, 1995) and enhancing information integrity and transparency (Williamson, 1979; Lin et al., 2014), vertical integration enables more accurate demand forecasting and inventory planning (Wan and Sanders, 2017). This leads to more efficient inventory levels, reducing the likelihood of excess inventory because highly vertically integrated firms may not carry excessive safety stock to guard against supply uncertainties (Syntetos et al., 2009). In this subsection, we examine the interaction effect between vertical integration and firm inventory on corporate yield spreads and further analyze this interaction effect amid supply chain disruptions.

Considering inventory levels vary significantly across industries, we use the industry-adjusted inventory to assets ratio from the quarter preceding each monthly bond observation to gauge a firm's inventory level over time. We define a firm's inventory level as high (low) by setting a dummy variable to 1 when the industry-adjusted inventory to assets ratio lies within the top (bottom) quartile of the sample for each month, and 0 otherwise. Next, we include the interaction term between vertical integration and the high/low inventory dummies in the baseline regression. Regression results are reported in Column (1) and (2) of Table 7. We find that the interaction term with the high inventory dummy (High INVT) is positive but insignificant, while the interaction term with the low inventory dummy (Low INVT) is negative and significant. With a one-standard-deviation increase in VI for firms with low inventory, there is an additional reduction of yield spreads by 6 bps (-5.591 * 0.0115) compared to other firms.This indicates that vertical integration plays a more substantial role for firms with low inventory levels, suggesting that vertical integration can improve inventory management efficiency and further reduce the risk premium. In contrast, for firms with high inventory levels, the effect of vertical integration is not significantly different from that of other firms.

Next, we further examine this interaction effect amid supply chain disruptions. To investigate this issue, we use a triple-interaction term involving vertical integration, the high/low inventory dummies, and supply chain disruption indicators (*Covid* and TW Phase 1). We report the results with *Covid* in Columns (3) and (4) of Table 7 and the results with U.S.-China Trade War in Columns (5) and (6). Interestingly, we find a positive coefficient on the triple interaction term with Covid, but a negative coefficient with the U.S.-China Trade War for low inventory firms. The opposite effect is likely due to the different nature of these two disruptions. During the Covid pandemic, the entire supply chain was disrupted. Even for firms that are more vertically integrated, those with low inventory levels may still have difficulty replenishing needed inventory. This can result in supply shortages, leading investors to demand a higher premium. In contrast, the U.S.-China trade war led to high tariffs between the two countries, resulting in higher supply chain costs. Although this situation caused supply chain disruptions, the global supply chain system continued to function, albeit at a higher cost. In this scenario, vertically integrated firms could quickly adapt to disruptions and cope with unexpected changes in supply, maintaining inventory levels and reducing risk premiums. It is also worth noting that interaction terms between Low INVT and disruption dummies are both positive, showing the investors demand higher premiums for firms with low inventory level during supply chain disruptions.

6.2 Vertical Integration and Production Market Competition

Our main result documents a negative and significant effect of firm-level vertical integration on bond yield spreads, indicating that investors demand a lower risk premium for more vertically integrated firms. In the dynamic global business environment, vertical integration can be an innovative strategy for firms to overcome supply chain challenges and mitigate supply chain risks. Additionally, economists have shown that vertical integration can increase a firm's market power (Arora et al., 2024) and reduce market competition (Boehm and Sonntag, 2023). Existing horizontal market power creates further motivation for firms to vertically integrate to better exploit the market power they already have (Díez-Vial, 2007). Given such insights, we provide an additional analysis on whether a firm's level of vertical integration intersects with variations in its product market power in determining corporate yield spreads.

To test our question, we incorporate firm-level product similarity and industry concentration measures from Hoberg and Phillips (2016) into our study. Unlike traditional methods that use pre-defined industry group stratifications, this approach identifies related firms through textual analysis of the business description section in the 10-K reports. *Product Similarity* is determined by the total similarity data customized to each firm based on the Text-based Network Industry Classification (TNIC) data, and is negatively related to pricing power according to product differentiation theory (Hotelling, 1929). Alternatively, *Product Pricing Power* is measured using the TNIC industry concentration, and is customized to each firm.[40] We define a high (low) product similarity dummy as 1 when the total product similarity score lies within the top (bottom) quartile of the sample for each month, and 0 otherwise. Likewise, a high (low) pricing power dummy is defined as 1 if the industry concentration (HHI) score falls within the top (bottom) quartile of the sample for each month, and 0 otherwise.

Table 8 presents the results of our findings. Across Columns (1) to (4), VI remains negative and significant. Interestingly, the coefficient on the interaction terms in Columns (2) and (3) is negative and significant at the 1% level, while those in Columns (1) and (4) are not statistically significant. Our findings show that the impact of vertical integration on reducing yield spreads is more pronounced among firms characterized by lower product similarities and greater pricing power. This suggests that vertical integration could potentially increase a firm's market power and reduce risk premiums when its product is unique compared to competitors and has stronger pricing power. For instance, For firms with high product pricing power, a one-standard-deviation increase in vertical integration marginally reduces yield spreads by an additional 5 bps (-4.194*0.0115) compared to other firms. However, for firms characterized by high product similarities with their competitors, typically in more competitive industries, the role of vertical integration in further reducing risk premiums is indifferent from that of other firms.

