Supply Chain Disruptions and Firm Outcomes

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Abstract

This paper examines how firms' exposure to supply chain disruptions (SCD) affects firm outcomes in the EU. Exploiting heterogeneous responses where each country imposes work place closures during the pandemic as a shock to global SCD, we provide empirical evidence that firms in industries that rely more on foreign inputs experience a significant decline in their sales compared to other firms. Highly leveraged firms suffer less than lowly leveraged firms during the pandemic because loans from banks seem to signal firms' reputation and help mitigate the effect of SCD. Our results also indicate that declines in firm sales are more pronounced for small and medium sized firms. Lowly diversified firms and firms that source their inputs from far distant partners are more vulnerable to global supply disruptions.

JEL-Codes: G21, G28, K11.

Keywords: supply chain, pandemic, firm sales.

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1 Introduction

The production of goods and services nowadays is organized around complex, global, and interconnected supply chains (Carvalho et al., 2021). While this process could bring about a substantive efficiency gains (Halpern et al., 2015), regional disruptions to the orderly flow of goods and services could trigger systemic risk around the world. Although there is growing attention on how supply chain disruptions affect the economy (Baldwin and Freeman, 2021), empirical evidence at the firm level has been scant. In this paper, we fill this important void and ask how firms' exposure to global supply chain disruptions affect firm outcome in the EU. Exploiting the stringency of workplace closures during the pandemic as a shock to the global supply chain, we provide evidence on the role of supply chain disruption for the transmission of shocks from one country to industries and firms in other countries.

To formulate answers to our research question, we rely on three main data sets. First, we exploit the dataset from Amadeus that contains firm financial information for approximately 1.6 million firms in 17 EU economies between 2018 and 2020 in all industries of the economy. For each firm-year, we observe a set of firm-level characteristics such as size, leverage, liquidity and solvency. Second, based on each firm's industry and location, we are able to obtain some measures on its exposure to the global supply chain using the OECD inter-country input-output tables on how much its industry uses foreign inputs to produce total final outputs. Third, we measure supply chain disruptions during the pandemic using the Oxford workplace closure stringency index of the country of inputs. [1] The underlying reason is intuitive, when a country that provides intermediate goods to an industry in another country imposes restrictions on workplace closures, the industry of the home country may face a shortage of these intermediate goods which can affect firm outcomes along this supply chain.

Using difference-in-differences estimation, we examine whether supply chain disruptions have an effect on firms by comparing the sales growth of highly exposed firms to global supply chains to a group of control firms that are not exposed much to

[1] The stringency index is normalised to a value ranging from 0 to 100 (100 = strictest).

global supply chains. We define highly exposed firms as firm with the ratio of inputs from other countries over total outputs of its industry above the 75th percentile within its country exposure. We find that on average, when a country of suppliers increases its stringency on workplace closures by one standard deviation during the pandemic, sales growth of a highly exposed firm in the home country declines by roughly 0.5 percentage points (14% compared to the mean of sales growth of lowly exposed firms). The result is similar when we use a continuous treatment measure, that is, the ratio of total foreign inputs over total outputs of a firm's industry.

Moreover, by exploiting a large sample of EU firms, we are able to track and trace the findings across different firm characteristics. Specifically, we find that unlike a financial crisis, the pandemic is a liquidity crisis where highly leveraged firms are better off compared to lowly leverage firms due to their banking relationships. Firms that borrow more from banks experience a smaller decline in sales growth compared to firms that borrow less from banks. In terms of firm size, we find evidence that the decline in firm sales is more pronounced among small firms and firms that have a lower number of employees. Further evidence shows that firms which are less concentrated in their sources of foreign inputs and firms that source their inputs from less distant partners are more resilient to disruptions. Taken together, while our findings provide substantial evidence on the effect of supply chain disruptions, they also suggest that having a broad network of suppliers from a number of countries reduces the effect of a global disruption.

The setting of our study provides some advantages. First, the EU economy setting greatly improves identification since there are many sectors that have become increasingly complex with further fragmentation of production enabled by technological change and globalization. Second, our time period is also chosen to not overlap with the previous crisis to closely capture the nature of the pandemic shock in 2020.

This study is important for three reasons. First, the paper extends and complements a growing literature that emphasizes the role of supply chain as a mechanism for propagation and amplification of shocks. Carvalho et al. (2021) provides a quantification of the role of input-output linkages by showing that supply disruption caused by the Great east Japan earthquake propagated upstream and downstream along supply chains,

affecting its direct and indirect firms. Barrot et al. (2021) highlights the important implications of input-output analysis for understanding the propagation of epidemics in production network, and their associated overall macroeconomic impact. In spite of their theoretical plausibility, credible identification of the role of supply chain disruption has remained largely unexplored. Thus, we provide micro-level evidence on the effect of global supply chain disruptions on firm outcomes in the EU.

Second, this paper contributes to a growing body of work on the economic impact of the Covid-19 pandemic. A majority of these studies shows the effect of the pandemic on firms and the real economy in one particular country such as Acemoglu et al. (2020); Alon et al. (2020); Bonadio et al. (2021); Guerrieri et al. (2020), and Kaplan et al. (2020). Li et al. (2020) document that banks were able to accommodate high liquidity demands of firms during the pandemic because of the coincident inflows of funds to banks from both the Federal Reserve's liquidity injection programs and from depositors. Using Covid-19 as a global supply chain shock, Ersahin et al. (2022) find that firms that face higher supply chain risk establish relationships with closer and domestic suppliers and with suppliers that are industry leaders. In addition, firms that do not face financial constraints are more likely to engage in vertical mergers and acquisitions when they face supply chain risk. We depart from this literature and provide one of the first evidences on the supply chain disruption on firm sales during the pandemic in a multi-country setting.

Third, our finding complements the literature on the uniqueness of bank loans. Previous studies have documented that receiving bank loans, especially when these loans are from existing banking relationship, signals positive firm development to the stock market and other investors (James, 1987; Lamont, 1995). Diamond (1991) provides a model that explains how firms choose high-cost bank debt to signal its reputation with suppliers and customers. Chod et al. (2020) develop a theory that suggests signalling a firm's fundamental quality to lenders through adoption of block chain technology leads to less costly operation distortions compared to signalling through loan requests. However, the literature on debt overhang highlights that during financial crisis, firms with higher debt level reduce their investment more than other firms (Myers, 1977; Hennessy, 2004; Kalemli-Özcan et al., 2018). In contrast to these papers, we show that during a liquidity

crisis, firms with access to debt markets, especially, firms that borrow more from banks are less likely to suffer a decline in sales growth.

Our paper also has important policy implications because it provides insights on the cost of globalisation during a global shock. Specifically, we document how firm exposure in a particular sector to the global supply chain affects its outcomes.

2 Institutional Background

2.1 Global Supply Chain and the Reliance on Foreign Inputs

Our aim is to investigate how disruption to global supply chain affects firm outcomes. To do so, we first measure the reliance of each firm to the global supply chain. Data suggest an overall increase in the reliance on foreign inputs of each country over time. For example, Li et al. (2019) show that in 2017, GSC activities contribute around 12.9% to the world GDP, a massive increase from that of 9.6% in 1995. To measure the participation to the GSC, the literature offers two main approaches. The first approach relies on a "tear down" analysis that assign the value of individual components to source companies and their countries. Using micro level data on a product or a firm, it evaluates how shocks to a stage in the production chain provokes firm responses. Xing and Detert (2010), for instance, examine the case of iPhone production and find that value added by China contributed 3.6% to the final value of iPhone exports from the US in 2009, the remainder of the value added was from Germany, Japan, Korea, the US and other countries. Dedrick et al. (2010) discuss the case of iPod production and document a pattern of specialization among different countries where more advanced economies provide high-skilled labor and capital and emerging countries contribute cheap labour that is vital to the production chain but receive less rewards. Jacobs et al. (2022) present empirical evidence of the stock market reaction to the US government ban on US firms from supplying to ZTE, a Chinese telecommunications manufacturer. While this approach can gives researchers detailed information to establish the causality between shocks to GSC and firms, the focus on specific firms and products means these studies may not be representative to understand

the broader role of production networks and inter-industry and inter-countries linkages in the whole value creation process.

The second approach exploits inter-country input-output (ICIO) tables and discusses the role of a country or industry in the global supply chains. In this approach, each industry in a country acts as an upstream supplier and provides inputs to the final product of another industry in the destination country. This methodology dates back to Leontief (1936) who shows that the complex linkages among different industries in an economy can be expressed as various inter-industry transactions into chessboard-type matrices. The advantage of this approach is that one can trace all the foreign inputs that are directly and indirectly needed to produce final goods and show how prone the domestic production chain is to international fragmentation.

In the spirit of Krugman et al. (1995) and Timmer et al. (2014), we "slice up" the global supply chain and measure how much an industry in a home country depends on foreign inputs using the following equation:

$$SCI_{ci} = \frac{\sum_{k \neq c}^{N} Inputs_{ki}}{Outputs_{ci}}, \tag{1}$$

where indices i, c, k refer to industry, home country, and foreign country of inputs, respectively. SCI_{ci} is the total amount of input that industry i needs from foreign countries (i.e., all countries k that are different from home country c in our dataset) scaled by the total output that the industry i in the home country c produces.

