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Raphaël LAFROGNE-JOUSSIER

Institut national de la statistique et des études économiques

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RAPHAËL LAFROGNE-JOUSSIER†

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Département des Études Économiques – Timbre G201
88, avenue Verdier – CS 70 058 – 92 541 MONTROUGE CEDEX – France
Tél. : 33 (1) 87 69 59 54 – E-mail : d3e-dg@insee.fr – Site Web Insee : http://www.insee.fr

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† Insee: Department of Economic Studies. Email: raphael.lafrogne-joussier@insee.fr.

Stocks, diversification et vulnérabilités commerciales

Pour réduire leur exposition aux risques liés aux chaînes d'approvisionnement, les entreprises recourent généralement à deux stratégies : la constitution de stocks et la diversification des sources d'approvisionnement. Cet article présente de nouvelles données sur la manière dont les entreprises manufacturières françaises ont utilisé les stocks et diversifié leurs risques d'approvisionnement spécifiques à certains pays entre 2012 et 2023. L'utilisation de ces stratégies varie fortement : les grandes entreprises sont en général plus diversifiées et maintiennent des niveaux de stocks plus faibles que les petites entreprises. Dans l'ensemble, les entreprises qui diversifient davantage ont tendance à stocker moins, même à taille égale. La diversification est également associée à une moindre volatilité des importations. Pris ensemble, ces éléments suggèrent que les stocks jouent un rôle d'amortisseur lorsque les entreprises ne peuvent pas réduire les risques par la diversification. Ces constats sont importants pour évaluer les vulnérabilités du commerce : les produits provenant de peu de pays peuvent sembler exposés au risque mais, en pratique, ils sont souvent importés par des entreprises disposant de stocks importants. Prendre en compte les stocks peut réduire de moitié le nombre de produits considérés comme très vulnérables.

Mots-clés : Stocks, Diversification, Risques liés aux chaînes d'approvisionnement, Vulnérabilités

Codes JEL : F1, F6

Inventories, Diversification, and Trade Vulnerabilities

To reduce their exposure to supply-chain risk, firms commonly rely on two strategies: input stockpiling and diversification of supply sources. This paper presents new evidence on how French manufacturing firms used inventories and diversified their country-specific supply risks between 2012 and 2023. The use of these strategies varies widely: large firms are generally more diversified and maintain lower inventories relative to smaller firms. Overall, firms that diversify more tend to stockpile less, even conditional on firm size. Diversification is also linked to lower import volatility. Together, these patterns suggest that inventories act as a buffer when firms are unable to reduce risk through diversification. These insights matter for assessing trade vulnerabilities: products sourced from few countries may appear exposed to risk, yet in practice they are often imported by firms holding large stocks. Accounting for inventories can halve the number of products considered highly vulnerable.

Keywords: Inventories, Diversification, Supply-chain risk, Vulnerabilities.

JEL Code : F1, F6

Introduction

Supply-chain disruptions have become increasingly common, as illustrated by events such as the COVID-19 pandemic, the Suez Canal blockage, and geopolitical tensions like the Russia-Ukraine conflict and the Red Sea blockade.[1,2] These incidents have highlighted vulnerabilities in global supply chains and spurred policymakers to introduce programs aimed at reducing risks and enhancing the resilience of supply chains – their "ability to return to normal operating performance within an acceptable period" (Peck, 2005).[3] However, much of the current evidence on what makes supply-chains resilient to these disruptions remains anecdotal or limited to industry-level analyses. Key questions remain: How do firms insure against supply-chain disruptions? How well-protected are they?

This paper offers answers to these questions by studying two key strategies for strengthening supply chains: inventories and diversification. Firms indeed frequently identify these measures as their primary responses to supply chain disruptions.[4] Inventories are costly, but firms may want to stockpile inputs so that in the event of a negative supply shocks – a disrupted trade route, a flood at a supplier's plant, supplier's bankruptcy, etc. –, production can keep on, as confirmed by recent literature (He, 2023; Lafrogne-Joussier et al., 2023). On the other hand, firms may invest in supply reliability to reduce the variance of supply shocks, or sourcing risk (Elliott et al., 2022). Such investments may be made in finding alternative suppliers, which can be useful either to split orders – as a diversified portfolio – or to have alternatives to bounce back quickly if the chosen supplier cannot provide the input in time. This last facet of supply-chain strategy is diversification. This paper shows that the use of inventories and diversification is highly heterogeneous across firms and that large firms hold fewer inventories, suggesting high costs of storage, but are more diversified. It also shows that inventories and diversification appear to be strategic substitutes, as diversification reduces the variance of supply and thus the need for inventories. I conclude by providing an evaluation of France's trade vulnerabilities that takes into account the firm heterogeneity in supply-chain robustness I uncover.

I measure the extent to which importing firms stockpile inputs and diversify their international supply sources using detailed firm-level data for over more than 10 years on French manufacturing firms. I combine data from firms' fiscal forms recorded in Insee's FARE dataset with customs data, from 2012 to 2023. Fiscal records provide the value, in euros, of input inventories held by firms at the

[1] In Appendix A, I present a collection of figures and facts about supply chain disruptions.

[2] 50% of exporters rank shortages of inputs and labor among the top risks against activity in 2024 (Allianz Global Trade Survey 2024); "Insufficient supply of materials" is one of the most frequent sources for production being below full capability among US manufacturers, especially since 2020 (Quarterly Survey of Production Capacity).

[3] "Increasing security and reducing dependencies" is one of the three main areas for action identified by the report commissioned by the European Commission to Mario Draghi and published in September 2024, "The future of European competitiveness".

[4] When asked "What measures have you taken to increase the resilience of your supply-chain?", firms surveyed by the EBRD (2023) primarily cite an increased stock of inputs (55%) and supply diversification (49%).

end of the year. I divide this amount of inventories by total material inputs available to the firm over the year to construct what I call the inventory ratio. The inventory ratio is the fraction of inputs kept as inventories.As uncertainty around the amount of available inputs in the future increases, firms tend to stockpile more. Customs data can be used to build measures of supplier diversification on imported inputs, by counting the number of countries a given firm sources its material inputs from, as an average over narrowly defined categories of goods. It measures diversification of country-level risk. Several alternative measures can be built to take into account domestic supply, the substitutability of varieties within categories of goods, or the concentration of supply.

The first part of the paper explains the choice of these measures and describes extensively their magnitude across the distribution of importing firms, within and across sectors, and over time. Inventory ratios vary across firms but mostly within industries: industry fixed-effects explain at most 17% of the variance in the inventory ratio across firms. Indeed, some firms consistently report no inventories, while others display an inventory ratio of 50%. I then investigate the determinants of inventories and diversification at the firm-level and uncover a novel empirical pattern: the inventory ratio decreases linearly with (log) firm size, measured by sales. Firms in the first decile of annual sales holds on average 25% of inputs as inventories, while this figure drops to 15% in the last decile of the firm size distribution. This negative relationship between the inventory ratio and firm size is robust to a variety of measures of firm size and also holds within firm over time.

Beyond firm size, I regress inventories on several variables that capture different layers of intuition and that corroborate existing evidence on the determinants of inventories. Importing firms tend to stockpile more, and this tendency increases with the share of imports in their total intermediate consumption. This aligns with existing evidence on the high fixed costs of international trade, that make import shipments lumpy and mechanically creates a motive for holding inventories (Kropf and Sauré, 2014; Alessandria et al., 2010).

Diversification also exhibits a large variance across firms. When firms are ranked by the number of source countries per product, the median importer sources each product from an average of 2.4 countries, while firms in the top decile source the same product from more than 5 countries. Again, only a small fraction of the variance in diversification across firms is explained by industry fixed-effects (12%). In contrast to the inventory ratio, diversification increases with firm size. Firms in the first decile of firm size connect to one supplier per imported product on average, while this number increases to 4.5 in the last decile. This finding is consistent with previous literature documenting the positive relationship between firm size and the number of trade linkages (Antras et al., 2017; Bernard et al., 2018; Dhyne et al., 2023), and more generally to a theory featuring fixed costs per supplier-buyer relationship to set-up. Hence, it may be that large firms choose not to hold inventories because they face lower variance of international sourcing. These results suggest that optimal supply-chain strategies evolve along the firm's size, with large firms diversifying supply sources and small firms stockpiling.

The third part of the paper explores the relationship between inventories, diversification, and import supply risk. I first document that the inventory ratio and diversification are negatively correlated. The correlation is very robust, from the raw correlation to the within firm over time correlation. This is true conditional on firm size, and broadly across the range of alternative diversification measures. An interpretation of this finding is the following: diversification is a device used to reduce the volatility of supply. Besides, inventories are used as a buffer against negative supply shocks, and the more risk on the supply side, the more inventories are needed by the firm. Hence, diversified firms should exhibit lower inventory levels, all else equal. To lend support to this interpretation, I show that in the data, higher diversification is systematically associated with lower import volatility, across various sets of fixed effects and controlling for potential common drivers, such as firm size. It also lends supports to using the number of countries as a measure of supply diversification. These two results suggest that firms may use diversification to reduce the volatility of supply, but once hit by a negative supply shock, they use inventories to keep on with production.