We find our results intriguing from the perspective of supply chain management. Conceptually, firms in highly competitive industries might have more incentives to utilize a vertical integration strategy to mitigate supply chain risk. However, for these firms where product similarities with competitors are high, the marginal benefits of being more vertically integrated with upstream and downstream partners diminish. Instead, the reduction in risk premiums manifest more prominently

[40] The Text-based Network Industry Classification (TNIC) industry classification is tailored to individual firms, each with its unique array of competitors (Hoberg and Phillips, 2016).

for firms that possess high pricing power, as these firms are typically the leaders in their sectors and could disproportionately increase the market power from vertical relatedness in the highly concentrated industries.

7 Conclusion

In recent years, the growing significance of global supply chains and disruptions caused by events like the U.S.-China trade war and the Covid-19 pandemic have emphasized the need for effective supply chain management. While vertical integration within firms is recognized as a valuable tool for managing supply chain risk, its impact on asset prices has remained uncertain. This paper fills this gap by examining the interaction between firm-level vertical integration, supply chain disruptions, and corporate bond yield spreads.

Our findings show that firm vertical integration is priced in the corporate bond market, with reduced risk premiums for more vertically integrated firms. We identify that this negative effect operates through the supply chain risk channel. Our results shed light on how, in the midst of supply chain disruptions, vertical integration emerges as a strategic tool to mitigate risks associated with external suppliers. A more vertically integrated company, through ownership or control of critical elements along the supply chain, reduces reliance on external sources for essential inputs and gains greater control over the entire production process. This enhanced control not only establishes a buffer against disruptions affecting external suppliers but also allows the company to adapt more quickly to changes in supply and demand. Consequently, during significant supply chain disruption events when market risks are exacerbated, firms with higher levels of vertical integration can be better positioned to mitigate supply chain risks.

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Table 1: Summary Statistics

This table reports summary statistics for bond-month observations over the sample period from 2002 to 2020. The descriptive statistics include the sample mean, median, standard deviation (Std Dev.), 10^{th} percentile, and 90^{th} percentile of the variables used in this study. The main variables include vertical integration and bond yield spreads (%). Vertical integration (VI) measures the degree to which a firm provides products or services that are vertically related, as estimated by Frésard et al. (2020). Bond yield spread is defined as the difference between corporate bond yield and the corresponding treasury bond yield. Bond characteristics include Roll (1984)'s illiquidity measure (%), credit rating, issuing size (in millions), maturity in years and coupon rate (%). The bond's numerical credit rating is determined using the following letter rating conversion scheme: AAA=1, AA+=2, ..., C=21, and D=22. Firm characteristics include long-term debt to assets (Long-Term Debt/Assets), total debt to capitalization (Total Debt/Capitalization), operating income to sales (Operating Income/Sales), equity volatility and pretax interest coverage. We also include other variables used in our study, including firm-level supply chain risk, Covid risk (estimated during the Covid-19 Pandemic period), the proportion of imported goods from China (Input China), the proportion of imported differentiated products from China (Input China (Diff)), industry-adjusted inventory to assets ratio (Inventory/Assets), and product similarity and product pricing power scores. The detailed construction of variables are defined in Appendix A.

Variable	10^{th} Pctl.	Mean	Median	Std Dev.	90^{th} Pctl.
Vertical Integration (VI)	0.0025	0.0141	0.0112	0.0115	0.0296
Yield Spread (%)	0.40	1.60	1.08	2.11	3.21
Illiquidity (%)	0.09	1.44	0.78	2.26	3.29
Credit Rating	4.00	7.60	8.00	2.88	10.00
Issue Size (in Millions)	200	593.6	450	607.7	1,200
Maturity (in years)	2.08	10.59	7.00	9.04	26.67
Coupon (%)	2.70	5.25	5.38	1.88	7.55
Long-Term Debt/Assets	0.15	0.30	0.29	0.12	0.45
Total Debt/Capitalization	0.11	0.32	0.30	0.19	0.57
Operating Income/Sales	0.09	0.24	0.23	0.14	0.42
Equity Volatility (%)	0.18	0.46	0.39	0.30	0.82
Pretax Interest Coverage	2.75	9.17	6.09	10.18	18.62
Supply Chain Risk	0.74	4.20	2.15	7.57	6.74
Covid Risk	0.00	0.14	0.10	0.19	0.38
Input China	0.00	0.19	0.00	0.34	0.91
Input China (Diff)	0.00	0.14	0.00	0.30	0.75
Inventory/Assets	-0.08	0.00	0.00	0.07	0.06
Product Similarity	1.03	3.74	1.84	4.59	7.85
Product Pricing Power	0.03	0.24	0.15	0.25	0.59