In this paper, we collect information on foreign inputs and industry outputs of 45 industries across 17 EU countries from the OECD inter-country input-output tables for 2018. Figure 1 shows that on average, to produce 1 unit of final output, each EU country in our sample needs around 0.45 to 0.75 units of input from other industries in other countries. While countries like Sweden and Norway seem to be less reliant, Belgium, Poland, Czech Republic, and Austria rely quite heavily on foreign inputs.

[Insert Figure 1]

Table 2 decomposes the level of reliance on foreign inputs of each country into 45 industries. Overall, energy intensive industries such as the production of Coke and

refined petroleum, Chemical and Chemical Products, and Manufacturing and Repairs need more foreign inputs to deliver final outputs more than other industries. Among others, Food production, Water Transportation, and Air Transportation also rely heavily on foreign inputs.

[Insert Table 2]

2.2 Covid-19 and Global Supply Chain Disruptions

Previously, researchers have focused on the global supply chain disruptions caused by natural disasters, such as storms, earthquakes, volcanic eruptions, floods, and landslides. During the recent pandemic, as the spread and magnitude of COVID-19 is by far greater than any other supply chain disruptions in recent decades (Araz et al., 2020), academics have paid tremendous attention to the COVID-19 crisis.

There are two important measures that have significantly affected Supply Chain operations worldwide in fighting the virus. First, the persistent social distancing measures and second, lockdowns, especially the lockdown of workplaces. Since these actions have been implemented by almost every country, whether severely hit by the virus or not, to ensure that the spread of the virus is curtailed, the scale of disruption in supply chain it causes is to the global level.

In this paper, we use the closure of workplaces, the Oxford stringency index, developed by Hale et al. (2021) to capture the severity of the supply chain disruption. This index varies between 0 and 100 whereby 100 represents the most restrictive lockdown of workplaces in a country. Our approach shares similarity with Ersahin et al. (2022) and Li et al. (2020). Specifically, to measure supply chain disruptions, we calculate the weighted average of workplace closure stringency index of all foreign countries that provide inputs for each industry in the home country. To account for the difference in the importance of each foreign country of inputs for each industry in the home country, we use the total amount of inputs provided by each foreign country as the weight to calculate the Weighted Average Stringency Index as

$$\overline{StringencyIndex}_{ict} = \frac{\sum_{k \neq c}^{N} StringencyIndex_{kt} * Inputs_{ick}}{\sum_{k \neq c}^{N} Inputs_{ick}}, \quad (2)$$

where indices i, c, k, t refer to industry, home country, foreign country of inputs, and time, respectively. $\overline{StringencyIndex}_{ict}$ is the weighted stringency index respresenting the distruption in supply chain that industry i in the home country c at time t faces. This index equals 0 for the year 2018 and 2019 where the pandemic has not happened. $Inputs_{ick}$ is the amount of inputs in dollars that industry i in the home country c needs from the foreign country k in 2018 (pre-shock figure from the OECD ICIO table). $StringencyIndex_{kt}$ is the Workplace Closure Stringency Index of the foreign country k at time t.

Figure 2 shows how each EU country c is exposed to the workplace closure measurements of all other foreign countries k that provide inputs for country c.

[Insert Figure 2]

2.3 Supply chain disruption and firm outcomes

Theories offer some insights into how supply chain disruptions affects firms. Hopp et al. (2008) argue that supply chain disruptions can lead to both tactical (e.g., loss of short term sales) and strategic (e.g. loss of long term market share) consequences. They model the impact of regional supply disruptions on competing supply chains and describe generic strategies which consist of two stages, the preparation stages where firms detect the issue of supply chain risk, and the response stage where firms response to disruptions. The post-disruption responses of firms from Hopp et al. (2008) have implications for our paper and suggest the first hypothesis:

H1: Firms that are exposed more to supply chain disruptions suffer lower sales growth compared êith firms that are exposed less to supply chain disruptions.

Can firms mitigate the effect of supply chain disruptions? Previous literature on managing supply chain risk has focused on diversifying supply sources and frequently stress testing the supply chain risk (Chopra and Sodhi, 2004). However, the disruption

during the recent pandemic is not caused by idiosyncratic shocks by some suppliers but a global systemic risk where almost all firms are hit. In such circumstances, suppliers have to choose the best customers to send their limited goods to to maintain longer term relationship and avoid delayed payments.

We focus our next analysis on the role of bank loans and ask whether obtaining bank loans can mitigate the risk of slower growth during the pandemic. The underlying reason for our focus on bank debt is intuitive: The most notable effort of policy makers around the world to limit the financial consequences for firms during the Covid-19 crisis has been providing more credit to firms through bank lending channels. For example, Li et al. (2020) show that firms demand massive cash to pay their employees, suppliers, and creditors and draw up all credit lines that they have with banks.

The literature on the role of debt provides mixed prediction for our research question. On the one hand, obtaining credit from banks may give firms, especially smaller and new firms, a reputation advantage because it signals the creditworthiness of firms and the payment ability. A theory of the choice of firm debt by Diamond (1991) suggests that firms build reputation by endogenously deciding on taking on costly bank-monitored debt. James (1987); Lamont (1995) document a positive effect of obtaining bank loans on firm stock performance. However, the debt overhang literature documents that firms with higher debt level reduce their investment more than other firms (Myers, 1977; Hennessy, 2004; Kalemli-Özcan et al., 2018). Thus, we formulate our second hypothesis as follows:

H2: Bank loans help firms to mitigate the effect of supply chain disruption.

Accepting this hypothesis means that our result is in line with the uniqueness of bank loans literature whereas rejecting it supports the findings of the debt overhang literature.

3 Data Collection

The firm data is from Bureau Van Dijk Amadeus which contains annual financial information, stock prices, ownership, and subsidiaries information for 95% of all public and private companies in European countries. We collect data for 3 years between 2018 and 2020. Based on each firm's industry and location, we match the firm data with the OECD inter-country input-output tables on how much its sector uses foreign inputs to produce total final output.

The supply chain linkages is collected from the OECD, the Inter-Country Input-Output (ICIO) Table of 2018. In this table, we are able to extract information on how much inputs each industry in an EU country needs from another industry in another country. In total, the ICIO covers 45 sectors and 66 input countries plus the rest of the world.

Treated and Control groups are based on the SCI. We classify treated firms as firms that belong to an industry that relies heavily on foreign inputs (highly exposed firms) and control firms as firms that belong to a less exposed industry (lowly exposed firms). We first define highly exposed firms as firms whose foreign input reliance SCI at the industry level is above the 75th percentile of all industries in a country. Later on, instead of using the dummy for treated and control firms, we check the sensitivity of the results by using the continous measurement of SCI. We use the 2018 pre-pandemic data to measure the SCI to ensure that we control for existing observable variations between treated and control firms that may determine the effect while reducing possible selection bias in the sample.

Stringency Index that measures the level of supply chain disruption is from Oxford stringency index developed by Hale et al. (2021). We collect the daily data from Hale et al. (2021) and calculate the mean of stringency index in 2020 for all countries to merge it to our yearly data. We treat the Stringency Index in 2018 and 2019 as 0 because no workplace lockdown has taken place in these two years.

Table 1 shows variable definitions and Table 3 reports summary statistics of our main variables. In addition, Table A1 shows the raw numbers of active firms in each EU country from Amadeus. In total, there were 2,284,565 firms. As our main variable of interest is

firm sales growth, we require that all firms in our sample report firm sales in all three years. After this cleaning process, we obtain the final data set for 1,605,007 firms (70% of all firms reported in Amadeus) with 16.8% of firms belong to the highly exposed group. All variables are winsorized at the 1th and 99th percentile to rule out the concern on outliers. On average, the annual EU firm sales growth is around 3.8%. Figure A1 shows the distribution of firm sales and illustrates that a majority of firms in our data set are smaller firms with total sales of less than 2 million EUR.

[Insert Table 3]

4 Identification strategy and empirical results

To test our first hypothesis, we employ a difference-in-differences (DiD) estimation to establish a causal relationship between supply chain disruptions and firm sales growth. We estimate the equation

$$\begin{aligned} Y_{fict} = {} & \beta_1 HighlyExposed_{fci} \times \overline{StringencyIndex_{ict}} \\ & + \beta_2 \overline{StringencyIndex_{ict}} \\ & + \gamma_1 C_{ct} + \gamma_2 F_{it} \\ & + \zeta_f + \zeta_{it} + \varepsilon_{fict}, \end{aligned} \tag{3}$$

where Y_{fict} is the growth rate of firm sales for firm f in industry i locating in country c at time t. $HighlyExposed_{fci}$ is a dummy variable that equals 1 if the SCI of its industry exceeds the 75th percentile in the distribution of SCI in the home country c in 2018. $\overline{StringencyIndex_{ict}}$ is the Weighted Average of the workplace closure index at time t of all input countries that provide goods to industry i in country c with the amount of inputs from each input country used as weights as in Equation (2). C_{ct} is a vector of home country characteristics including work place stringency index of the home country c.