In the wake of the COVID-19 pandemic, subsequent worldwide shortages, and rising geopolitical tensions, assessments of the exposure to foreign suppliers have burgeoned. The goal of these exercises is to come up with a list of products that are particularly at risk, to guide policy choices. Most assessments make the diversification of supply the cornerstone of the analysis, partly because diversification can be easily computed using publicly available data such as BACI. What the results of this paper suggest is that an assessment of trade vulnerabilities based solely on the supply sources diversification may be pessimistic: non-diversified firms may have the inventories needed to face most short-term supply disruptions. I design three measures that together categorize inputs as "at risk" or not. First, the diversification of sourcing of the product, as the average number of countries from which the product is sourced by French firms. It is a proxy for foreign supply risk. Second, the concentration of supply at the worldwide level, using BACI. It is a proxy for how easy it could be to find an alternative supplier, should the usual supplier got disrupted; it is intended to measure the potential to recover from a disruption over the medium run. Third, I compute the average inventory ratio among firms importing the product, a proxy for the level of the firm inventories of the product, capturing the ability to cope with disruptions over short-term horizons. To reduce the impact of idiosyncratic shocks, I build those measures over 5 years (2015-2019); I also restrict to French manufacturing importing firms, in line with the rest of the paper.

Overall, introducing the criteria on inventories reduces the number of inputs "at risk" by half, across various thresholds for reflecting the fact that poorly diversified products are imported by firms with a higher level of inventories. In the main exercise, I categorize an input at risk in the short-term if it is imported from at most two countries, if the HHI of world export supply is greater than 0.25, and if there is less than a month worth of inventories among French manufacturing importers. There are 174 products "at risk", according to the first two criteria, and only 79 once we condition on the third.

Related literature. This paper makes several contributions to the literature. First, it connects to the rapidly expanding body of work on how firms adapt to risk, in particular their supply chain. Studies such as Khanna et al. (2022); Balboni et al. (2024); Castro-Vincenzi et al. (2024); Castro-Vincenzi (2024); Pankratz and Schiller (2024) demonstrate how firms adapt their production in space in response to climate risk. Blaum et al. (2023) examine how the volatility of ocean shipping times influences the sourcing decisions of U.S. importers, while Lafrogne-Joussier et al. (2023) show that French importers diversify their supply sources following the lockdown in China in early 2020. Unlike these studies, which focus on the aftermath of disruptions, this paper investigates supply-chain strategies over nearly a decade. Moreover, it analyzes both diversification and inventories at the same time.

Second, it contributes to the literature that explicitly considers inventories as a buffer against international shocks. Most, constrained by data limitations, rely on industry-level data, firm-level data from specific sectors, or data from individual firms (see, e.g., Alessandria et al., 2010; Ferrari, 2023; Alessandria et al., 2023). The study by Carreras-Valle (2024) is most closely related to the present paper, which considers uncertainty around delivery times in foreign sourcing and shows that it may explain well the recent increase in inventories among importers in the US. I add a layer of decision for firms in this paper: the number of foreign suppliers so that the firm can decrease uncertainty around supply. To a certain extent, the paper also speaks to the literature on the adoption of just-in-time inventory management. Pisch (2020) shows that the probability of adopting just-in-time inventory management increases with firm size. Here, I show that the same holds at the intensive margin of inventories: large firms hold fewer inventories.

Finally, this paper aims to provide a framework that can complement existing analyses of supply-chain vulnerabilities. Most assessments of vulnerabilities have focused on the diversification of supply sources (e.g., Commission, May 2021; Vicard and Wibaux, 2023; Mejean and Rousseaux, 2024). These studies highlight the risks of supplier concentration and the scarcity of alternative sources for critical products. High reliance on a handful of suppliers may be a point of policy intervention, for reasons of economic security, strategic dependencies, or geopolitical reasons. From an economic point of view, supplier concentration *per se* is less worrying if production can adapt to disruptions by using inventories. By incorporating inventories into the analysis, this paper brings an additional margin to have in mind when assessing vulnerabilities: firms highly reliant on low-diversified products may hold inventories – from the systematic negative relationship between inventories and diversification –, which in turn can mitigate concerns about "under-diversification", at least regarding short-term disruptions.

The paper is organized as follows. Section 1 and Section 2 describe the measures of inventories and diversification, respectively, as well as empirical patterns about firm-level inventory ratio and diversification. Section 3 explores the relationship between sourcing risk, inventories and diversification. Finally, I draw implications for trade vulnerabilities in Section 4.

1 Firm-level inventories

1.1 Measuring inventories

In fiscal forms, firms must report the nominal value of their inventory of inputs. This variable is absent from standard balance sheet data used by researchers (*FARE*), but is available in raw fiscal forms, and is of satisfying quality (see Appendix B). This variable S_{ft} is a stock, meaning that when they fill out the fiscal form, firms report the value of inventories they have at hand, and they have to value it at the purchasing price. I restrict my analysis to manufacturing firms[5] and I apportion this level of inventories to total inputs available to the firm throughout the year to obtain a ratio that I call the inventory ratio. [6] This measure is scale-free, which facilitates comparisons of inventories across sectors, firms or over time. Specifically, I calculate the inventory ratio as follows:

$$\begin{aligned} \text{Inv. Ratio}_{ft} &= \frac{S_{ft}}{M_{ft} + S_{f,t-1}} \\ &= \frac{\text{Inv. of inputs}_{ft}}{\text{Material inputs expenditures}_{ft} + \text{Inv. of inputs}_{ft} - \Delta S_{ft}} \end{aligned} \tag{1}$$

The inventory ratio is the fraction of total available inputs throughout the year that the inventories at the end of the year S_{ft} account for. $M_{ft} + S_{f,t-1}$ is the sum of material inputs expenditures (from *FARE* data) and end-of-year last year's inventories. I make use of the balance sheet variable recording changes in inventories ΔS_{ft} (from *FARE*), and the fact that $S_{f,t-1} + \Delta S_{ft} = S_{ft}$, to build $S_{f,t-1}$. It is important to note that the inventory ratio is measured at the end of the year, and may not reflect the average level of inventories in the firm throughout the year. Furthermore, inventories are valued at acquisition cost, meaning that inventories of the same input may be valued at different prices, depending on inflation and when they were purchased. During periods of high inflation, such as those observed in 2022–2023, this valuation method can affect changes in the ratio, depending on how inventories were used and replenished during the year. It is unclear how it affects the cross-sectional distribution of inventory ratios and its evolution over time. Sector-specific time dummies in regressions will capture part of this effect.

[5] Manufacturing firms account for more than 80% of total inventories of inputs in France.

[6] The firm does not use all inputs available for production in year t: it retains a portion, denoted by S_{ft}, which will be available for production in year $t+1$. While the denominator of the inventory ratio captures the potential output based on all inputs available, an alternative measure of inventories could be expressed as $\frac{S_{ft}}{M_{ft} - \Delta S_{f,t}}$, representing the share of year-end inventories relative to the inputs actually used for production during year t. However, inventories are not simply a by-product of the production process or of timing constraints; they represent a deliberate strategy by firms to buffer their production against shocks. The ratio scales year-end inventories with their intended functions — sustaining production and absorbing fluctuations. Another way to interpret this ratio is that is corresponds to the inputs a firm has retained at the end of the year relative to all the inputs it had at its disposal to produce during the year (its potential production). In practice, these measures are closely related, since inventories are generally small compared with total inputs (see Figure S.4).

1.2 Descriptive facts about inventories of inputs

The average inventory ratio, i.e. the aggregate version of Eq. (1) computed as the sum of firms' stocks over the sum of firms' inputs, was around 12% in 2019 for importing manufacturing firms: firms kept an average of 50 days' worth of input inventory. Panel A of Figure 1 shows that the average inventory ratio was between 10 and 15% between 2012 and 2023, with a stable level between 2012 and 2017 and a notable increase from 10 to 16% between 2018 and 2023. This increase is shared by other economies like the US or Japan (see Carreras-Valle, 2024) and may reflect increasing uncertainty over the period. This average value is below the median inventory ratio, between 15 and 20%, first because a non-negligible amount of firms, around 7%, do not hold inventories, and second because large firms display a lower level of inventories, as I show in the next section. The interquartile range is also stable over time until 2019 but increases markedly between 2019 and 2021: the 75th percentile of the inventory ratio distribution increases from 26% to almost 32%, while the 25th percentile also grows but modestly (from 8% to 10%), driving the increase in both the median and the mean inventory ratio.[7]

Panel B of Figure 1 shows the median inventory ratio across 2-digit manufacturing industries. First, it reveals differences in stock levels across industries, ranging from around 10% of material input expenditure in the food industry to 30% in the pharmaceutical or electrical products industry. This suggests that the depreciation of stored inputs may explain the inventory ratio, as food and beverage inputs depreciate faster than molecules or electrical products. The graph also reports the interquartile range of the inventory ratio distribution across firms within industries. It reveals significant heterogeneity: in the apparel industry, for example, one quarter of firms operate with less than 10% of stored inputs, while another quarter operate with more than 60%. Such heterogeneity may signal differences in the mix of inputs, production organization or even products, given that 2-digit industries are relatively large categories.

Nevertheless, this heterogeneity within industries remains significant when industries are defined more narrowly. Appendix Table S.1 displays the R^2 of several versions of a regression of the firm-level inventory ratio on industry fixed effects. Overall, industry fixed effects explain a maximum of 17% of the variance in the inventory ratio across firms. Its means that it is not much the activity of the firm that explains its level of inventories, but rather firm-level differences explain the lion's share of the differences in the inventory ratio across firms.[8] Indeed, the distribution of inventory ratios across firms is highly dispersed. Some importing firms do not hold any inventories: 7% report no inventories in any given year. This may seem high and cast doubt on the quality of the inventory data. However, there are good reasons to believe these are genuine zeros. Firstly, wholesalers almost

[7]The patterns are similar for the whole manufacturing industry, including non-importing firms: an average between 10 and 15%, an increase between 2018 and 2021, and large heterogeneity. See Figure S.4.