Table 2: Vertical Integration and Corporate Yield Spreads

This table presents the panel regression results of the effect of vertical integration on corporate yield spreads. The dependent variable is the bond yield spread, defined as the difference between corporate bond yield and the corresponding treasury bond yield. The main variables of interest is vertical integration (VI) estimated from Frésard et al. (2020). The yield spread determinants are based on bond-specific effects (credit ratings, bond illiquidity, maturity in years, issue size and coupon), and firm-specific characteristics (long-term debt to assets, total debt to capitalization, operating income to sales, equity volatility and pretax interest coverage). The pretax interest coverage is further grouped into one of four categories according to Blume et al. (1998). The bond's numerical credit rating is determined using the following letter rating conversion scheme: AAA=1, AA+=2, ..., C=21, and D=22. We include rating dummy variables as a fixed effect to capture variations across different rating categories. The detailed construction of variables are defined in Appendix A. Industry and time fixed effects are included in all regressions and t-values based on standard errors clustered at the issuer and year level are reported in parentheses. *, ** or *** denotes the significance at the 10%, 5%, or 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)
VI	-14.576***	-11.764***	-3.002**	-3.546***	-3.555***
	(-4.93)	(-5.35)	(-2.26)	(-2.62)	(-2.63)
Illiquidity		0.260***	0.206***	0.198***	0.198***
		(9.10)	(8.93)	(8.46)	(8.48)
Maturity		-0.012***	0.005***	0.006***	0.006***
		(-5.85)	(3.63)	(3.69)	(3.71)
Ln [Issue Size]		-0.057	0.002	-0.004	-0.005
		(-1.52)	(0.11)	(-0.22)	(-0.22)
Coupon		0.277***	0.085***	0.083***	0.083***
		(30.04)	(13.66)	(12.89)	(12.85)
Long-Term Debt/Assets				-0.978***	-0.980***
				(-5.06)	(-5.06)
Total Debt/Capitalization				1.947***	1.949***
				(8.43)	(8.43)
Operating Income/Sales				-0.017	-0.018
				(-0.12)	(-0.13)
Equity Volatility				1.363***	1.363***
				(3.98)	(3.99)
Pretax D1				-0.713***	-0.714***
				(-2.60)	(-2.61)
Pretax D2				-0.583**	-0.583**
				(-2.44)	(-2.44)
Pretax D3				-0.473**	-0.473**
				(-2.07)	(-2.07)
Pretax D4				-0.453**	-0.453**
				(-2.01)	(-2.01)
Rating Dummies	No	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Month FE	No	No	No	No	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Observations	393,379	391,035	391,035	381,694	381,694
Adj. R^2	0.203	0.335	0.525	0.541	0.542

Table 3: Supply Chain Risk and the Vertical Integration Effect

This table presents the panel regression results of the effect of vertical integration on corporate yield spreads sorted by supply chain risk. The dependent variable is the bond yield spread, defined as the difference between corporate bond yield and the corresponding treasury bond yield. The main variables of interest is vertical integration (VI) estimated from Frésard et al. (2020). We categorize the samples into three groups, considering both firm-level and industry supply chain risks (Ersahin et al., 2024). Specifically, firms are classified into three groups based on their individual supply chain risk: high if it exceeds 75%, medium if it falls between 25% and 75%, and low if it is below 25%. Additionally, an alternative classification is conducted based on industry supply chain risk. Industries ranking within the top 10 in overall supply chain risk are designated as high-risk, while those in the bottom 10 are classified as low-risk. The remaining industries fall into the medium-risk category. The yield spread determinants are based on bond-specific effects (credit ratings, bond illiquidity, maturity in years, issue size and coupon), and firm-specific characteristics (long-term debt to assets, total debt to capitalization, operating income to sales, equity volatility and pretax interest coverage). The pretax interest coverage is further grouped into one of four categories according to Blume et al. (1998). We include rating dummy variables as a fixed effect to capture variations across different rating categories. The detailed construction of variables are defined in Appendix A. Industry and time fixed effects are included in all regressions and t-values based on standard errors clustered at the issuer and year level are reported in parentheses. *, ** or *** denotes the significance at the 10%, 5%, or 1% level, respectively.

	Firm Supply Chain Risk			Industry Supply Chain Risk		
	(1) High	(2) Medium	(3) Low	(4) High	(5) Medium	(6) Low
VI	-5.365***	-3.248**	-3.172*	-5.161**	-4.623***	-1.318
	(-3.20)	(-2.06)	(-1.94)	(-2.28)	(-2.66)	(-0.52)
Illiquidity	0.122***	0.217***	0.119***	0.357***	0.140***	0.108***
	(7.19)	(3.70)	(12.90)	(4.91)	(17.02)	(13.59)
Maturity	0.013***	0.007**	0.013***	-0.003	0.006***	0.006***
	(7.82)	(2.01)	(8.52)	(-0.50)	(6.40)	(5.09)
Ln [Issue Size]	-0.067***	-0.019	-0.083***	0.088**	-0.051**	-0.129***
	(-3.19)	(-0.97)	(-2.69)	(2.41)	(-2.18)	(-4.31)
Coupon	0.088***	0.071***	0.102***	0.054***	0.085***	0.107***
	(9.69)	(6.25)	(12.68)	(3.25)	(16.81)	(11.94)
Long-Term Debt/Assets	-0.484**	-0.901***	-0.391*	-1.223***	-0.452**	-0.729**
	(-2.41)	(-2.82)	(-1.70)	(-2.98)	(-2.56)	(-2.44)
Total Debt/Capitalization	1.852***	2.485***	1.792***	2.815***	1.574***	1.219***
	(5.29)	(5.25)	(7.02)	(4.73)	(6.74)	(3.86)
Operating Income/Sales	-0.300	0.115	-0.136	-0.131	-0.327***	-0.073
	(-1.38)	(0.66)	(-0.80)	(-0.15)	(-2.71)	(-0.21)
Equity Volatility	1.140***	1.248*	1.687***	1.071	1.656***	1.038***
	(5.50)	(1.85)	(6.27)	(1.43)	(6.63)	(2.78)
Pretax D1	-0.456**	-0.424***	-0.352**	-1.076	-0.605***	-0.302
	(-2.19)	(-2.86)	(-1.96)	(-1.28)	(-4.24)	(-0.68)
Pretax D2	-0.385**	-0.298**	-0.272*	-0.760	-0.579***	-0.147
	(-2.15)	(-2.18)	(-1.73)	(-1.11)	(-4.52)	(-0.34)
Pretax D3	-0.307*	-0.226*	-0.087	-0.553	-0.457***	-0.070
	(-1.88)	(-1.67)	(-0.58)	(-0.89)	(-3.65)	(-0.16)
Pretax D4	-0.304*	-0.184	-0.100	-0.446	-0.469***	-0.251
	(-1.92)	(-1.36)	(-0.67)	(-0.84)	(-3.66)	(-0.57)
Rating Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	65,626	151,003	64,317	93,442	236,644	51,608
Adj. R^2	0.665	0.566	0.680	0.564	0.576	0.675