We saturate the equation with firm fixed-effects ζ_f to control for factors that are firm specific and time invariant and industry-time fixed-effects ζ_{it} to control for industry specific factors that vary over time. We cluster our standard errors at the firm level.

The main coefficient of interest is β_1 which shows how highly exposed firms to the global supply chain affected by the disruption caused by the pandemic compared to lowly exposed firms. Since our variation in treatment status comes from the industry level and the supply chain disruption is from cross industry, cross country, and cross time variation, we are not able to comment in details about the effect across firm characteristics at this stage. For example, both BMW and Volkswagen in Germany would face the same level of supply chain disruption in our settings because they both have the headquarters in Germany and belong to the Automobile industry.

In the next step, we investigate the heterogeneity in our findings across several firm characteristics. In particular, to test the second hypothesis, we collect information on firm leverage and the amount of bank debt and estimate Equation (3) separately for the sample of firms with low leverage, medium leverage, and high leverage ratios, as well as for the sample of firms with low bank debt, medium bank debt, and high bank debt.

4.1 Parallel trends

Critical to our identification strategy is the exogeneity of the pandemic with respect to firm sales growth. Since the pandemic is an unprecedented event, it is plausible that firms are caught by surprise with the effect of supply chain disruptions caused by the pandemic. However, the validity of our DiD design still depends on the asumption that the treated and control groups would follow the same trend in the absence of treatment. Using information on firm characteristics in the pre-shock year of 2018, we follow the approach by Imbens and Wooldridge (2009) and calculate the normalized differences by treatment status in various firm characteristics. As suggested by Imbens and Wooldridge (2009), an absolute normalized difference smaller than 0.25 indicates that there is no significant difference between treated and control groups. Table 4 shows that highly exposed and lowly exposed firms are not significantly different in firm size, return on total assets, leverage ratios, solvency ratios, and liquidity ratios.

[Insert Table 4]

4.2 Evidence on the effect of supply chain disruptions

Table 5 presents the estimate of equation (3) using firm sales growth as the dependent variable. We first present the result without any control variables in Column 1. Column 2 includes firm control variables such as firm size, return on assets, solvency, leverage, and liquidity ratios. We exclude the year 2019 from our sample in Column 3 and 4 because China started some measurements to contain the Covid-19 virus in the last month of 2019 and no data is available to sufficiently measure the workplace closure at that time. We perform a collapsed DiD in Column 5 and 6 where we take the difference of all variables between 2020 and 2018 and run a cross sectional regression. Taking these differences mean we effectively control for all differences in firm characteristics over time and the coefficient β_1 shows the effect of supply chain disruption on firm sales growth.

[Insert Table 5]

Across all specifications, we find that on aggregate, there is a significant evidence on the effect of global supply chain disruptions. An one standard deviation (26.6) increase in the workplace closure stringency index of an input country reduces sale growth of highly exposed firms in the home country by 0.5 percentage points (26.6*0.02) compared to lowly exposed firm. To understand the economic magnitude, we compare the estimated coefficient with the average sale growth of lowly exposed firms which is 3.5% in our sample. Thus, our estimated coefficient represents a 14% decline in firm sale growth of highly exposed firms, relative to the counterfactual. This decline only decreases moderately when the firm controls are included suggesting that our findings are unlikely to be biased by omitted variables. To some extent, our result is inline with Bonadio et al. (2021) who find that the pandemic at home country causes on average 29.6% GDP drop whereas around 23.3% of the contraction of GDP comes from foreign shocks. Our result is different in the sense that we zoom in the shrink of the economy to the firm level and focus more on the foreign shocks.

4.3 The role of debt

Are there any firm characteristics that help mitigate the effect of supply chain disruptions? We tackle this question by looking at the heterogeneity in our findings from the baseline analysis across several groups of firms. We focus our analysis on the role of leverage and bank debt because it reflects the financial strength of firms. Highly leveraged firms may suffer more because of debt overhang issues (Hennessy, 2004; Kalemli-Özcan et al., 2018). However, one could also argue that one of the most notable effort of policy makers around the world during the pandemic was to limit the financial consequences for firms through lending channels and having access to external finance can help firms signal their repayment ability and reputation to overcome the pandemic.

[Insert Table 6]

In Table 6, we split our sample by firm total debt ratios (i.e., the ratio of total short-term and long-term debt over total assets). Column 1 reveals that there is no significant effect of supply chain disruption on highly exposed firms compared to lowly exposed firms among the sample of highly leveraged firms. We define highly leveraged firms as firms whose leverage ratios are above the 75th percentile of the distribution. Among firms with leverage ratios between the 25th percentile and the 75th percentile of the distribution (medium leverage level), an increase of one standard deviation in foreign stringency index leads to 0.57 percentage points decline (26.6*0.0216) in sales growth of treated firms compared to the counterfactual. Using the mean of sales growth among control firms, this result implies a decline of 16.4%. For lowly leveraged firms, Column 3 of Table 6 shows that the effect is even stronger, an increase of one standard deviation in foreign stringency index leads to 1.18 percentage points decline (or 32% decline) in sales growth of a treated firm compared to the counter factual. Chow tests in Appendix Table A2 confirm that these coefficients in three columns of Table 6 are significantly different from each other. Taken together, leverage seems to help mitigate the effect of supply chain disruption during the pandemic.

As the main source of finance for EU firms is from banks, in the next step, we examine whether bank debt helps firms mitigate the effect of supply chain disruption. Table 7

paints a similar picture that Table 6 shows. Firms with high level of bank debt suffer the least during the pandemic whereas the effect is strongest for firms with low bank-debt. We view our results as an evidence for the uniqueness of bank loans as in James (1987); Diamond (1991), and Lamont (1995).

[Insert Table 7]

5 Further evidence and robustness checks

Firm size We examine the heterogeneity in our findings across firm size by looking at the sample of firms with different level of total assets, and firms with more and less number of employees. We find evidence that the decline in firm's sales is more pronounced among small and medium firms and firms with lower number of employees.

[Insert Table 8]

The role of diversitication and distance We additionally examine several ways firms can improve resilience to the supply chain disruption: diversification in the source of intermediate goods to produce final outputs and transportation cost. The diversification measure was measured by the Herfindahl-Hirschman Index (HHI) which shows the level of input market concentration for each sector. Specifically,the higher the HHI, the lower the diversification in the source of inputs from foreign countries that an industry in the home country has. We define diversified firms as firms with HHI of its industry below the median within the country. Column 1, 2, and 3 of Table 9 show that firm sales growth only declines among less diversified firms. We view this finding as follow: while there is substantial evidence on the effect of supply chain disruption, having a broader network of suppliers from a number of countries reduces the effect of a global disruption.

Next, we proxy transportation costs by the distance between an input country and the home country. Column 4, 5, and 6 show that firms that source their inputs from countries more distant from them to be more vulnerable to supply chain disruption.

[Insert Table 9]

The effect from several large economies Among 66 countries of inputs, Russia, USA, and China are three most important countries that provide intermediate goods to the EU. We then regress the workplace stringency index of these countries separately and see how supply chain disruption from these countries affects firm sales growth. Column 1 of Table 10 shows that one standard deviation increase in stringency index of China leads to 0.13 percentage points decline in sales growth for treated firms compared to control firms. Column 2 and 3 also show that supply chain disruptions caused by workplace closure in Russia and the USA significantly reduce sales growth of firms in the EU. Given the current Russia-Ukraine war and the trade tension between the US and China, our results shed light to the issues of supply chain disruptions caused by these events.

[Insert Table 10]

Falsification Tests Lastly, we implement several falsification tests where we assume the pandemic would have happened prior to 2020. Table 11 shows that sales growth in earlier years did not respond to the stringency index of 2020. This confirms that our previous findings capture the causal effect of supply chain disruption on firm sales growth.

[Insert Table 11]

6 Conclusion

This paper presents novel evidence that supply chain disruptions at the global level negatively affects firm sales growth. When a country of suppliers implement workplace closure measures, firms that belong to an industry that relies more on foreign inputs suffer 14% decline in sales growth compared to the counterfactual. This first order effect of supply chain disruption supports the findings in the macroeconomic literature on the shrinking of economics during the pandemic such as in Bonadio et al. (2021).

We find that bank debt plays an important role in mitigating the effect of supply chain disruptions and link our findings to the literature on the uniqueness of bank loans. Intuitively, firms that have access to external finance, especially ones that receive loans

from banks benefit during the pandemic because these external finance channels may signal their reputation and make firms appear more credible to their suppliers.

Our findings are applicable beyond the scope of the pandemic and show how vulnerable EU firms are to disruptions in trade partners in other parts of the world. We also point out which firm characteristics help mitigate the effect of a global supply shock. In the next step, we will expand the analysis on the role of bank debt in this paper to better understand the mechanism how access to external finance helps firms overcome the effect of supply chain disruptions.