[8]Besides, industry fixed-effects also poorly predict the extensive margin – holding inventories of inputs or not –, as they explain less of the variance across all firms when including those without inventories.

never display zero inventories. Secondly, because the correlation between not holding inventories for two consecutive years at firm level is high (more than 90%). Thirdly, inventories are assets to the firm. Under-reporting inventories would make the firm appear less profitable than it actually is. The distribution of inventory ratios across firms is close to a log-normal distribution (see Appendix Figure S.6).

1.3 Who holds inventories?

As most of the variation in inventory ratios across firms occurs within industry, I am now turning to regressions of the inventory ratio on various characteristics of the firm.

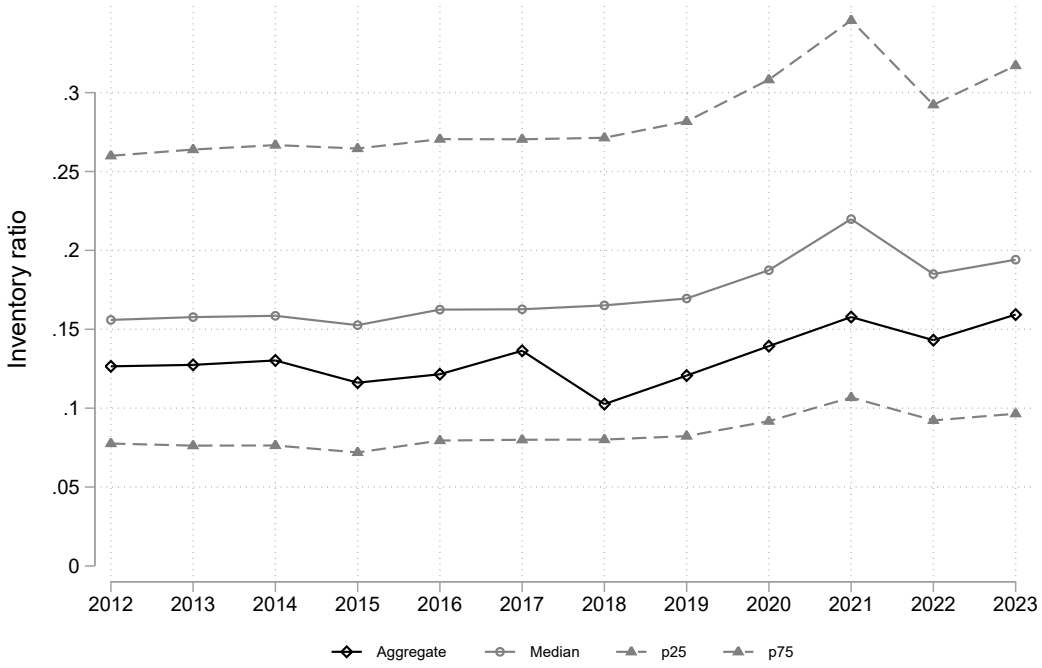
The inventory ratio decreases with firm size. The first key finding is that, relative to their size, large firms hold fewer inventories than small firms. Panel A of Figure 2 displays the inventory ratio according to firm size decile among French importers. There is a strong negative relationship between inventory ratios and size, which is nearly log-linear. On average, firms in the first decile of sales keep 25% of material inputs in inventories. The inventory ratio of firms in the last decile is approximately 15%. Panel B takes this a step further by residualising the variables on industry-year fixed effects, indicating that this strong relationship is not due to industry composition, time trends or industry-specific time trends. The OLS coefficients and standard errors reported below the graphs confirm that this relationship is statistically significant.

However, these results do not provide information about the mechanism driving the relationship, but some can be discarded.

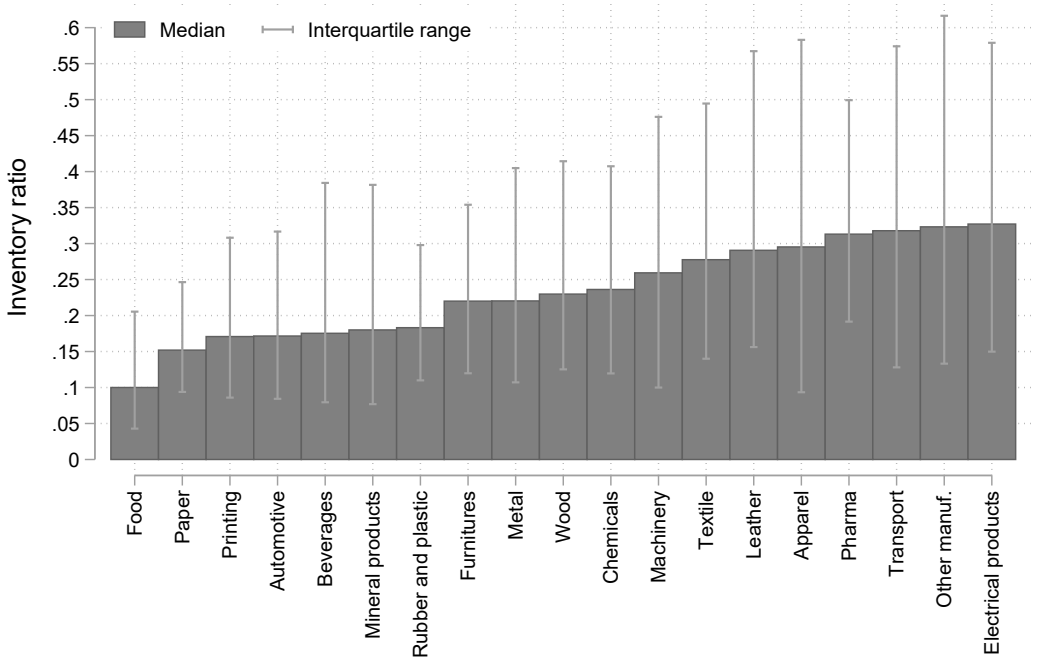
The correlation may be driven by variation in inventory costs across firms within industries. For instance, firms may use different input mixes, even within narrowly defined industries (Boehm and Oberfield, 2020), hence different inputs may depreciate at different rates. Or, a digitised supply chain department may reduce warehouse losses while improving firm productivity. To discard those explanations and try to determine whether size is directly related to the inventory ratio, I make use of the full depth of the data and narrow down the regressions to the correlation between size and the inventory ratio within firms over time, that is conditional on firm fixed effects. This allows supply-chain costs and sales to be correlated across firms in levels: the digitization of the firm may help in reducing inventories and improving productivity, but with a constant effect over time. Panel C of Figure 2 shows that this relationship remains strong and is even stronger than the raw correlation: as firms grow, they reduce their inventory holdings. A ten percent increase in sales is associated with a 0.75 percentage point decrease in the inventory ratio, representing 4% of the average inventory ratio. Table S.5 in Appendix shows that the relationship holds if, instead of sales, firm size is proxied by the number of physical employees, value-added or value-added per worker. The fact that firms hold fewer inventories as they grow might mechanically reflects that higher-than-expected demand

Figure 1: Inventory ratio among importing firms at the aggregate and industry level

Panel A: Aggregate inventory ratio over time



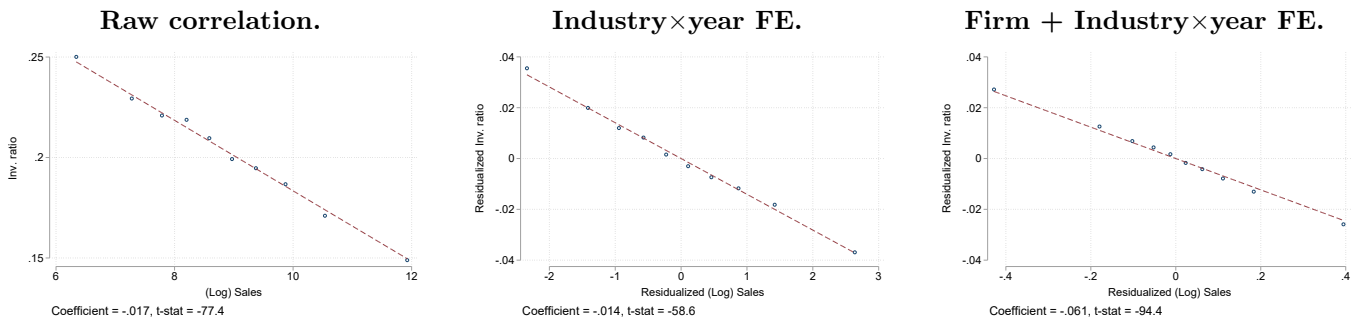
Panel B: Inventory ratio across sectors



Notes: **Panel A:** "Aggregate" is the inventory ratio of importing firms of the manufacturing industry, over time. Median, 25th, and 75th percentile correspond to the distribution of the inventory ratio across all manufacturing and importing firms. **Panel B:** Histogram of the median, 25th, and 75th percentile of the inventory ratio distribution across importing firms within the industry on the x-axis. One observation per importing firm-year, between 2012 and 2023.

increases sales while depleting stocks. More generally, large firms hold fewer inventories because they may be convex costs of inventories, as proposed by Ramey and West (1999), that make inventory more expensive for large firms. Small firms may be less able to predict demand and supply conditions, so stockpile more to prevent stock-outs. The focus of this paper is on the role of diversification: large firms may also be less exposed to supply risk as they happen to be more diversified, as I show in Section 2, reducing the need for inventories.