Table 4: The Vertical Integration Effect Sorted by Credit Risk and Illiquidity Risk

This table presents the panel regression results of the effect of vertical integration on corporate yield spreads sorted by bond credit risk and illiquidity risk. The dependent variable is the bond yield spread, defined as the difference between corporate bond yield and the corresponding treasury bond yield. The main variables of interest is vertical integration (VI) estimated from Frésard et al. (2020). We categorize the sample into three groups, considering both bond credit risk and illiquidity risk (Chen et al., 2007; Huang and Huang, 2012). Specifically, bond are classified into three groups based on on their credit ratings: high credit risk with credit ratings of BB+ or below, medium credit risk with ratings between BBB- to A+, and low credit risk with ratings of AA- or above. Alternatively, bonds are sorted into three groups based on Roll (1984)'s bond illiquidity measure: high if it exceeds 75%, medium if it falls between 25% and 75%, and low if it is below 25%. The yield spread determinants are based on bond-specific effects (credit ratings, bond illiquidity, maturity in years, issue size and coupon), and firm-specific characteristics (long-term debt to assets, total debt to capitalization, operating income to sales, equity volatility and pretax interest coverage). The pretax interest coverage is further grouped into one of four categories according to Blume et al. (1998). We include rating dummy variables as a fixed effect to capture variations across different rating categories. The detailed construction of variables are defined in Appendix A. Industry and time fixed effects are included in all regressions and t-values based on standard errors clustered at the issuer and year level are reported in parentheses. *, ** or *** denotes the significance at the 10%, 5%, or 1% level, respectively.

	Credit Risk			Bond Illiquidity Risk		
	(1) High	(2) Medium	(3) Low	(4) High	(5) Medium	(6) Low
VI	-5.478	-2.813***	-3.077	-5.941***	-2.413***	-2.552***
	(-0.56)	(-3.67)	(-0.84)	(-3.03)	(-3.86)	(-3.25)
Illiquidity	0.312***	0.092***	0.031***	0.238***	0.468***	0.423***
	(5.32)	(14.21)	(5.15)	(15.15)	(26.27)	(7.86)
Maturity	-0.033***	0.012***	0.015***	-0.009***	0.008***	0.017***
	(-2.96)	(18.66)	(14.85)	(-4.42)	(10.99)	(17.01)
Ln [Issue Size]	0.049	-0.077***	0.019	0.087***	0.017	-0.093***
	(0.63)	(-7.68)	(1.51)	(2.62)	(1.56)	(-6.75)
Coupon	0.160***	0.103***	0.065***	0.054***	0.075***	0.095***
	(4.49)	(30.98)	(16.52)	(4.00)	(16.42)	(20.31)
Long-Term Debt/Assets	-3.910***	-0.097	0.139	-1.897***	-0.596***	-0.910***
	(-4.77)	(-1.07)	(0.99)	(-7.65)	(-8.24)	(-8.80)
Total Debt/Capitalization	3.983***	1.108***	1.158**	2.583***	1.638***	1.976***
	(6.04)	(8.63)	(2.14)	(9.40)	(17.93)	(18.19)
Operating Income/Sales	-0.432	-0.082	0.936***	0.258*	-0.044	-0.249***
	(-0.69)	(-0.69)	(4.05)	(1.88)	(-0.81)	(-3.36)
Equity Volatility	0.567	1.097***	0.908***	1.590***	1.210***	1.199***
	(0.86)	(8.49)	(4.04)	(7.19)	(13.98)	(8.76)
Pretax D1	-1.298	-0.275***	-0.158	-1.323***	-0.449***	-0.512***
	(-1.46)	(-3.98)	(-1.02)	(-5.34)	(-6.84)	(-5.89)
Pretax D2	-0.826	-0.256***	-0.010	-1.169***	-0.387***	-0.350***
	(-1.06)	(-4.03)	(-0.17)	(-5.09)	(-6.60)	(-4.78)
Pretax D3	-1.588**	-0.186***	0.044	-1.081***	-0.300***	-0.230***
	(-2.08)	(-2.95)	(0.76)	(-4.76)	(-5.34)	(-3.34)
Pretax D4	0.255	-0.158**	0.071	-1.113***	-0.265***	-0.182***
	(0.28)	(-2.42)	(1.24)	(-4.83)	(-4.72)	(-2.71)
Rating Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	37,487	304,069	40,138	94,894	190,637	96,163
Adj. R^2	0.474	0.504	0.534	0.546	0.565	0.549