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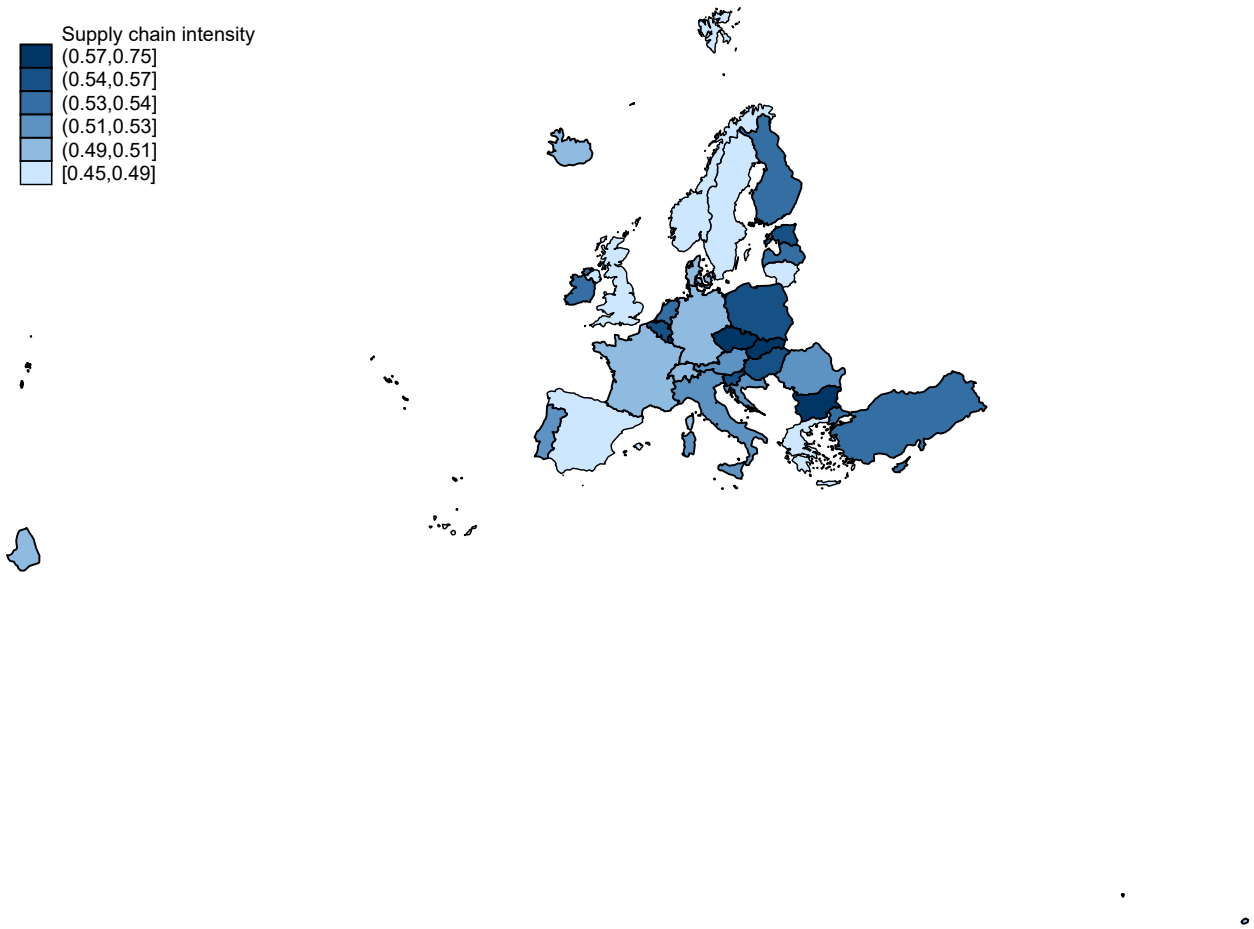
Table 1: Variable description

Variable	Description	Source
Dependent variable		
Sales growth	Growth rate of firm sales (in %)	Amadeus
Firm characteristics		
Total assets	Naural logarithm of total assets (Mil. EUR)	Amadeus
Leverage ratio	The ratio of the sum of long-term debt and debt in current liabilities to total assets	Amadeus
Solvency ratio	Solvency ratio (%)	Amadeus
ROA	Firms' return on total assets (%)	Amadeus
Liquidity ratio	The ratio of firms' cash and cash equivalent to total assets	Amadeus
Bank loan	The ratio of firms' current liabilities from bank loan	Amadeus
Employers	The number of firms' employees	Amadeus
Supply chain link		
Amount of inputs	Total amount of inputs from foreign countries (Mil. USD)	OECD
Supply chain intensity	Total amount of input from foreign countries scaled by the total output from each sector in the home country	OECD
Pandemic country characteristics		
Stringency index (input countries)	A constructed measure based on the following response metrics: workplace closures.	OxCGRT
Country variables		
Stringency at home	Government stringency index imposed at the home country	OxCGRT

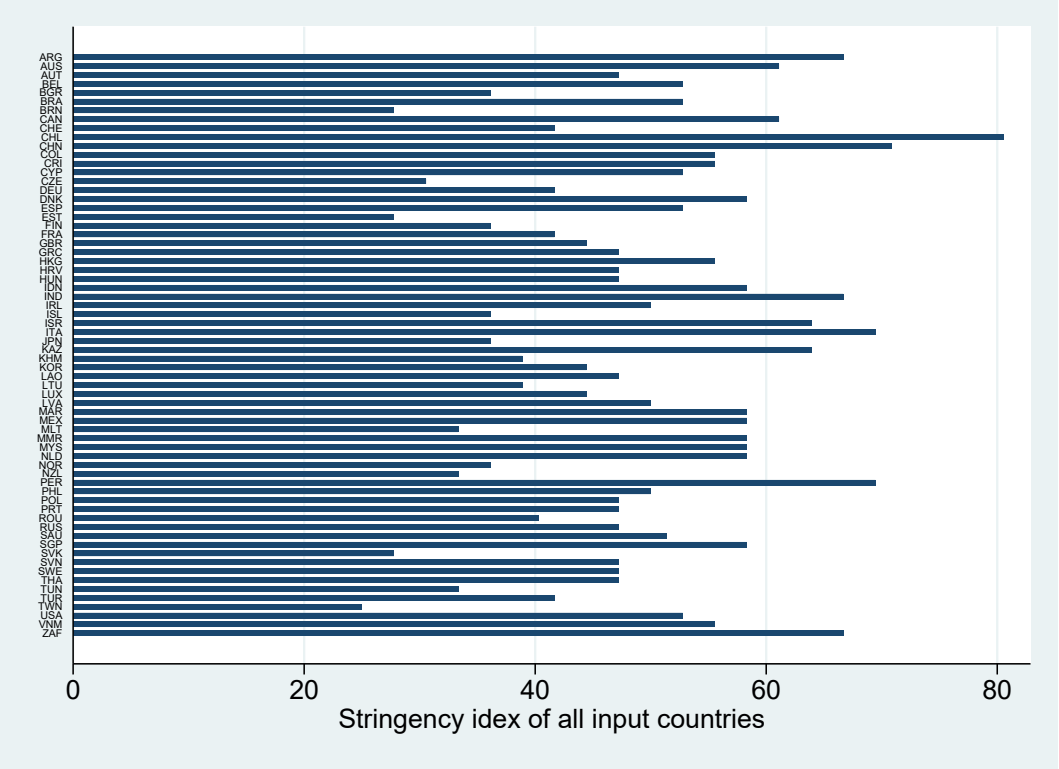
Figure 1: Intensity of European countries' exposure to the global supply chain



Data source: NUTS 2021 layers from Eurostat GISCO.

Source: Authors' Calculation
Notes: Supply chain intensity here is measured by the total amount of input a given country uses from other countries scaled by the total output of that country.

Figure 2: Government stringency index in 2020



Source: OxCGRT (2020).
Notes: The index is a construct measure based on government stringency towards workplace closures normalised to a value ranging from 0 to 100 (100 = strictest). A higher score indicates a stricter response (i.e. 100 = strictest response).