Figure 2: Inventory ratio by firm size



Notes: This figure reports binscatters of the inventory ratio on log sales. **Panel A**: raw data. **Panel B**: after removing 5-digit industry×year fixed effects. **Panel C**: after removing firm and 5-digit industry×year fixed effects. Regression lines and coefficients below are estimated from the corresponding firm×year-level OLS.

Other determinants of inventories. Although this pattern is striking, firm size is not the only factor driving the inventory ratio. The granularity of customs data enables us to examine supply-chain differences across firms that may affect inventory levels in more detail. To begin with, importing firms are more likely to hold inventories of inputs at the extensive margin (see Column 1 of Table 1). Starting to import increases the probability of holding inventories by 7% (0.011/0.16). This is not surprising, given existing evidence that importers hold more inventory (Alessandria et al., 2010), and this is true even when controlling for firm size (Column 2). Large firms are more likely to hold inventories, suggesting that fixed costs such as bookkeeping, purchasing inventory management software and renting a warehouse are involved. Once they are holding inventories, importers hold more of them (Column 3), and the inventory ratio increases with the share of material inputs purchased internationally (Column 4). This has several interpretations. First, importers may keep more inventory because international sourcing involves higher fixed costs than domestic sourcing. If so, firms import less frequently to save on fixed costs — international trade is "lumpy". As in Alessandria et al. (2010), I can measure the lumpiness of international sourcing as the HHI of import transactions from origin-product observations in a given year. A high HHI reflects the concentration of imports over a few shipments throughout the year — that is, less frequent shipments. Column (5) displays the results of regressing the inventory ratio against the lumpiness of import transactions: the more lumpy (i.e. less frequent) the import shipments, the more inventories a firm keeps, in line with previ-

ous literature (Alessandria et al., 2010). A second interpretation is that international trade is riskier than domestic trade, hence increasing the need for inventories. One risk factor for international shipping is the use of sea transportation for imports, which is subject to high variability in transport times (Blaum et al., 2023). Furthermore, inventories may increase with delivery times, hence with distance from suppliers (Carreras-Valle, 2024). The data supports this: the inventory ratio increases with the share of imports shipped by sea and with the sea distance to sourcing countries (Column 6). I will return to the role of sourcing risk in Section 3.

All in all, importers and large firms are more likely to hold inventories. Conditional on holding some inventories, the inventory ratio is larger among small firms, all the more so as the imported input share is high. I provide suggestive evidence of two channels for this finding: first, international shipments are less frequent than domestic ones, and second, international shipping is riskier.

Table 1: Inventories and correlates

	Inv. Ratio > 0		Inv. Ratio			
	(1)	(2)	(3)	(4)	(5)	(6)
Importer dummy	0.011***	0.005***	0.003***			
	(0.001)	(0.001)	(0.001)			
(Log) Sales		0.054***	-0.070***	-0.077***	-0.073***	-0.079***
		(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
(Log) Import share				0.007***	0.010***	0.013***
				(0.000)	(0.000)	(0.001)
(Log) HHI of imports					0.017***	
					(0.001)	
(Log) Share of imports by sea						0.002***
						(0.000)
(Log) Distance of imports by sea						0.002***
						(0.001)
Avg.	0.160	0.160	0.190	0.220	0.220	0.230
Obs.	594,405	594,405	526,256	181,009	179,912	109,136

Notes: This table reports various regressions of the binary variable equal to one if the firm holds inventories of inputs (Columns 1-2) or the inventory ratio on firm-level variables. Inv. ratio is the ratio between inventories of inputs and total available inputs in a given year. Columns (3) to (6) restrict to firms with positive inventories. One observation per firm × year. All regressions include firm and industry × year fixed effects. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

2 Firm-level diversification

2.1 Measuring firm-level diversification

I use customs data to build a measure of diversification of supply sources at the firm level. The main measure of diversification averages firm-product-level diversification at the firm-level. It is built as a weighted average of the number of countries from which a firm sources its inputs:

$$\text{Diversification}_{ft} = \sum_{p} \omega_{fpt} N_{fpt} \tag{2}$$

Eq. (2) is a generic version of the actual measure I use, defined in Eq. (3). ω_{fpt} is the cost share of product p in firm f in year t and N_{fpt} is the number of countries the firm sources product p from. I choose a weighted average to aggregate product-level diversification to mirror the inventory ratio that bundles all inputs, hence is a weighted average of product-level inventory ratios, weighted by cost shares.[9] To bring the diversification measure closer to the inventory measure, which is about material inputs expenditures, I restrict the diversification measure to products classified as intermediate goods, following the UN-BEC classification of products. Measuring firm-level diversification that way requires some discussion.

Firms vs. countries. When counting the number of supply sources to measure diversification, the ideal data would give the number of individual firms supplying the product. It is impossible to construct this measure as it is not recorded in French data as of 2025. The most detailed data on purchases of inputs to date is customs data, in which all imports for most importing French firms are broke down by product, origin country, and time (a calendar month). In other words, customs data are silent about the number of individual suppliers in foreign country c, whose exports to firm f end up being aggregated into total imports of good p from country c. Hence, the best measure of number of suppliers is the number of individual countries firm f sources product p. This measure of diversification of supply sources captures hedging between country-specific shocks, as in Grossman et al. (2023), which can reflect geopolitical risk, climate risk, or even risk on trade routes specific to the origin country. It however falls short of capturing other strategies to hedge risk within countries, such as relying on different suppliers within countries (Castro-Vincenzi et al., 2024) or different shipping companies and shipping ports in order to mitigate shipping risk (Blaum et al., 2023).

[9] Measuring firm-level diversification as the average diversification across inputs implicitly puts restrictions on how inputs are combined. For instance, if the production function is Leontief, so that the elasticity of substitution between products is zero, an adequate measure of firm-level diversification should be the minimum diversification across inputs. More generally, averaging diversification with cost shares reflects the first order effect of shocks to inputs on input costs, which is proportional to cost shares. Conceptually, two other measures could be put out: the minimum number of countries from which a firm sources its inputs; and a measure of concentration of suppliers across products.

Domestic sourcing. Customs data cannot do much more than delivering information on international sourcing. However, not taking domestic sourcing into account introduces a bias in the measure of diversification. Because we do not observe domestic sourcing, not only the actual number of countries from which firm f sources its input p is unknown – either the number of foreign countries N^M_{fpt} or the number of foreign countries plus France –, but also the set of inputs the firm purchases. From here, we can take alternatively two polar assumptions. The first one would be that the firm's international sourcing is representative of the firm's sourcing, in the sense that products sourced internationally are identical to products sourced domestically – hence from $1 + N^M_{fpt}$ countries –, and that the cost share ω_{fpt} of product p is equal to its import share of product p. Diversification is then measured as:

$$\text{Div.}_{ft} = \sum_{p \in Imp} \omega^M_{fpt}(N^M_{fpt} + 1) \tag{3}$$

Throughout the paper, I choose Div._{ft} as the main measure of diversification.

A subtlety here is that not all products are produced or even available in France, hence for some products, the assumption that the number of sourcing countries is $N^M_{fpt} + 1$ cannot be true. There is no proper way to collect the set of available products in France, but I can retrieve the set of products produced in France, from annual production surveys conducted by Insee (*Enquête Annuelle de Production*) that are specifically designed to inform about the production capability of manufacturing firms in France. Hence, a refined version of Div._{ft} can be built:

$$\text{Div.}^{FR}_{ft} = \sum_{p \in Imp} \omega^M_{fpt}(N^M_{fpt} + \mathbb{1}(p \text{ is produced in France})) \tag{4}$$

Div.^{FR}_{ft} is highly correlated with Div., as almost 90% of imported 8-digit products are also produced in France. Still, products produced in France may be exported, and some products are not produced in France but can nonetheless be purchased from wholesalers and retailers, so even Div.^{FR}_{ft} may overstate diversification through French suppliers. One can turn to the opposite polar assumption which amounts to consider that products sourced internationally are not sourced domestically, in which case the diversification measure would write

$$\text{Div.}^{*}_{ft} = \sum_{p \in Imp} \omega_{fpt} N^M_{fpt} + \sum_{p \in Dom} \omega_{fpt} = \sum_{p \in Imp} \omega_{fpt} N^M_{fpt} + S^{dom}_{ft} \tag{5}$$

where S^{dom}_{ft} is the cost share of domestic inputs, capturing the fact that domestic inputs are sourced only from the domestic country. This measure suffers from two main limitations. First, the assumption of no sourcing in France is unlikely to hold given the high coverage of imported products by French production (90%). Moreover, S^{dom}_{ft} cannot be precisely measured in the data. S^{dom}_{ft} is given by one minus the ratio between imports of inputs (from customs data) and material inputs expenditures

(from fiscal data). The use of two different sources of data creates extreme values, with almost 10% of importers exhibiting a negative domestic share, that I assign to a zero domestic share. Because of these limitations, I will report results for Div.^*_{ft}, but they are at best indicative.