Table 5: The Vertical Integration Effect in Covid-19 Pandemic

This table presents the panel regression results of the interaction effect between vertical integration and the Covid-19 pandemic on corporate yield spreads. The dependent variable is the bond yield spread, defined as the difference between corporate bond yield and the corresponding treasury bond yield. The main variable of interest is the interaction term between vertical integration (VI) and Covid-19 pandemic period (Covid). The pandemic period is defined as from February to April of 2020. Firm Covid-19 risk (Covid Risk) is estimated from transcripts of earnings call during the Covid-19 pandemic period (Hassan et al., 2023). Firm supply chain risk is estimated from transcripts of earnings call following Ersahin et al. (2024). The yield spread determinants are based on bond-specific effects (credit ratings, bond illiquidity, maturity in years, issue size and coupon), and firm-specific characteristics (long-term debt to assets, total debt to capitalization, operating income to sales, equity volatility and pretax interest coverage). The pretax interest coverage is further grouped into one of four categories according to Blume et al. (1998). The detailed construction of variables are defined in Appendix A. Industry and time fixed effects are included in all regressions and t-values based on standard errors clustered at the issuer and year level are reported in parentheses. *, ** or *** denotes the significance at the 10%, 5%, or 1% level, respectively.

	(1)	(2)	(3)
VI	-3.538***	-3.265**	-2.350**
	(-2.60)	(-2.38)	(-2.32)
VI * Covid	-2.786**		-1.622**
	(-2.47)		(-2.13)
VI * Covid Risk		-35.190***	
		(-3.16)	
VI * Covid * Supply Chain Risk			-0.164**
			(-2.22)
VI * Supply Chain Risk			-0.177**
			(-2.39)
Covid * Supply Chain Risk			0.003*
			(1.94)
Covid	0.630***	0.642***	0.624***
	(7.40)	(10.68)	(6.06)
Covid Risk		0.32**	
		(2.18)	
Supply Chain Risk			0.002**
			(2.31)
Illiquidity	0.197***	0.196***	0.174***
	(8.42)	(8.03)	(5.10)
Maturity	0.006***	0.006***	0.010***
	(3.76)	(3.80)	(4.91)
Ln [Issue Size]	-0.005	-0.005	-0.034
	(-0.25)	(-0.25)	(-1.43)
Coupon	0.083***	0.083***	0.082***
	(12.82)	(12.56)	(11.49)
Long-Term Debt/Assets	-0.984***	-0.993***	-0.657***
	(-5.08)	(-4.99)	(-3.54)
Total Debt/Capitalization	1.952***	1.949***	2.034***
	(8.42)	(8.21)	(7.43)
Operating Income/Sales	-0.016	0.007	-0.068
	(-0.11)	(0.05)	(-0.55)
Equity Volatility	1.359***	1.324***	1.298***
	(3.97)	(3.74)	(2.91)
Pretax D1	-0.723***	-0.752**	-0.381***
	(-2.63)	(-2.47)	(-3.29)
Pretax D2	-0.591**	-0.621**	-0.286***
	(-2.46)	(-2.33)	(-2.72)
Pretax D3	-0.480**	-0.511**	-0.200**
	(-2.09)	(-2.01)	(-1.99)
Pretax D4	-0.459**	-0.493*	-0.183*
	(-2.03)	(-1.96)	(-1.89)
Rating Dummies	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Month FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Observations	381,694	280,946	381,182
Adj. R^2	0.543	0.539	0.591

Table 6: The Vertical Integration Effect in U.S-China Trade War

This table presents the panel regression results of the interaction effect between vertical integration and the U.S.-China trade war on corporate yield spreads. The dependent variable is the bond yield spread, defined as the difference between corporate bond yield and the corresponding treasury bond yield. The main variable of interest is the interaction term between vertical integration (VI) and trade war indicator variables. We examine two distinct phases of the U.S.-China trade war. The initial phase (TW Phase 1) spans from March to June 2018, while the second phase (TW Phase 2) ranges from July to October 2018. The yield spread determinants are based on bond-specific effects (credit ratings, bond illiquidity, maturity in years, issue size and coupon), and firm-specific characteristics (long-term debt to assets, total debt to capitalization, operating income to sales, equity volatility and pretax interest coverage). The pretax interest coverage is further grouped into one of four categories according to Blume et al. (1998). Input China is the proportion of the estimated value of imported goods from China to the total estimated value of imported goods from the world in 2017, and Input China (Diff) is the ratio of the estimated value of imported differentiated products from China to the total estimated value of imported goods in 2017 (Huang et al., 2023). The detailed construction of variables are defined in Appendix A. Industry and time fixed effects are included in all regressions and t-values based on standard errors clustered at the issuer and year level are reported in parentheses. *, ** or *** denotes the significance at the 10%, 5%, or 1% level, respectively.