Table 2: Heatplot: Supply chain intensities among country-industry

S/N	Sector name	Austria	Belgium	Estonia	Finland	France	Germany	Greece	Italy	Latvia	Lithuania	Luxembourg	Malta	Netherlands	Portugal	Slovakia	Slovenia	Spain
1	Agriculture, hunting, forestry	0.56	0.76	0.66	0.48	0.57	0.59	0.48	0.43	0.64	0.61	0.70	0.47	0.60	0.54	0.52	0.50	0.44
2	Fishing & aquaculture	0.68	0.71	0.55	0.46	0.71	0.43	0.31	0.46	0.41	0.66	0.00	0.89	0.40	0.40	0.57	0.67	0.46
3	Min. and quarry, energy producing prod.	0.39	0.00	0.46		0.13	0.73	0.39	0.65	0.63	0.52		0.74	0.26	0.00		0.38	0.12
4	Min. & quarry, non-energy producing prod.	0.59	0.70	0.46	0.60	0.64	0.32	0.41	0.11	0.56	0.56	0.57	0.52	0.62	0.52	0.61	0.69	0.57
5	Mining support service	0.40	0.87	0.50	0.62	0.10	0.28	0.49	0.10	0.77	0.34	0.58	0.36	0.55	0.74	0.20	0.76	0.62
6	Food products, beverages and tobacco	0.72	0.81	0.76	0.76	0.73	0.75	0.66	0.80	0.73	0.63	0.72	0.67	0.77	0.76	0.73	0.70	0.79
7	Textiles, textile products, etc.	0.66	0.71	0.67	0.59	0.70	0.66	0.69	0.70	0.55	0.47	0.74	0.66	0.68	0.63	0.57	0.68	0.53
8	Wood and wood products	0.72	0.73	0.76	0.79	0.71	0.71	0.72	0.67	0.72	0.61	0.82	0.58	0.67	0.71	0.55	0.66	0.72
9	Paper products and printing	0.67	0.71	0.70	0.75	0.66	0.68	0.66	0.71	0.66	0.58	0.82	0.62	0.70	0.73	0.71	0.72	0.69
10	Coke and refined petroleum products	0.83	0.95	0.72	0.93	0.87	0.92	0.95	0.94	0.63	0.93	0.00	0.90	0.96	0.93	0.91	0.79	0.92
11	Chemical and chemical products	0.81	0.72	0.73	0.72	0.71	0.66	0.59	0.78	0.72	0.73	0.73	0.63	0.77	0.83	0.70	0.72	0.77
12	Pharma., med-chemical and botanical prod.	0.50	0.72	0.52	0.29	0.54	0.54	0.57	0.67	0.56	0.38	0.77	0.83	0.54	0.56	0.60	0.54	0.54
13	Rubber and plastics products	0.62	0.72	0.71	0.66	0.65	0.64	0.67	0.71	0.69	0.60	0.94	0.50	0.67	0.70	0.69	0.65	0.70
14	Other non-metallic mineral products	0.61	0.66	0.65	0.64	0.67	0.62	0.58	0.67	0.62	0.57	0.75	0.77	0.66	0.65	0.65	0.63	0.70
15	Basic metals	0.74	0.86	0.95	0.82	0.79	0.78	0.76	0.85	0.96	0.70	0.85	0.44	0.74	0.83	0.77	0.82	0.80
16	Fabricated metal products	0.61	0.70	0.69	0.65	0.63	0.58	0.63	0.63	0.64	0.61	0.65	0.70	0.65	0.64	0.63	0.60	0.69
17	Computer, electronic equipment	0.59	0.61	0.89	0.62	0.54	0.53	0.59	0.63	0.68	0.49	0.48	0.75	0.86	0.79	0.87	0.59	0.61
18	Electrical equipment	0.58	0.67	0.71	0.67	0.68	0.57	0.72	0.72	0.66	0.64	0.79	0.71	0.61	0.76	0.73	0.70	0.75
19	Machinery and equipment, nec	0.62	0.65	0.68	0.66	0.69	0.61	0.57	0.70	0.57	0.56	0.71	0.78	0.63	0.67	0.71	0.68	0.67
20	Motor vehicles, trailers & semi-trailers	0.77	0.83	0.74	0.66	0.81	0.66	0.57	0.78	0.70	0.66	0.77	0.57	0.82	0.84	0.88	0.80	0.82
21	Other transport equipment	0.68	0.61	0.70	0.78	0.80	0.70	0.37	0.73	0.63	0.58	0.72	0.63	0.82	0.76	0.73	0.70	0.72
22	Manufacturing, repairs etc.	0.62	0.66	0.68	0.58	0.59	0.59	0.50	0.65	0.58	0.54	0.57	0.57	0.55	0.60	0.62	0.57	0.54
23	Electricity, gas, steam etc.	0.81	0.59	0.55	0.56	0.69	0.60	0.53	0.72	0.68	0.64	0.70	0.88	0.54	0.71	0.81	0.53	0.62
24	Water supply; sewerage etc.	0.58	0.65	0.59	0.55	0.60	0.53	0.41	0.61	0.50	0.47	0.49	0.58	0.61	0.63	0.52	0.73	0.59
25	Construction	0.61	0.72	0.64	0.61	0.61	0.55	0.67	0.65	0.72	0.47	0.61	0.70	0.70	0.64	0.59	0.67	0.55
26	Wholesale and retail trade	0.44	0.50	0.48	0.47	0.51	0.42	0.43	0.48	0.44	0.27	0.62	0.39	0.44	0.41	0.49	0.46	0.41
27	Land transport & pipelines	0.47	0.61	0.64	0.55	0.52	0.52	0.50	0.53	0.62	0.51	0.35	0.77	0.60	0.59	0.56	0.64	0.56
28	Water transport	0.93	0.70	0.79	0.74	0.91	0.76	0.70	0.71	0.53	0.41	0.70	0.87	0.70	0.77	0.67	0.57	0.66
29	Air transport	0.74	0.86	0.99	0.71	0.68	0.72	0.72	0.75	0.78	0.86	0.75	0.88	0.69	0.79	0.90	0.93	0.75
30	Warehousing & transportation support	0.41	0.62	0.68	0.67	0.54	0.63	0.44	0.55	0.70	0.48	0.53	0.57	0.51	0.54	0.62	0.55	0.58
31	Postal and courier activities	0.53	0.55	0.61	0.48	0.33	0.60	0.45	0.55	0.56	0.46	0.53	0.83	0.68	0.50	0.54	0.44	0.52
32	Accommodation and food service	0.37	0.58	0.60	0.58	0.47	0.49	0.46	0.47	0.54	0.39	0.50	0.60	0.50	0.43	0.45	0.53	0.45
33	Publishing, & broadcasting	0.58	0.59	0.52	0.56	0.55	0.56	0.62	0.63	0.51	0.70	0.77	0.69	0.72	0.59	0.56	0.60	0.56
34	Telecommunications	0.53	0.53	0.51	0.46	0.54	0.60	0.50	0.54	0.54	0.41	0.70	0.60	0.48	0.56	0.43	0.61	0.57
35	IT & other information services	0.50	0.52	0.41	0.49	0.40	0.42	0.41	0.48	0.33	0.39	0.89	0.65	0.54	0.44	0.48	0.45	0.53
36	Financial and insurance activities	0.49	0.52	0.38	0.52	0.64	0.55	0.25	0.44	0.43	0.40	0.86	0.90	0.43	0.41	0.48	0.41	0.43
37	Real estate activities	0.33	0.26	0.32	0.26	0.17	0.24	0.10	0.13	0.25	0.29	0.34	0.40	0.45	0.13	0.29	0.17	0.15
38	Professional, & scientific activ.	0.49	0.52	0.49	0.44	0.53	0.44	0.41	0.41	0.39	0.41	0.55	0.66	0.52	0.53	0.51	0.48	0.47
39	Administrative and support services	0.34	0.47	0.44	0.41	0.41	0.40	0.55	0.53	0.50	0.45	0.75	0.56	0.41	0.37	0.54	0.42	0.44
40	Public admin. & defence; compul social sec	0.34	0.26	0.32	0.48	0.27	0.34	0.18	0.31	0.27	0.28	0.26	0.38	0.39	0.24	0.29	0.33	0.26
41	Education	0.18	0.14	0.27	0.29	0.18	0.21	0.10	0.17	0.25	0.17	0.13	0.15	0.23	0.12	0.23	0.23	0.15
42	Human health and social work activities	0.33	0.44	0.37	0.38	0.24	0.31	0.30	0.42	0.33	0.27	0.26	0.37	0.29	0.41	0.37	0.37	0.33
43	Arts, entertainment and recreation	0.36	0.58	0.55	0.55	0.46	0.36	0.41	0.60	0.44	0.39	0.52	0.78	0.51	0.51	0.80	0.53	0.40
44	Other service activities	0.37	0.53	0.56	0.50	0.39	0.28	0.48	0.38	0.46	0.35	0.38	0.45	0.43	0.40	0.43	0.51	0.32
45	Activities of households as employers		0.00	0.00	0.00		0.00		0.00	0.00					0.00		0.00	0.00

Notes: The amount of input were scaled by the total output from each industry in the destination country. 0 represents less foreign input reliance while 1 represents higher foreign input reliance.