Substitutability of imported varieties. It is nearly impossible to tell whether two countries supplying the same good are supplying the exact same variety of that good. An assumption behind measuring diversification as the number of countries from which a firm sources a given 8-digit product is that imported product × countries within a product category are substitutes. This assumption may in general be a good approximation, as products here refer to 8-digit categories of the Combined Nomenclature (CN), an EU classification system that derives from the international product classification (the Harmonized System, HS) defined by the World Customs Organization – 8-digit CN headings are sub-headings of 6-digit HS headings. 8-digit CN categories can be very narrow: for instance, 7005 is "Float or polished glass", 700510 is "Non-wired glass, having an absorbent layer", and 70051025, 70051030, and 70051080 correspond to a thickness of glass below 3.5mm, between 3.5mm and 4.5mm, and above 4.5mm. Still, some 8-digit categories contain products for which substitutability across suppliers is difficult – for instance, "internal combustion engines with a cubic capacity exceeding 500 cm^3 but not exceeding 1,000 cm^3" (CN 84073380) may be customized depending on the vehicle in which the engine is to be embedded. The sourcing of such products has implications for the measure of diversification: if we consider these products as fully differentiated, then no diversification is possible and we overstate diversification by counting the number of countries. Therefore, I explore the robustness of the main empirical results by constructing alternative measures of diversification that focus on products for which a large number of supplying countries is likelier to be indicative of diversification rather than product variety. I do so by restricting the set of products in Equation (2) to non-differentiated products in the sense of Rauch (1999), or to products for which supplier switching is particularly easy (first three quartiles of the relationship stickiness of Martin et al., 2023).

An alternative measure of product-level diversification. Equation (2) aggregates one product-level diversification measure, the number of sourcing countries. Conceptually, a measure of product supply diversification should inform about how costs vary with shocks to one source of supply. Here, I choose to measure diversification with the number of supply sources, as a high number of suppliers usually means a lower variance of supply. For instance, when all suppliers are identical and uncorrelated, the variance of total supply is inversely proportional to the number of suppliers. More generally, the variance of supply goes to zero as the number of suppliers increases, unless the risk profile of some suppliers is fat-tailed. That way, measuring diversification with the number of supplying countries is agnostic on which country is riskier. An alternative would be to measure the concentration of supply across suppliers. I reproduce some of the results in the following sections using a

Herfindahl-Hirschmann index as an alternative measure of product-level diversification, defined as:

$$\text{HHI}_{ft} = \sum_{p \in Imp} \omega^M_{fpt} \sum_c (\omega^c_{fpt})^2 \tag{6}$$

where ω^M_{fpt} is the import share of product p and ω^c_{fpt} is the share of country c in imports of product p by firm f.

All in all, given a set of inputs, there are three ways to build a measure of diversification from customs data (the number of source countries with France, without France, and the HHI across foreign countries), and each time, the set of products can be narrowed down to products with substitutable varieties. Diversification can also take into account which products are also produced in France (Div.$^{FR}_{ft}$). In what follows, I use Div.$_{ft}$ on all products as the main measure of diversification, mainly because it is easiest to replicate and it is the most precisely measured in the data – it uses only customs data – but also because it is the most agnostic about product substitutability. I replicate the main results in the Appendix first using the measure including French products, second restricting to non-differentiated or non-sticky products, using Div.$^*_{ft}$, and last using the HHI.

2.2 Diversification across firms

Diversification is heterogeneous. Table 2 shows statistics about the main measure of diversification, Div.$_{ft}$, in the sample. Overall, there is dispersion in diversification across firms. Across all firms, more than 50% of them source all their inputs from only one country (including France). Importing firms import the same product from 3.2 countries on average, but at least a quarter of firms import from only one country, 50% only from at most 2.4 countries, and 10% from at least 5.3 countries. As for inventories, diversification is mostly explained by firm-level characteristics, as time-varying industry fixed effects can explain at most 20% of the variation in diversification across firm×years (see Appendix Table S.3). The several alternative diversification measures also display a high degree of heterogeneity (see Appendix Table S.2). All are fairly correlated with the main measure, especially for Div.^{FR}; as said above, almost 90% of imported products are also produced in France. Diversification on non-sticky products is also highly correlated with Div.; that may be due to the threshold chosen for non-sticky, that groups 75% of products.

Large firms are more diversified. Panel A of Figure 3 shows diversification by decile of firm size among French importers. The relationship between the number of foreign suppliers and size is log-log. Firms in the first decile of sales connect to a little more than one supplier per imported product, while they connect to 4.5 suppliers on average in the last decile. Panel B goes one step further with variables residualized on industry×year fixed effects, and indicate that this relationship is not due to industry composition, or industry-specific time trends. The OLS coefficients and standard errors

Table 2: Summary statistics on the inventory ratio and the diversification measure

	Avg.	P10	P25	Med.	P75	P90	Obs.
Inv. Ratio	.17	0	.04	.12	.24	.39	602,645
Inv. Ratio, importers	.2	.02	.08	.17	.29	.42	202,489
Div.	1.75	1	1	1	2	3.15	602,645
Div., importers	3.22	2	2	2.39	3.49	5.27	202,489

Notes: This table displays the average and several percentiles of the distribution of the inventory ratio and diversification measures across firm × year in our sample. Inventory ratio is the ratio between inventories of inputs and material inputs expenditures. Diversification is measured as the average number of sourcing countries per imported NC8 product in a given year – see Equation 3. Lines 2 and 4 restricts to importing firms.

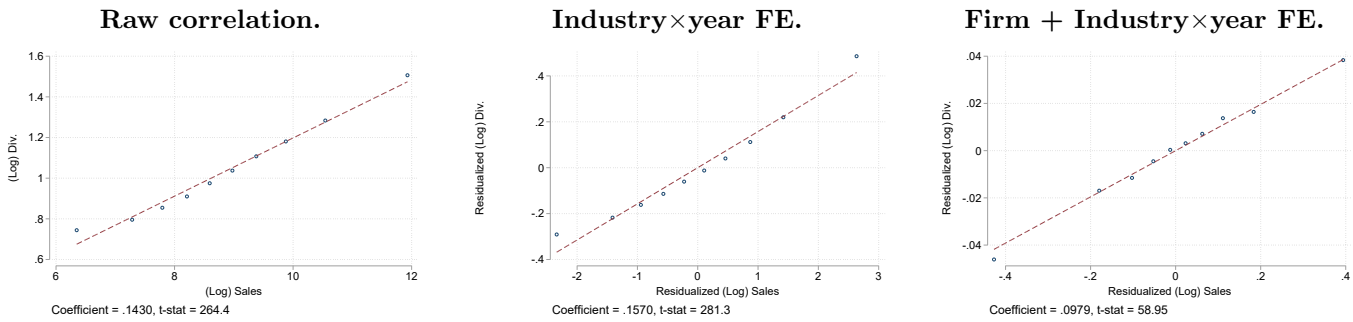
reported below the graphs confirm that these relationships are statistically significant. The finding that large firms connect with more suppliers per product is a well-known feature of international sourcing – see, for instance, Antras et al. (2017); Bernard et al. (2018); Dhyne et al. (2023). The novelty here is that this fact holds within narrowly defined categories of products.

Why are large firms more diversified? Intuitively, this is because diversification involves sunk costs. The more suppliers, the more sunk costs to be paid, therefore the more expensive it is for small firms. Still, this mechanism is not the sole driver behind diversification. The correlation here might just reflect variation in sunk costs across firms, or other mechanisms that happen to be correlated with both firm size and the costs or benefits to diversify. For instance, large firms may import goods that are easier to diversify; or they are more likely multinational firms with foreign affiliates abroad, for which the sunk cost to connect with is low. Similarly, if sunk costs of connecting with a new supplier is the sum of a sunk cost to connect to a given country and a sunk cost to find a supplier within this country, then it is relatively cheaper for large firms to diversify on an input if it is already diversified on other inputs. To try to isolate the role of size on diversification, I first make use of the full depth of the data and study the correlation between size and diversification within firms over time, that is conditional on firm fixed effects. This allows supply-chain costs (or benefits) and sales to be correlated across firms in levels.

Panel C of Figure 3 shows that the relationship still holds: as firms grow, they increase their diversification. A ten percent increase in sales is associated with a 1 percent increase in diversification. Table S.6 in Appendix shows that the relationship holds if, instead of sales, firm size is proxied by the number of physical employees, value-added or value-added per worker.

Other determinants of diversification. Table 3 provides further analysis on firm-level diversification. Column (1) replicates Panel C of Figure 3. Column (2) includes the number of imported products as a control: as explained above, if there is a sunk cost to connect to a new supplying

Figure 3: Diversification by firm size



Notes: This figure reports binscatters of diversification on log sales. **Panel A**: raw data. **Panel B**: after removing 5-digit industry×year fixed effects. **Panel C**: after removing firm and 5-digit industry×year fixed effects. Regression lines and coefficients below are estimated from the corresponding firm×year-level OLS.

country, there are economies of scale on diversification in the number of imported inputs. Similarly, a high reliance on imports may create economies of scale on the costs of connecting to suppliers, so I include the share of imported inputs in total material expenditures as a covariate. The regression confirms the intuition: both are positively correlated with diversification. Besides, the coefficient on sales decreases slightly, as large firms import a higher number of different products, and their supply-chain is more international. Last, some of the variation in diversification across firms may reflect variation in inputs mixes, some inputs being easier to diversify than others. If inputs mixes are stable over time, then firm fixed-effects should absorb this variation. If firms change their production processes, start new products or stop producing others, input mixes change. This calls for controlling for the input mix, but it would imply adding as many fixed effects as there are combinations of the 8,000 products. Rather, I build a measure of supplier availability by aggregating a measure of 'potential' diversification of products. Specifically, I use the BACI-COMTRADE dataset to compute the number of countries supplying each product, each year, that I then aggregate using firm-level import shares (as in Equation 3). This provides a measure of how diversified a firm could be. I add this regressor in Column (3), and it correlates positively with firm-level diversification.