	(1)	(2)	(3)	(4)
VI	-3.050**	-3.102**	-3.042**	-3.039**
	(-2.19)	(-2.24)	(-2.15)	(-2.13)
VI * TW Phase 1	-2.801**		0.182	-0.034
	(-2.22)		(0.04)	(-0.01)
VI * TW Phase 2		-0.245		
		(-0.20)		
VI * TW Phase 1 * Input China			-27.257**	
			(-2.16)	
VI * TW Phase 1 * Input China (Diff)				-36.140**
				(-2.28)
TW Phase 1 * Input China			0.231**	
			(1.98)	
TW Phase 1 * Input China (Diff)				0.310**
				(2.22)
TW Phase 1	-0.002		-0.029	-0.028
	(-0.10)		(-0.46)	(-0.45)
TW Phase 2		-0.019		
		(-1.10)		
Illiquidity	0.224***	0.224***	0.224***	0.224***
	(7.14)	(7.13)	(7.14)	(7.14)
Maturity	0.007***	0.007***	0.007***	0.007***
	(3.93)	(3.93)	(3.93)	(3.93)
Ln [Issue Size]	0.028	0.028	0.028	0.028
	(0.98)	(0.98)	(0.98)	(0.98)
Coupon	0.076***	0.076***	0.076***	0.076***
	(9.33)	(9.33)	(9.34)	(9.34)
Long-Term Debt/Assets	-0.915***	-0.914***	-0.916***	-0.917***
	(-3.71)	(-3.70)	(-3.71)	(-3.71)
Total Debt/Capitalization	1.983***	1.984***	1.984***	1.985***
	(6.90)	(6.91)	(6.91)	(6.91)
Operating Income/Sales	0.217	0.217	0.217	0.217
	(1.27)	(1.27)	(1.27)	(1.27)
Equity Volatility	1.634***	1.635***	1.634***	1.634***
	(3.83)	(3.83)	(3.83)	(3.83)
Pretax D1	-0.861**	-0.862**	-0.861**	-0.861**
	(-2.14)	(-2.14)	(-2.14)	(-2.14)
Pretax D2	-0.677**	-0.677**	-0.676**	-0.677**
	(-1.99)	(-1.99)	(-1.99)	(-1.99)
Pretax D3	-0.538*	-0.538*	-0.538*	-0.538*
	(-1.69)	(-1.69)	(-1.69)	(-1.69)
Pretax D4	-0.535*	-0.535*	-0.535*	-0.534*
	(-1.71)	(-1.71)	(-1.71)	(-1.71)
Rating Dummies	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Observations	311,204	311,204	311,204	311,204
Adj. R^2	0.523	0.523	0.523	0.523

Table 7: Vertical Integration and Firm Inventory

This table presents the panel regression results of the interaction effect between vertical integration and inventory level on corporate yield spreads. The dependent variable is the bond yield spread, defined as the difference between corporate bond yield and the corresponding treasury bond yield. The main variables of interest is vertical integration (VI) estimated from Frésard et al. (2020). Inventory to assets ratio is defined as the industry-adjusted inventory to assets ratio from the previous quarter for each bond observation. We define a high (low) inventory dummy as 1 if inventory to assets ratio falls within the top (bottom) quartile of the sample for each month and 0 otherwise. The yield spread determinants are based on bond-specific effects (credit ratings, bond illiquidity, maturity in years, issue size and coupon), and firm-specific characteristics (long-term debt to assets, total debt to capitalization, operating income to sales, equity volatility and pretax interest coverage dummies). We include rating dummy variables as a fixed effect to capture variations across different rating categories. The detailed construction of variables are defined in Appendix A. Industry and time fixed effects are included in all regressions and t-values based on standard errors clustered at the issuer and year level are reported in parentheses. *, ** or *** denotes the significance at the 10%, 5%, or 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
VI	-3.733***	-2.031**	-3.672***	-1.890**	-3.685***	-2.026**
	(-2.86)	(-2.22)	(-2.80)	(-2.05)	(-2.82)	(-2.20)
VI * High INVT	1.495		1.498		1.547	
	(0.89)		(0.88)		(0.91)	
VI * Low INVT		-5.591**		-6.118***		-5.400**
		(-2.54)		(-2.76)		(-2.44)
VI * High INVT * Covid			2.187			
			(0.69)			
VI * Low INVT * Covid				11.942***		
				(3.39)		
VI * High INVT * TW Phase 1					-2.516	
					(-0.92)	
VI * Low INVT * TW Phase 1						-7.528***
						(-2.86)
VI * Covid			-2.345**	-2.866***		
			(-2.29)	(-2.75)		
VI * Trade War					-2.963**	-1.204*
					(-2.22)	(-1.88)
High INVT * Covid			0.015			
			(0.08)			
Low INVT * Covid				0.102**		
				(2.15)		
High INVT * TW Phase 1					0.039	
					(0.45)	
Low INVT * TW Phase 1						0.136**
						(2.51)
High INVT	-0.078		-0.079		-0.079	
	(-1.62)		(-1.63)		(-1.62)	
Low INVT		0.020		0.034		0.018
		(0.36)		(0.61)		(0.32)
Covid			0.620***	0.752***		
			(5.53)	(8.23)		
TW Phase 1					0.008	-0.013
					(0.44)	(-0.83)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	381,583	381,583	381,583	381,583	381,583	381,583
Adj. R^2	0.539	0.539	0.539	0.540	0.539	0.539

Table 8: Vertical Integration and Production Market Competition

This table presents the panel regression results of the interaction effect between vertical integration and product market competition on corporate yield spreads. The dependent variable is the bond yield spread, defined as the difference between corporate bond yield and the corresponding treasury bond yield. The main variables of interest is vertical integration (VI) estimated from Frésard et al. (2020). Firm's product market competition is assessed through two main metrics: total product similarity and product pricing power, as estimated by Hoberg and Phillips (2016). We define a high (low) product similarity dummy as 1 if the product similarity score falls within the top (bottom) quartile of the sample for each month and 0 otherwise. Similarly, we define a high (low) pricing power dummy as 1 if the industry concentration (HHI) score falls within the top (bottom) quartile of the sample for each month and zero otherwise. The yield spread determinants are based on bond-specific effects (credit ratings, bond illiquidity, maturity in years, issue size and coupon), and firm-specific characteristics (long-term debt to assets, total debt to capitalization, operating income to sales, equity volatility and pretax interest coverage dummies). We include rating dummy variables as a fixed effect to capture variations across different rating categories. The detailed construction of variables are defined in Appendix A. Industry and time fixed effects are included in all regressions and t-values based on standard errors clustered at the issuer and year level are reported in parentheses. *, ** or *** denotes the significance at the 10%, 5%, or 1% level, respectively.