Table 3: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Dependent variable					
Sales growth (%)	3.872	37.958	-66.857	110.553	4,611,717
Firm characteristics					
Ln(assets)	13.304	1.893	7.363	18.357	4,611,717
ROA (%)	5.013	15.756	-63.68	68.75	4,611,717
Solvency ratio	38.143	32.212	-65.09	100	4,611,717
Leverage ratio	0.528	0.321	0	5.292	4,611,717
Liquidity ratio	0.187	0.217	0	0.999	4,611,717
Supply chain link					
Supply chain intensities	0.487	0.151	0.097	0.96	4,611,717
High exposure	0.168	0.374	0	1	4,611,717
High diversification	0.453	0.498	0	1	4,611,717
Long distant firms	0.442	0.497	0	1	4,611,717
Pandemic country characteristics					
Stringency index (input countries)	18.219	26.593	0	68.09	4,611,717
Stringency index (home)	18.376	27.099	0	69.444	4,611,717

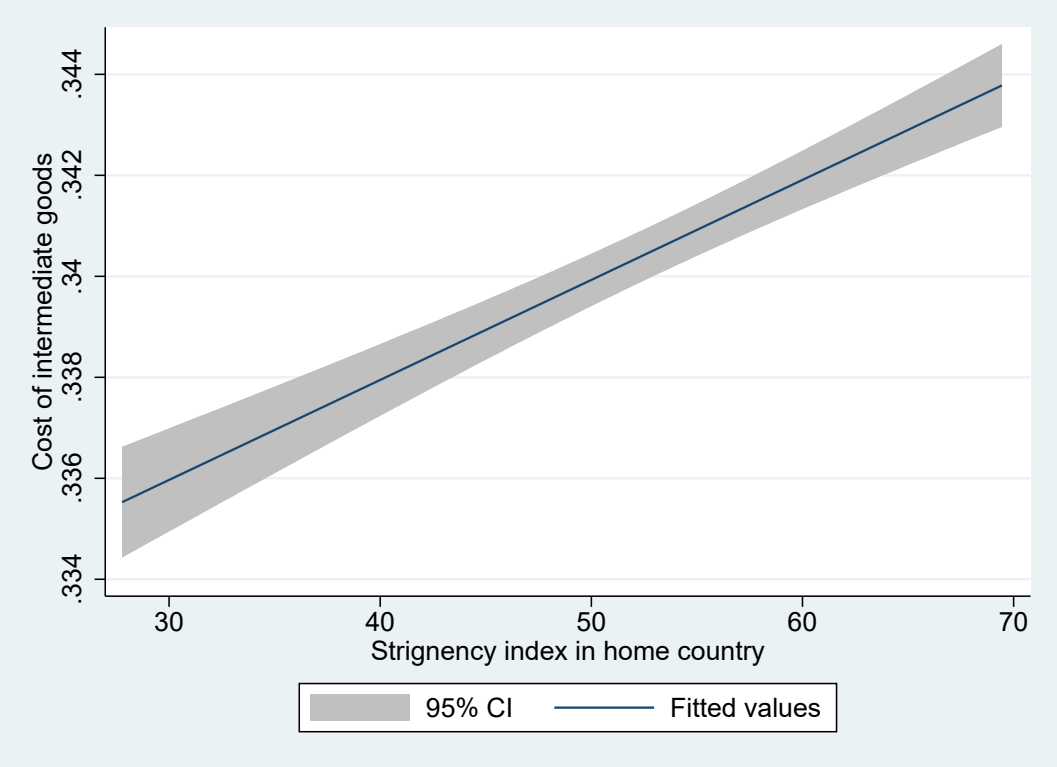
All the firm variables are winsorised at 1th and 99th percentile.

Table 4: Parallel Trend Tests

	Treated		Control		
Variables	Mean	SD	Mean	SD	ND
Firm assets (Ln)	13.087	2.258	12.692	2.095	0.13
ROA	5.700	17.306	5.586	18.289	0.00
Leverage ratio	0.628	0.619	0.620	0.664	0.01
Solvency ratio	40.459	33.396	40.340	35.447	0.00
Liquidity ratio	0.184	0.221	0.205	0.244	-0.07

Note: This table shows whether highly exposed firms are significantly different from lowly exposed firms before the pandemic. ND represents normalised difference. Imbens and Wooldridge (2009) suggests that a ND of more than 0.25 shows a significant difference between treated and control group.

Figure 3: Correlation relationship between stringency index in home country and cost of intermediate goods



Source: Authors' Calculation.
Notes: The cost of intermediate goods were measured at the industry-level and scaled by total assets of the industry. Stringency index is a construct measure based on government stringency towards workplace closures and normalised to a value ranging from 0 to 100 (100 = strictest). A higher score indicates a stricter response (i.e. 100 = strictest response).

Table 5: Baseline result

Dependent variable: Sales growth(%))

	(1)	(2)	(3)	(4)	(5)	(6)
Stringency index	-0.1742***	-0.2765***	-0.2261***	-0.1253***	-0.2261***	-0.1253***
	(0.0034)	(0.0396)	(0.0040)	(0.0466)	(0.0040)	(0.0466)
High exposure×Stringency index	-0.0181***	-0.0090***	-0.0237***	-0.0140***	-0.0237***	-0.0140***
	(0.0033)	(0.0031)	(0.0039)	(0.0037)	(0.0039)	(0.0037)
Ln(assets)		11.9431***		7.7657***		7.7657***
		(0.1140)		(0.1303)		(0.1303)
ROA		0.8608***		0.8201***		0.8201***
		(0.0025)		(0.0032)		(0.0032)
Solvency ratio		-0.2678***		-0.2237***		-0.2237***
		(0.0039)		(0.0047)		(0.0047)
Leverage ratio		11.4354***		12.6420***		12.6420***
		(0.3402)		(0.4214)		(0.4214)
Liquidity ratio		7.8335***		2.1214***		2.1214***
		(0.2571)		(0.3184)		(0.3184)
Stringency at home		0.0881***		-0.0750*		-0.0750*
		(0.0333)		(0.0392)		(0.0392)
Observations	4,611,717	4,611,717	2,888,554	2,888,554	1,444,277	1,444,277
R-Squared	0.3998	0.4516	0.5631	0.6001	0.0330	0.1147
Firm F.E.	Yes	Yes	Yes	Yes	-	-
Industry*Time F.E.	Yes	Yes	Yes	Yes	-	-
Controls	No	Yes	No	Yes	No	Yes
Clustering	Firm	Firm	Firm	Firm	Firm	Firm
Number of firms	1,605,007	1,605,007	1,444,277	1,444,277	1,444,277	1,444,277
Sample	2018 to 2020	2018 to 2020	2018 & 2020	2018 & 2020	2020-2018	2020-2018

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Column 1 and 2 are the result from our whole sample. Column 3 and 4 are the sample for our pre- and post- treatment in 2019 and 2020. Column 5 and 6 present the result of the collapsed difference-in-difference where we take the first difference of all variables between 2020 and 2018.

Table 6: The role of firm leverage

	(1) High leverage	(2) Medium leverage	(3) Low leverage
Stringency index	0.3322***	0.2925***	-0.2381***
	(0.0749)	(0.0526)	(0.0487)
High exposure×Stringency index	0.0080	-0.0216***	-0.0445***
	(0.0071)	(0.0043)	(0.0054)
Stringency at home	-0.3600***	-0.3455***	0.0662
	(0.0635)	(0.0444)	(0.0412)
Observations	868,360	2,796,777	1,143,310
R-Squared	0.1544	0.1088	0.1469
Industry*Time F.E.	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Clustering	Firm	Firm	Firm

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The high-leveraged firms are firms whose leverage ratio are above the 75th percentile distribution of the whole sample. The medium leveraged firms are above the 25th percentile but below the 75th percentile. The low-leveraged firms are below the 25th percentile. The Chow test in the Appendix Table A2 shows that the parameter of one group are different from those of other groups.

Table 7: Do bank loans mitigate the effect of supply chain disruption?

	(1) High bank-debt	(2) Medium bank-debt	(3) Low bank-debt
Stringency index	0.2141**	0.1386***	-0.0760
	(0.0848)	(0.0395)	(0.0760)
High exposure×Stringency index	-0.0140*	-0.0209***	-0.0589***
	(0.0073)	(0.0036)	(0.0084)
Stringency at home	-0.2871***	-0.2285***	-0.0707
	(0.0710)	(0.0335)	(0.0634)
Observations	628,347	3,812,250	367,849
R-Squared	0.1340	0.1208	0.1720
Industry*Time F.E.	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Clustering	Firm	Firm	Firm

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Firms with high bank-debt are firms whose bank debt are above the 75th percentile of the sample. The medium bank-debt are above 25th percentile but below the 75th percentile. Firms with low bank-debt are below the 25th percentile. The Chow test in the Appendix Table A2 shows that the parameter of one group are different from those of other groups.

Table 8: The role of Firm Size

	(1) Large-firms	(2) Medium-firms	(3) Small-firms	(4) More-employees	(5) Less-employees
Stringency index	0.4018***	-0.0715	-0.0440	-0.3230***	-0.2795***
	(0.0512)	(0.0542)	(0.0595)	(0.0775)	(0.0693)
High exposure×Stringency index	-0.0100*	-0.0211***	-0.0552***	-0.0001	-0.0410***
	(0.0055)	(0.0047)	(0.0062)	(0.0075)	(0.0090)
Stringency at home	-0.4259***	-0.1099**	-0.1566***	0.1582**	0.1171**
	(0.0432)	(0.0457)	(0.0504)	(0.0651)	(0.0575)
Observations	1,267,242	2,683,983	857,222	706,905	270,968
R-Squared	0.1240	0.1225	0.1418	0.1134	0.3039
Industry*Time F.E.	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Clustering	Firm	Firm	Firm	Firm	Firm

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The large firms are firms with total assets above the 75th percentile distribution of the whole sample. The medium firms are above 25th percentile but below the 75th percentile. The small firms are firms with total assets below the 25th percentile of the sample. Large employers are firms with the number of employees above the 75th percentile of the whole sample. Small employers are firms with the number of employees below the 25th percentile. The Chow test in the Appendix Table A2 shows that the parameter of one group are different from those of other groups.