Even after controlling for firm and industry × year fixed effects and potential confounders, the relationship between firm size and diversification is strong. It is consistent with large fixed costs and some economies of scale when diversifying supply sources. Moreover, it is constrained by availability of suppliers at the world level. These findings also hold for the other measures of diversification (see Appendix Table S.7).

3 Inventories, diversification, and supply-chain volatility

I now turn to the relationship between supply-chain risk, inventories, and diversification. I first provide evidence that diversification and inventories may be strategic substitutes in supply-chain

Table 3: Diversification and correlates

	(1)	(2)	(3)
(Log) Sales	0.098***	0.086***	0.086***
	(0.003)	(0.003)	(0.003)
(Log) Nb. of imp. products		0.018***	0.018***
		(0.002)	(0.002)
(Log) Import share		0.034***	0.035***
		(0.001)	(0.001)
World diversification			0.047***
			(0.005)
Obs.	195,204	195,204	194,989

Notes: The dependent variable is the main measure of diversification – see Section 2.1 for details. One observation per firm × year. All regressions include firm and industry × year fixed effects. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

strategies. I then show evidence for a plausible mechanism behind, that is the volatility of imports of diversified firms is lower, while inventories are used to smooth import shocks.

3.1 Inventories and diversification as strategic substitutes

Sections 1 and 2 showed that there was a strong negative relationship between inventories and firms size, and a strong positive relationship between diversification and firm size. These two sets of results suggest that inventories and diversification may be substitute strategies: the higher the diversification, the lower the inventory ratio. This section aims at deepening the evidence on this substitutability. I run regressions of the general form:

$$\text{Inv. Ratio}_{ft} = \beta D_{ft} + \text{Controls}_{ft} + FE + \epsilon_{ft} \tag{7}$$

where β is expected to be negative. To ease the interpretation of results, D_{ft} is the logarithm of one of the measures of diversification. I estimate the relationship and restrict to the intensive margin of inventories by discarding firm×year observations with no inventories.

Column (1) of Table 4 reports the raw firm-level correlation between diversification and the inventory ratio, which is negative and significant both statistically and economically: an increase from one to 2 suppliers on average decreases the inventory ratio by 2.8 percentage points, around 13% of its average value in the regression sample. The negative correlation holds within industries (Column (2)). I then control for the share of imported goods. As imported goods are more subject to stockpiling (see, e.g., Alessandria et al., 2010), firms with a large import share exhibit larger inventory ratios, regardless of risk. Indeed, I estimate a positive coefficient for the share of imports in

material inputs expenditures (Column (3)). Controlling for the import share increases the magnitude of the correlation between diversification and inventories from 0.030 to 0.049: this is because the import share and diversification are positively correlated. I then control for the number of imported products. Firms importing multiple products may benefit from some economies of scale on sunk costs to given sourcing countries, and be able to diversify more, and thus hold less inventories. As expected, including the number of imported products slightly decreases the magnitude of the correlation between inventories and diversification (Column (4)). Last, as emphasized by Sections 1 and 2, firm size drives a negative correlation between inventories and diversification. I thus control for total sales in Column (5) and the negative correlation still holds, albeit less strongly, suggesting that the trade-off between inventories and diversification is also driven by other factors than firm size – for instance, costs of connecting to new suppliers and inventory depreciation. These parameters may well be heterogeneous across firms, so in Column (6), I add firm-fixed effects to discard such time-unvarying firm-specific factors. The correlation is slightly less precisely estimated but still negative. Together, these results point to a robust negative relationship between the extent of inventories of inputs and supply diversification at the firm level.

Table 4: Inventories and diversification are substitutes

	Inv. Ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
(Log) Div.	-0.021***	-0.030***	-0.049***	-0.033***	-0.008***	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
(Log) Import share			0.009***	0.014***	0.009***	0.009***
			(0.000)	(0.000)	(0.000)	(0.000)
(Log) Nb. of imp. products				-0.016***	0.002**	-0.008***
				(0.001)	(0.001)	(0.001)
(Log) Sales					-0.025***	-0.074***
					(0.001)	(0.002)
Ind.*Year FE		✓	✓	✓	✓	✓
Firm FE						✓
Avg.	0.220	0.220	0.220	0.220	0.220	0.220
Obs.	181,009	181,009	181,009	181,009	181,009	181,009

Notes: This table reports the results of estimation of Equation 7. Inv. ratio is the ratio between inventories of inputs and total available inputs in a given year. Diversification is defined in Section 2.1. One observation per firm × year. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Alternative diversification measures. Appendix Table S.8 displays versions of the last column of Table 4 in which I replace diversification by the alternative measures defined in Section 2. The negative correlation between diversification and the inventory ratio holds when taking into account more precisely sourcing potential in France (Div.^{FR}), when measuring diversification with the HHI

across suppliers, and, notably, when restricting the diversification measure to non-differentiated products or to products with low relationship stickiness. As explained in Section 2, an assumption behind the measure of diversification is that imported product×countries are substitutes within 8-digit product categories. If they are not substitutes, they are different products, and in that case a high number of sourcing countries is likely to increase the inventory ratio. The correlation is still negative and significant, and slightly stronger than the baseline, when restricting the measure of diversification on 8-digit products for which varieties are more likely to be substitutable. I also control for the share of non-differentiated (or non-sticky) products in total imports and the estimated coefficient on this share is positive, meaning that the larger the share of these products in total imports, the larger the inventory ratio. This may be interpreted as firms stockpiling more on inputs with higher import shares.

The only diversification measure that correlates positively with the inventory ratio is the measure corrected by the share of domestic purchases Div^*. This result should be taken with care, as Div^* is a poor proxy of diversification, as explained in Section 2, in particular because the share of domestic purchases is highly noisy in the data.

An interpretation. Overall, I conclude that the inventory ratio and sourcing diversification are negatively correlated. This systematic negative correlation can be interpreted as inventories and diversification being substitutes in firms' supply-chain strategies. In the presence of supply risk, firms may stockpile inputs, so that in the event of a negative supply shocks – a disrupted trade route, a flood at a supplier's plant, supplier's bankruptcy, etc. –, production can keep on. The buffering role of inventories in absorbing industry-wide shocks has been recently demonstrated by He (2023) in the context of U.S. industries. Lafrogne-Joussier et al. (2023) show that French firms with a high level of inventories were able to fully absorb the foreign inputs disruption caused by the lockdown in China in early 2020. Theoretically, for risk-averse firms, the higher the sourcing risk, the higher the inventory ratio. On the other hand, firms may invest in supply reliability (Elliott et al., 2022) to reduce the variance of supply shocks, or sourcing risk. Such investments may be made by spending more time on due diligence or on designing contracts, or in finding alternative suppliers. Alternative suppliers can be useful either to split orders – as a diversified portfolio – or to have alternatives to bounce back quickly if the chosen supplier cannot provide the input in time. This last facet of supply-chain strategy is diversification.

The findings of this paper, that inventories and diversification are negatively correlated and that large firms are diversified while small firms hold inventories, can be rationalized by a simple model. Firms pay fixed costs to acquire new suppliers that reduce the variance of purchases, and stockpile inputs at a smaller fixed cost. Inventories depreciate at a constant rate, so the cost of holding inventories is linear in the amount of inputs stored. But inventories can be used to produce in the event of a negative supply shock. On the opposite, the fixed cost of diversification does not vary

with size and so is relatively cheaper for large firms. All in all, in this simple model, large firms diversify and small firms rather stockpile. There may also be convex costs of inventories, as proposed by Ramey and West (1999), that make diversification relatively cheaper for large firms. Besides, other sources of heterogeneity across firms can generate the negative correlation between inventories and diversification in the data, beyond firm size. Geography, for instance, is tied to the cost of land, that also dictates the cost of inventories, so the reliance on inventories to buffer supply risk may depend on firm location. Differences in input mixes lead to different depreciation costs, so two firms of the same size but with different positions in the supply chain may rely differently on inventories. A cornerstone of the empirical results of this paper and of this simple model is that diversification, measured by the number of supplying countries, actually reduces the variance of supply. The next subsection explores this question.

3.2 Diversification and imports volatility

Underlying the measure of diversification as the number of supplying countries is the assumption that supply risks stemming from different countries are not perfectly correlated. Firms with high diversification should then mechanically exhibit lower import volatility. But, firms may import products of the same 8-digit category from different countries for other reasons than pure diversification. Hence, it is an empirical question of whether a high number of supplying countries is associated with a lower volatility of import flows.

The first column of Table 5 shows the raw correlation between diversification and import volatility. I measure the volatility of import flows within a year as the standard deviation of monthly import growth. More diversified firms exhibit a lower imports volatility, and it is also true within industry (Column (2)), and within firm over time (Column (3)): in years in which the firm has a more diversified sourcing, its imports are more evenly distributed throughout the year. This is not sufficient to conclude that the number of countries is an actual measure of a pure diversification motive: other channels can affect both diversification and import volatility, which I try to address in turn.