	(1)	(2)	(3)	(4)
VI	-3.863***	-1.694**	-1.990**	-2.928***
	(-2.94)	(-2.03)	(-2.19)	(-2.77)
VI * High Product Similarity	3.194			
	(0.86)			
VI * Low Product Similarity		-5.896***		
		(-3.16)		
VI * High Product Pricing Power			-4.194***	
			(-2.79)	
VI * Low Product Pricing Power				-1.200
				(-0.37)
High Product Similarity	0.057			
	(1.43)			
Low Product Similarity		0.061		
		(1.31)		
High Product Pricing Power			0.001	
			(0.03)	
Low Product Pricing Power				0.178**
				(2.45)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Observations	381,694	381,694	381,694	381,694
Adj. R^2	0.539	0.539	0.539	0.539

Figure 1: Timeline of Global Supply Chains and Major Disruption Events

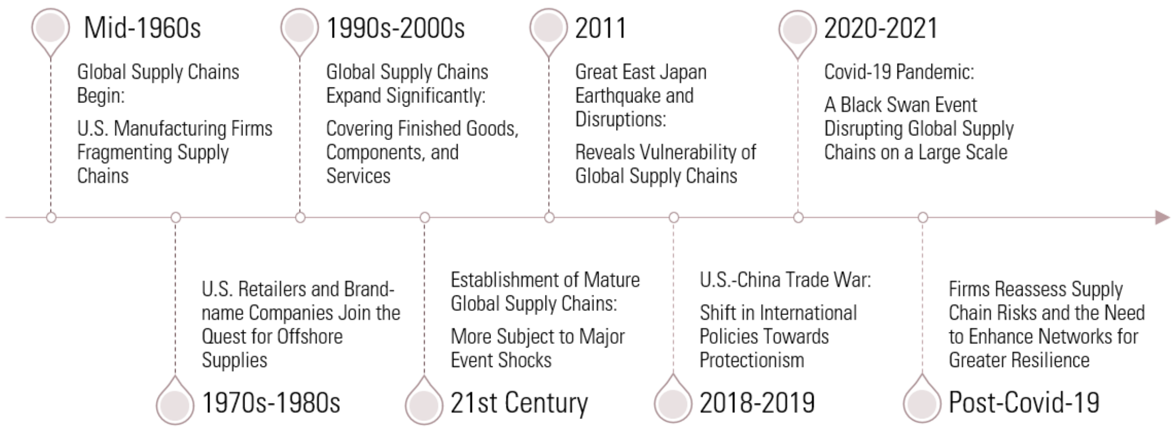

Figure 1 presents a flow chart illustrating the evolution of global supply chains from the mid-1960s to the post-Covid-19 era, outlining key milestones and events shaping their trajectory. It captures the historical evolution, demonstrating how global supply chains adapt and reassess continuously in response to significant events(Engardio et al., 2005; Constantinescu et al., 2020; Carvalho et al., 2021; Hass and Denmark, 2020).

Figure 2: Comparative Analysis of Vertical Integration: Tesla vs. Competitors

		Tesla	Competitors
Tesla's Vertical Integration	Auto	Cars, Trucks, Semi	BMW, Ford, GM, etc.
		Powertrain	Bosch, Mitsubishi
		Tesla Service	Dealerships
		Seats	Faurecia, Lear Corp, Recaro
		Part design	Bosch
	Energy	Superchargers	Electrify America, ChargePoint, Gas Stations
		Solar Panels/Roof	SunPower, Roofing shingles, etc.
		Powerwall	Panasonic EverVolt, Generac
		Grid services/Powerpack	Utility companies
		Battery design/production	Panasonic, LG Chem
	Information Technology (IT)	Infotainment	Apple Carplay, Andriod Auto
		FSD chip	Nvidia
		Dojo	Goole ML services, Intel's Aurora's ExaFLOP
		Autopilot/FSD	Waymo, MobileEye, Cruise
		Tesla Vision	LiDAR, HD maps
	Other	Insurance	Geico, Progressive, etc.
		Robo Taxi (in development)	Uber, Lyft

*Based on charts by Gabe Rodriguez Morrison; not affiliated with Tesla.

Figure 2 illustrates Tesla's diverse business segments and their respective competitors, providing a comprehensive overview of the company's vertical integration across automotive, energy, and information technology industries. It highlights key competitors in each sector, ranging from traditional automotive rivals in the auto division to competitors in energy solutions and information technology. This comprehensive figure visually represents Tesla's competitive positioning across its diverse business lines, showcasing how the vertical integration approach facilitates rapid learning and retained control over key design details (Perkins and Murmann, 2018).

Appendix A: Variable Descriptions

The variables used in the paper are listed below (with Compustat data items in parentheses).