Table 9: The role of diversification and distance

	(1) Diversified firms	(2) Less-diversified	(3) Whole sample	(4) Distant firms	(5) Less-distant	(6) Whole sample
Stringency index	0.7209***	-1.0393***	-0.4474***	-0.7183***	-0.6246***	-0.2906***
	(0.1109)	(0.0456)	(0.0405)	(0.0571)	(0.1229)	(0.0395)
High exposure×Stringency index	0.0559***	-0.0266***	-0.0202***	-0.0367***	0.0017	-0.0003
	(0.0067)	(0.0033)	(0.0033)	(0.0044)	(0.0051)	(0.0043)
Diversification×Stringency index			0.0485***			
			(0.0028)			
High exposure×Diversification×Stringency index			0.0528***			
			(0.0071)			
Long distance×Stringency index						-0.0201***
						(0.0018)
High exposure×Long distance×Stringency index						-0.0277***
						(0.0049)
Stringency at home	-0.7187***	0.6665***	0.2174***	0.4316***	0.4429***	0.1105***
	(0.0951)	(0.0376)	(0.0339)	(0.0450)	(0.1087)	(0.0334)
Observations	2,090,058	2,521,659	4,611,717	2,037,245	2,574,459	4,611,717
R-Squared	0.4184	0.4817	0.4517	0.4776	0.4347	0.4517
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Industry*Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Clustering	Firm	Firm	Firm	Firm	Firm	Firm

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Disruption in countries involved in the main supply chain participation

Dependent variable: Sales growth(%))			
	(1)	(2)	(3)
High exposure×Stringency index China	-0.0045**		
	(0.0023)		
High exposure×Stringency index Russia		-0.0067**	
		(0.0034)	
High exposure×Stringency index USA			-0.0060**
			(0.0030)
Stringency index at home	-0.1465***	-0.1465***	-0.1465***
	(0.0028)	(0.0028)	(0.0028)
Observations	4,611,717	4,611,717	4,611,717
R-Squared	0.4516	0.4516	0.4516
Firm F.E.	Yes	Yes	Yes
Industry*Time F.E.	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Clustering	Firm	Firm	Firm
Number of firms	1605007	1605007	1605007
Sample	2018 to 2020	2018 to 2020	2018 to 2020

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Falsification test

Dependent variable: Sales growth(t-1) (%)		
	(1)	(2)
Stringency index	-0.1486***	-0.1666***
	(0.0040)	(0.0499)
High exposure×Stringency index	-0.0003	-0.0051
	(0.0040)	(0.0040)
Stringency index at home		0.0140
		(0.0421)
Observations	2,958,862	2,958,862
R-Squared	0.5025	0.5049
Firm F.E.	Yes	Yes
Industry*Time F.E.	Yes	Yes
Controls	No	Yes
Clustering	Firm	Firm
Number of firms	1479431	1479431
Sample	2018 to 2019	2018 to 2019

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix

Table A1: Cross-section observation of the number of firms in each country

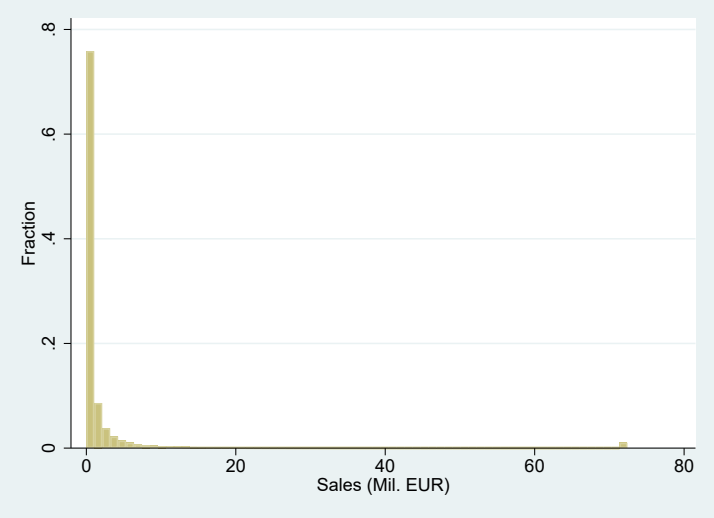
Country	**Year(Number of firms)**		
	2018	2019	2020
Austria	6,801	6,801	6,801
Belgium	32,486	32,486	32,486
Estonia	95,164	95,164	95,164
Finland	155,994	155,994	155,994
France	264,843	264,843	264,843
Germany	52,198	52,198	52,198
Greece	17,891	17,891	17,891
Italy	724,789	724,789	724,789
Latvia	60,913	60,913	60,913
Lithuania	10,866	10,866	10,866
Luxembourg	1,925	1,925	1,925
Malta	867	867	867
Netherlands	2,759	2,759	2,759
Portugal	236,384	236,384	236,384
Slovakia	49,171	49,171	49,171
Slovenia	86,899	86,899	86,899
Spain	484,615	484,615	484,615
Total	2,284,565	2,284,565	2,284,565

Table A2: Chow test

Groups	**F-stat**	**Prob.**
between large and medium firms	9295.76	0.0000
between medium and small firms	7003.28	0.0000
between large and small employers	8140.23	0.0000
between high and medium bank-debt	105.23	0.0000
between medium and low bank-debt	442.92	0.0000
between medium and low leverage	1721.2	0.0000

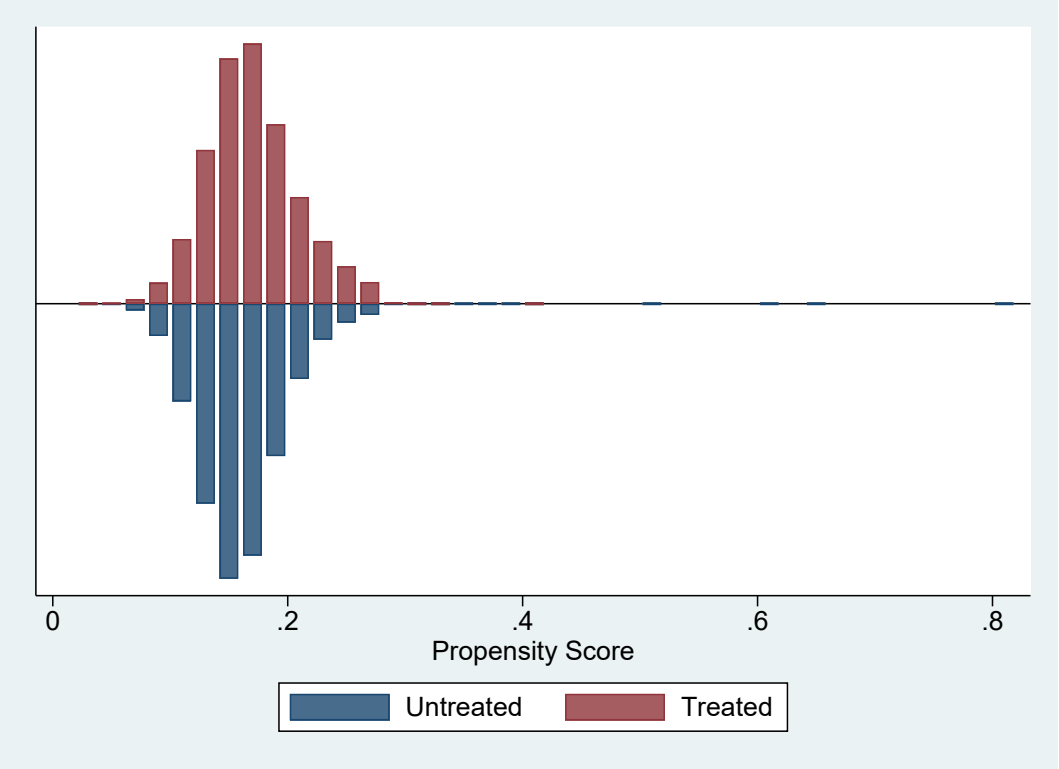
Note: The result is based on different groups among the firm characteristics.