First, large firms may be able to extract more reliability from their suppliers than small firms, if investing in relationship reliability is costly (as in Elliott et al., 2022). Similarly, disrupted suppliers may prefer to keep on serving demand from their largest customers and stop momentarily to serve small customers, so that the likelihood that large firms face a disruption on a given link is lower than for small firms, all else equal. Hence, even in the absence of diversification, we expect large firms to exhibit lower import volatility; because firms size and diversification are positively correlated, not controlling for size may drive down the negative correlation between diversification and import volatility. The data confirms this intuition, as imports are less volatile among large firms, and the estimated coefficient on diversification decreases in magnitude when controlling for firm size (Column (4)). However, diversification and import volatility may be mechanically correlated through the

way they are measured. If the firm splits its orders between 3 countries, three flows will show in the data, and they may arrive at different times, smoothing import flows across months. This would mechanically reduce the volatility of imports, but not because it smooths risk, but because it spreads transactions. Therefore, I first control for the number of months in which the firm imports (Column (5)). Second, I control for the number of import flows (Column (6)). In both cases, the negative correlation between import volatility and diversification decreases in magnitude, but is still significant. Not surprisingly, the number of transactions is highly correlated with import volatility, firms with a small amount of imports may import only once a year, making import flows highly volatile. The coefficient on diversification is small, but conditional on a number of import transactions, a diversification of two instead of one decreases the standard deviation of import growth by 0.019 ($= 0.028 \times \log(2)$), which amounts to 49% of the median standard deviation. I conclude that a higher number of sourcing countries is associated with a lower volatility of import flows, all else equal. It suggests that, although not perfect, counting the number of origin countries per imported product is indicative of sourcing diversification.

Table 5: Imports volatility decrease with diversification

	Std. Dev. of monthly imports growth					
	(1)	(2)	(3)	(4)	(5)	(6)
(Log) Div.	-0.641***	-0.645***	-0.222***	-0.196***	-0.159***	-0.028***
	(0.008)	(0.008)	(0.011)	(0.011)	(0.011)	(0.010)
(Log) Sales				-0.155***	-0.131***	-0.034***
				(0.011)	(0.010)	(0.011)
(Log) Nb. of months with imports					-0.157***	0.236***
					(0.013)	(0.017)
(Log) Nb. of imports transactions						-0.299***
						(0.008)
Ind.*Year FE		✓	✓	✓	✓	✓
Firm FE			✓	✓	✓	✓
Obs.	167,646	167,646	167,646	167,646	167,646	167,646

Notes: This table reports regressions of import volatility on diversification. One observation per firm × year. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

4 Inventories, diversification, and trade vulnerabilities

4.1 Product-level inventories and diversification

I now turn to the implications of the facts laid out above for product-level trade vulnerabilities. I compute a measure of diversification at the product level by averaging the firm-product level

diversification across firms. Specifically, I compute:

$$\text{Div.}_{pt} = \frac{\sum_f M_{fpt} N_{fpt}}{\sum_f M_{fpt}} \tag{8}$$

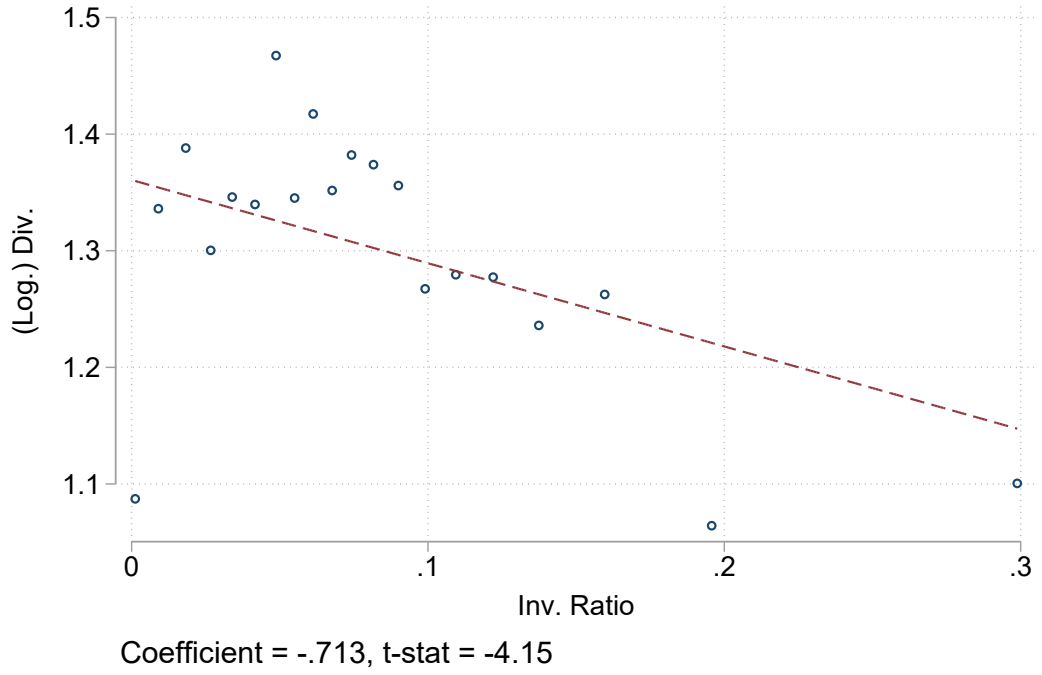
where t is a time period, M_{fpt} are the imports of product p by firm f, and N_{fpt} the number of countries from which f imports p. I compute this measure at the HS6 level, as most analysis of trade vulnerabilities are done at this level of aggregation. I restrict to intermediate goods and on imports of manufacturing firms, to be consistent with the rest of the paper. The measure can be interpreted as the average level of diversification among manufacturing firms. I choose the time period t to reduce the idiosyncrasy in the measure of import concentration, that can change extensively in two consecutive years at the product-level, as noted by Vicard and Wibaux (2023). Therefore, I aggregate the 5 years of data between 2015 and 2019. Note that this measure of product-level diversification aggregates firm-level data, while aggregate datasets such as BACI-COMTRADE were used in the previous reports on trade vulnerabilities. This ensures consistency with the inventory ratio measure, that is necessarily constructed from firm-level data. Indeed, I compute the average inventory ratio among firms importing this product:

$$\text{Inv. Ratio}_{pt} = \frac{\sum_f M_{fpt} \text{Inv. Ratio}_{ft}}{\sum_f M_{fpt}} \tag{9}$$

Figure 4 displays a binscatter plot of the (log. of the) diversification measure against the inventory ratio, at the product level. Products imported by firms with a higher inventory ratio are imported from fewer countries, on average. This directly mirrors the negative relationship between firm-level diversification and the inventory ratio uncovered in Section 3.

I then explore the role of different product characteristics in explaining product-level diversification. Diversification can be high if different countries provide different varieties of the good, which may be the case for differentiated products. I use the binary variable identifying differentiated goods of Rauch (1999), and the continuous product stickiness computed by Martin et al. (2023). I also control for product upstreamness from Antràs et al. (2012), as upstream products may be less specific and so easier to diversify. On the other hand, it may be that upstream products, close to natural resources, exhibit a more concentrated supply, making the relationship between upstreamness and diversification ambiguous. Column (1) of Table 6 shows the negative correlation between diversification and the inventory ratio. The estimated coefficients in the following columns make clear that more upstream products are less diversified, and more differentiated products are more diversified. When all these characteristics are included in the regression, the point estimates do not change qualitatively. The last column of Table 6 confirms that imported product diversification by French manufacturing firms

Figure 4: Diversification and inventory ratio at the product-level



Notes: This figure reports a binscatter of product-level diversification on the average inventory ratio of firms importing the product. Product-level of diversification is the average of firm-level diversification on the product. See Equations 8 and 9.

is dictated by the supply of diversification, as the number of countries exporting the product is strongly correlated with diversification. The same messages hold when using a product-level HHI[10] instead of the average number of countries (see Appendix Table S.9).

4.2 An assessment of trade vulnerabilities

The fact that products imported from fewer countries are imported by firms with a higher inventory ratio may soften the vulnerability attributed to some products based on import concentration. In this subsection, I propose an analysis of trade vulnerabilities that includes the two measures laid out in Section 4.1.

Method. I classify an input as vulnerable if it falls into the three following criteria: it is imported on average from less than two countries ($\text{Div.}_{pt} \leq 2$), its world supply is concentrated (world exports HHI above 0.25), and the inventory ratio at importers is lower than 1/12 – a month's worth of inventories. The first criterion pertains to the exposure to foreign shocks. The second aims at

[10]
$$\text{HHI}_{pt} = \sum_f \left(\frac{M_{fpt}}{\sum_f M_{fpt}}\right)^2 \text{HHI}_{fpt} \tag{10}$$

Table 6: Product-level diversification and characteristics

	Log. Div.$_{pt}$					
	(1)	(2)	(3)	(4)	(5)	(6)
Inv. Ratio	-0.760***				-0.570***	
	(0.180)				(0.176)	
Upstreamness		-0.157***			-0.122***	
		(0.016)			(0.018)	
Relationship stickiness			0.120***		0.124***	
			(0.021)		(0.020)	
Diff. product				0.255***	0.163***	
				(0.025)	(0.028)	
(Log.) World Div.						1.102***
						(0.031)
Obs.	2,841	2,841	2,841	2,841	2,841	2,841

Notes: This table reports estimation results of the OLS regression of the product-level diversification on product characteristics. Diversification is the (log.) number of countries from which the product is imported, averaged across manufacturing importing firms. Inv. ratio is the average inventory ratio across firms importing the product. Variables are relative to 2015-2019. Intermediate goods. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

measuring ex-post diversification opportunities: following the disruption of one supply link, how easy it is to find a new supplier. The third one is intended to measure short-term ex-post buffer capacities: following a disruption, how long can French firms last before running out of the input. This one-month threshold covers short-term disruptions – strikes, shipping delays, climate events – , but may be too low to cover longer or even persistent shocks, like geopolitical or sanitary risks. In the event of long-term disruptions, firms rely on inventories until they found a new supplier for the input. In practice, this time to find a new supplier is highly variable across firms, sectors, and countries, and one month may be deemed a too small period of time, even if it can be lower than a month.[11] This is the sense of combining multiple criteria: the quickness with which new suppliers are on-boarded is notably hampered by a concentrated world supply, that the second criterion captures. Hence, if the input is supplied by a diversified set of suppliers, sourcing may resume within a month following a disruption. Before turning to the vulnerable products analysis, it is worth mentioning the main limitations of the exercise. First, as explained in Section 2, because the diversification metric measures diversification of risks across countries, and is silent about diversification across suppliers within countries and about supply in France, the analysis informs about vulnerabilities towards country-specific risks – for instance, geopolitical and climate-related risks. Second, while the other variables used are measured throughout the year, the inventory ratio is measured at the end of the year, which makes it less representative of the inventories strategy of the firm. However, I

[11] At IBM, for instance. See https://newsroom.ibm.com/How-Blockchain-Is-Redefining-Supplier-Onboarding.

use averages across 5 years, which mitigates part of the idiosyncratic variation inherent to measuring inventories at one single date and bring the inventory ratio closer to its average level. Still, a more comprehensive analysis of buffer stocks may want to measure the average level of inventories over the year, the weeks spent below one month-worth of inventories, or the lowest level in the year.