Variable	Definition
Main variables	
Vertical Integration	Measures the degree to which a firm provides products or services that are vertically related (Frésard et al., 2020).
Yield Spreads	Defined as the difference between corporate bond yield and the corresponding Treasury bond yield with a comparable maturity.
Control variables	
Illiquidity	Roll's illiquidity measure. Roll (1984) finds that the percentage bis-ask spread equals two times the square roo of minus the covariance between consecutive returns: $$\text{Roll}_t = 2\sqrt{-cov(R_{t,k}, , R_{t,k-1})}$$ where $R_{t,k}$ and $R_{t,k-1}$ are returns to two consecutive trades indexed by k and $k-1$, the covariance is computed over all trades during a 21-day window ending on day t. We require at least one trade during the 21-day window for the daily Roll measure to be valid. Then the monthly Roll measure is the median of all valid daily Roll measures during the month.
Credit Rating	The bond's numerical credit rating based on the following letter rating conversion scheme: AAA=1, AA+=2, ..., C=21 and D=22. We mainly use the Standard & Poor's (S&P) rating from the FISD; when it is not available, we use Moody's or Fitch rating when possible and drop bonds whose ratings are not identified.
Maturity	Bond's time to maturity in years
Issue Size	The amount of the bond issue.
Coupon	Bond's annual coupon rate in percentage.
Long-term Debt/Assets	Ratio of long-term debt (dltt) to book assets (at)
Operating Income/Sales	Ratio of operating income (oibdp) to sales (sale).
Equity Volatility	Equity volatility is estimated as the variance of the issuer's daily excess stock returns over the past 252 days from the fiscal year t.
Pretax Interest Coverage	Ratio of operating income after depreciation (oiadp) plus interest expense (xint) to interest expense.
Pretax D1	First increment of pretax interest coverage ratio between 0 and 5, using the procedure outlined in Blume et al. (1998).
Pretax D2	Second increment of pretax interest coverage ratio between 5 and 10, using the procedure outlined in Blume et al. (1998).
Pretax D3	Third increment of pretax interest coverage ratio between 10 and 20, using the procedure outlined in Blume et al. (1998).
Pretax D4	Fourth increment of pretax interest coverage ratio between 20 and 100, using the procedure outlined in Blume et al. (1998).
Other variables	
Supply Chain Risk	Firm supply chain risk measure estimated from transcripts of earning calls (Ersahin et al., 2024).
Covid Risk	Firm Covid-19 risk measure estimated from transcripts of earning calls (Hassan et al., 2023).

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Variable	**Definition**
Input China	The proportion of imported good from China, measured as the ratio of a firm's input from China to its total imported inputs (Huang et al., 2023).
Input China (Diff)	The proportion of imported differentiated good from China, measured as the ratio of a firm's differentiated input from China to its total imported inputs (Huang et al., 2023).
Inventory/Assets	Industry-adjusted inventory to asset ratio, estimated as the difference between the raw inventory to assets ratio (invt/at) and medians for two-digit industries.
Product Similarity	Product similarity scores obtained by parsing the product descriptions from the firm 10Ks customized to each firm based on TNIC data (Hoberg and Phillips, 2016).
Product Pricing Power	Firm-level Text-based Network Industry Classifications (TNIC) HHI measure of industry concentration (Hoberg and Phillips, 2016).

Appendix B: Supplementary Tables

Table B1: Sample Distribution by Year

This table reports the sample distribution by year from July 2002 to June 2020. It includes the total number of observations, the number of bonds and issuers for each year, as well as the average vertical integration score and yield spreads (%).

Year	# of Observations	# of Bonds	# of Bond Issuers	Vertical Integration	Yield Spreads
2002	9,830	2,412	397	0.0176	3.26
2003	20,714	2,785	422	0.0177	1.91
2004	18,979	2,447	407	0.0170	1.14
2005	16,451	2,147	388	0.0166	1.29
2006	15,376	1,966	373	0.0166	1.40
2007	14,016	1,918	372	0.0166	1.61
2008	14,429	1,864	351	0.0158	3.75
2009	17,048	2,058	359	0.0155	3.42
2010	17,969	2,173	379	0.0152	1.55
2011	19,045	2,177	380	0.0154	1.44
2012	21,685	2,596	397	0.0141	1.49
2013	24,454	2,753	380	0.0129	1.22
2014	25,571	2,859	387	0.0130	1.02
2015	27,170	3,033	397	0.0129	1.46
2016	28,287	3,091	383	0.0120	1.58
2017	27,738	3,065	365	0.0121	1.05
2018	29,280	3,196	361	0.0119	1.19
2019	30,271	3,270	360	0.0119	1.22
2020	15,741	3,260	345	0.0126	1.99

Table B2: Industry Level Supply Chain Risk

This table reports the top and bottom 10 industries in terms of overall supply chain risk. Industry-year average of firms' supply chain risk is used to rank the industries.

SIC2	Top 10 industries	SIC2	Bottom 10 industries
20	Food and Kindred Products	21	Tobacco Products
30	Rubber & Miscellaneous Plastic Products	23	Apparel, Finished Products from Fabrics & Similar Materials
33	Primary Metal Industries	27	Printing & Publishing
35	Industrial Machinery & Equipment	39	Miscellaneous Manufacturing Industries
36	Electronic & Other Electric Equipment	48	Communications
37	Transportation Equipment	53	General Merchandise Stores
42	Trucking & Warehousing	56	Apparel and Accessory Stores
44	Water Transportation	72	Personal Services
52	Building Materials, Hardware, Garden Supplies & Mobile Homes	79	Amusement & Recreation Services
75	Auto Repair, Services, & Parking	80	Health Services