Figure A1: Distribution of firm sales in our data



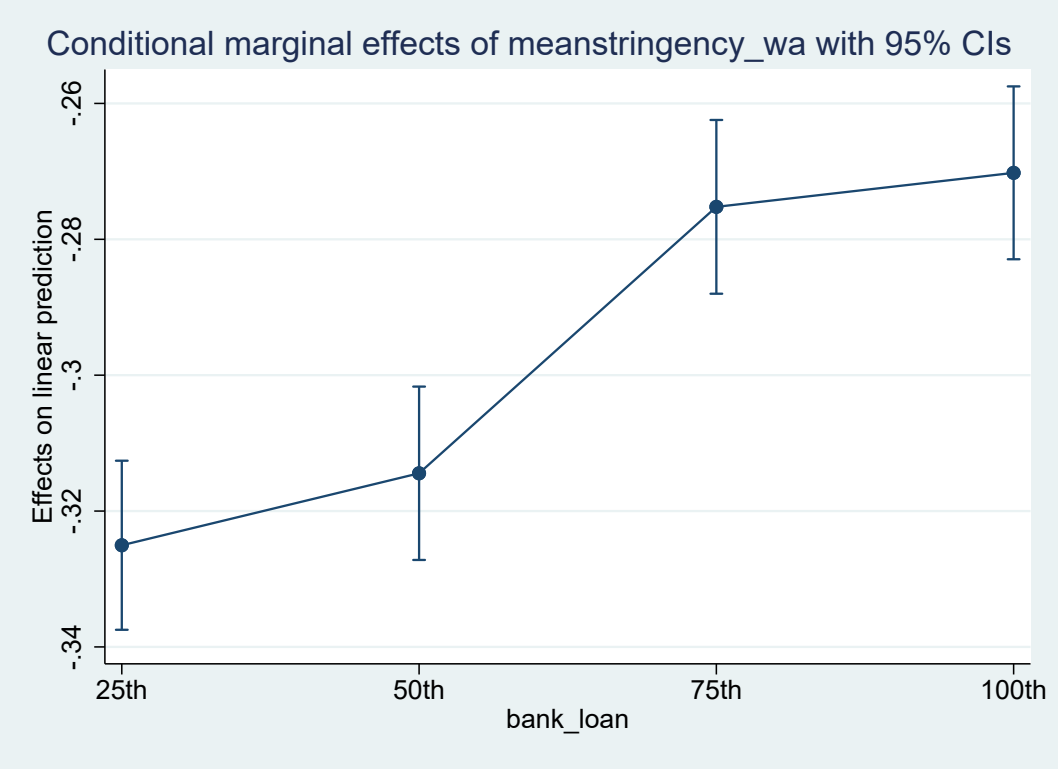
Notes: The figure shows that the distribution of firm sales in our dataset are right skewed.

Figure A2: Histogram of the propensity score by the exposure to the global supply chain



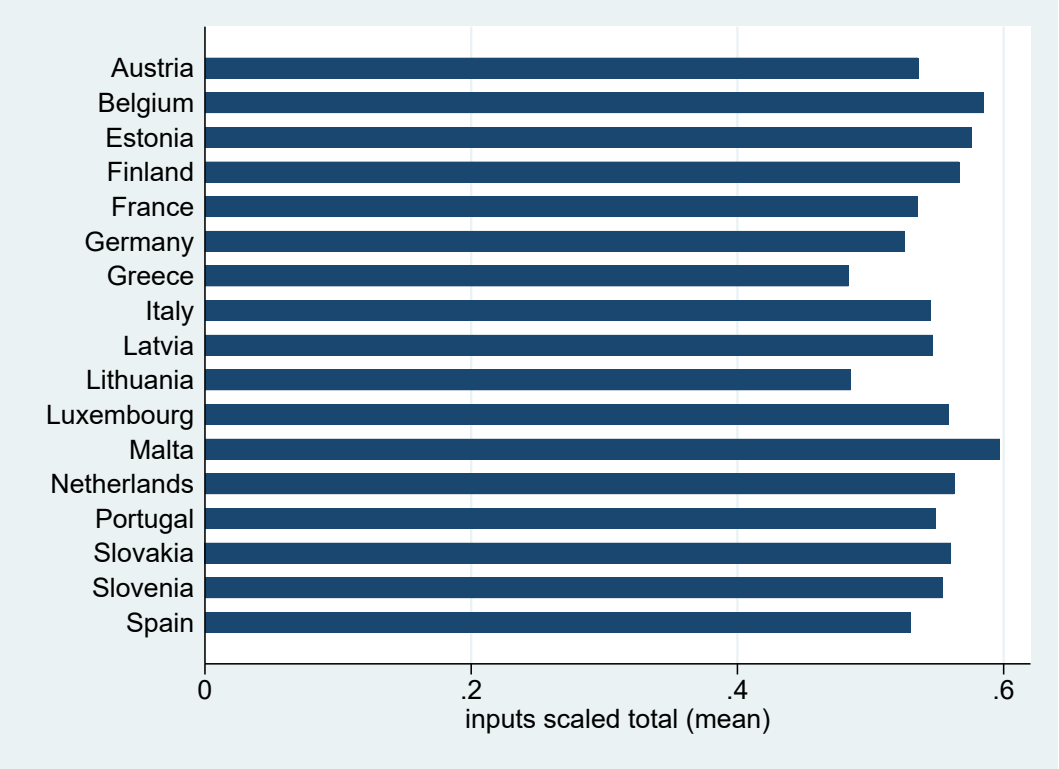
Notes: This represents the histogram plot of the propensity score by our treatment status.

Figure A3: Conditional marginal plot of firms with access to bank loans during disruption



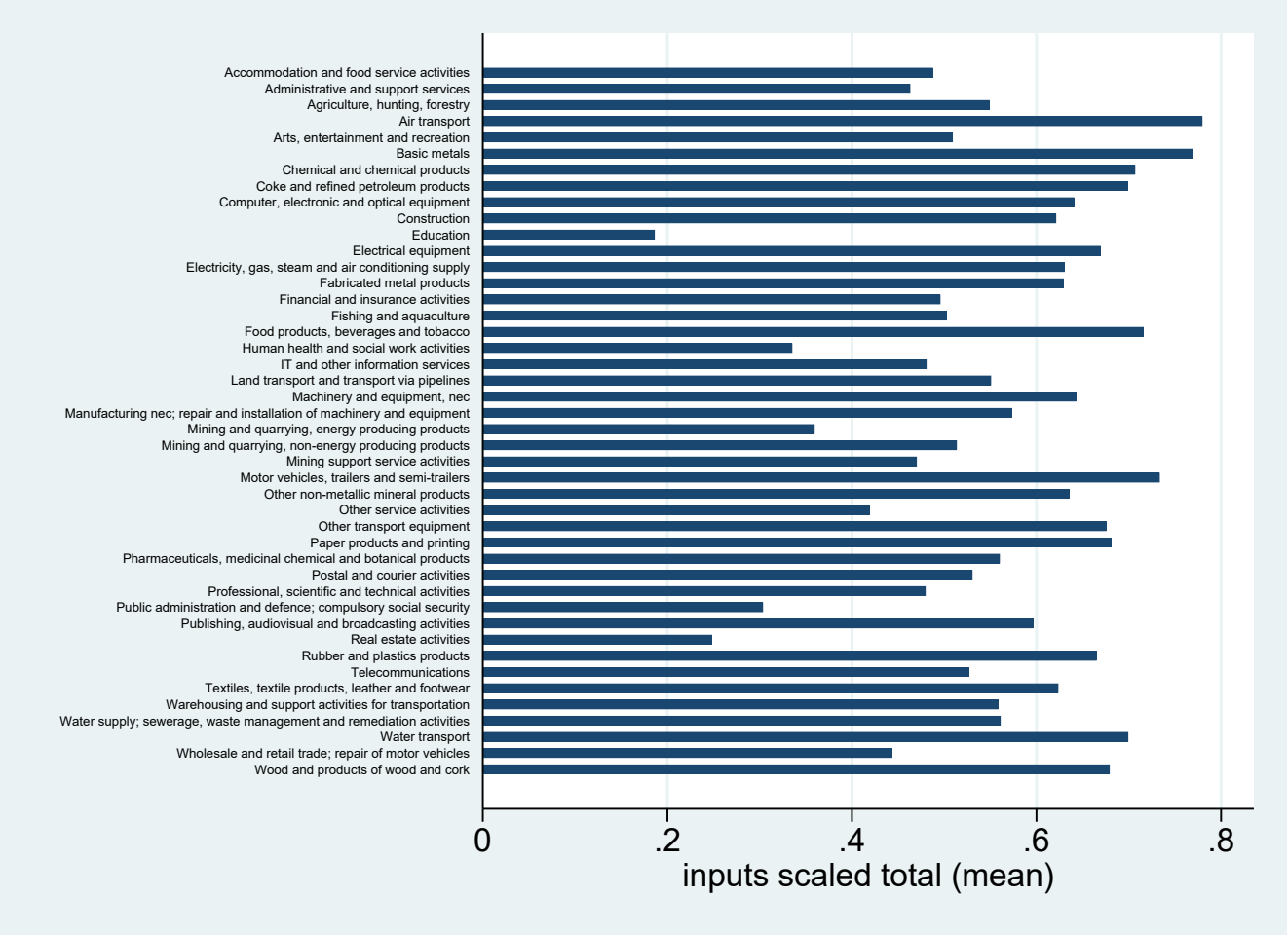
Notes: This shows the marginal effect of firms' access to bank loan on firm sales in a supply disruption. The x-axis shows the level of percentile for each firms' access to bank loans. The y-axis shows the linear prediction obtained from the baseline result.

Figure A6: Amount of inputs by country



Notes: This shows the variation of supply chain intensity across countries.

Figure A6: Amount of inputs by industry



Notes: This shows the variation of supply chain intensity across industries.