Results. With these limitations in mind, Figure 5 provides a breakdown of the 3,175 HS6 intermediate goods imported by France over the period 2015-2019 across the three criteria. 624 are imported on average from less than two countries. 496 are products which supply is concentrated at the world level. Note that although sourcing diversification is partly constrained by world supply concentration, the overlap between the two criteria is far from complete: less than half of globally concentrated products are sourced from more than 2 countries, with 174 products meeting both criteria. Last, 1,839 products are sourced by firms with a low inventory ratio. This number may seem large but first, a quarter of importers exhibit an inventory ratio lower than one month (8.3%, see Table 2); second, large firms both exhibit a low inventory ratio and account for the bulk of international trade. Combining the three criteria identifies 79 products that are potentially at risk: they have low sourcing diversification, limited diversification potential, and low buffer stocks. Taking inventories into account thus reduces the number of products at risk by half (174 to 79).

The 95 products that are not vulnerable anymore when taking inventories into account are primarily textile products, and organic chemicals and medical supplies, such as polypeptide hormones and chloramphenicol (see Figure S.7). Other products include metals (copper, steel, iridium) and rare earths (beryllium and thallium). The main origin countries of those 95 products are European countries (Italy, Germany, Belgium, Spain), China, and India.

Among the 79 vulnerable products, 14 are purchased primarily in Germany, 8 in the Netherlands, and 7 in India and in Spain; only 3 of them are primarily sourced in China (see Figure S.7). This relatively low number may reflect the fact that firms sourcing from China diversify and stockpile precisely because they expect supply disruptions, but this might also reflect longer trade routes from China than from the majority of other supplying countries (Carreras-Valle, 2024). The vulnerable products are primarily organic chemicals, such as amino-alcohols, used in the textile, cosmetic, and medical industry, and amino-acids, primarily used in feedstocks. 12 products are minerals, such as cobalt, used in batteries and in gas turbines aircraft engines, but also kieserite, used as a fertilizer. It is worth noting that these 79 vulnerable products account for a small amount of total imports of intermediate goods by manufacturing firms (0.2%). However, even inputs with a small cost share may disrupt production, as evidenced by the low elasticity of substitution between inputs and between inputs and labor, at least at business-cycle frequency (Barrot and Sauvagnat, 2016; Atalay, 2017; Boehm et al., 2019). Besides, for some critical products such as pharmaceutical components, the cost share undermines the welfare costs associated with shortages.

Sensitivity. The reduction by half of the number is partly due to the negative correlation between diversification and the inventory ratio uncovered above. Importantly, this reduction by half is not specific to the chosen criteria on diversification (less than two supplying countries) and world supply concentration (HHI above 0.25). Table 7 reports the number of vulnerable products depending on the values of criteria of world supply concentration, diversification, and inventories. In all cases, products vulnerable with less than one month of inventories are half as many as products deemed vulnerable only based on diversification and world concentration. The threshold of one month is however arbitrary and may seem low. Setting this threshold to two months leads to 20 % fewer vulnerable products than without the inventories criterion. Increasing this threshold further to three months is far less restrictive, as almost all products (3,066 out of 3,175) are imported by firms with less than three months of inventories. Table 7 also informs that a large proportion of imported inputs are imported from less than 3 countries on average (1,284 out of 3,175, that is 40 %), and that few inputs are imported from only one country (62). Being imported from only one country is an extreme case of low diversification, corresponding to products which supply is highly exposed to country-specific risk. However among those, only 14 exhibit a concentrated world supply (HHI $\geq$ 0.25) and are imported by firms with less than one month of inventories.

Alternative criteria. The first criterion measures exposure to foreign shocks, that can alternatively be proxied by a measure of import concentration. Following previous analysis using this metric, I set the threshold on import concentration to 0.4 (Commission, May 2021; Vicard and Wibaux, 2023; Mejean and Rousseaux, 2024). It lowers the number of vulnerable products to 29 – see Panel A of Figure S.8. The remaining 29 products still encompass mineral and organic chemical products.

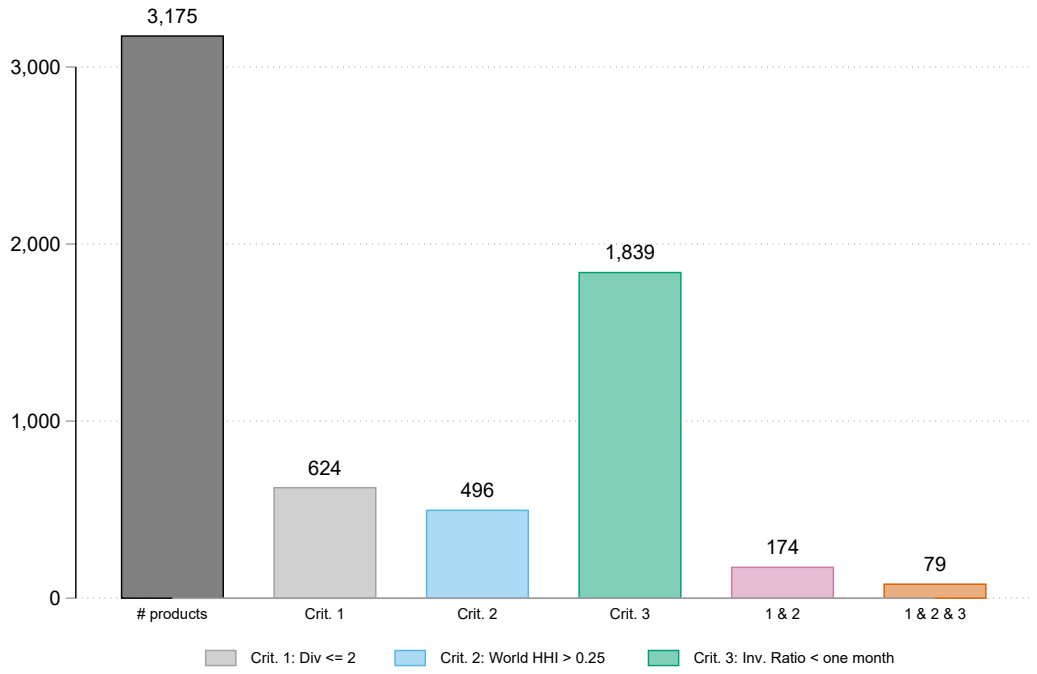
The potential impacts of trade vulnerabilities may be softened by production capacities in France. A concentrated and at risk sourcing from foreign sourcing is less critical for products which consumption is primarily served by domestic supply. The European Commission proposes to restrict to products for which imports are larger than exports. I instead follow Mejean and Rousseaux (2024) and rely on a measure of imports over domestic absorption, that is the amount of product used in France. Specifically, I compute for each product the ratio between total imports and production plus imports minus exports. A ratio greater than 0.5 means that more than the half of consumption is covered by foreign supply. I draw domestic production from annual production surveys described in Section 2 and in Appendix B. As the mapping between the surveys' product classification and the Harmonized System is not perfect, it reduces the number of products that can be analyzed here to 2,726 – see Panel B of Figure S.8. Among those, 1,291 are mainly sourced from foreign countries. The sample restriction reduces the number of vulnerable products identified by the first three criteria to 56. The restriction to products mainly sourced abroad decreases the number of vulnerable products to 18. This time, the list of vulnerable products includes few organic and mineral products.

Table 7: Number of vulnerable products, varying the criteria

Panel A: All intermediate goods				
	Div. ≤ 1	Div. ≤ 2	Div. ≤ 3	All
Inv. Ratio ≤ 1 month	32	328	682	1839
Inv. Ratio ≤ 2 months	45	510	1087	2820
Inv. Ratio ≤ 3 months	57	589	1220	3066
All	62	624	1284	3175
Panel B: World HHI ≥ 0.25				
	Div. ≤ 1	Div. ≤ 2	Div. ≤ 3	All
Inv. Ratio ≤ 1 month	14	79	145	255
Inv. Ratio ≤ 2 months	20	132	244	415
Inv. Ratio ≤ 3 months	24	158	280	464
All	26	174	303	496
Panel C: World HHI ≥ 0.4				
	Div. ≤ 1	Div.≤ 2	Div. ≤ 3	All
Inv. Ratio ≤ 1 month	5	30	48	72
Inv. Ratio ≤ 2 months	9	53	85	118
Inv. Ratio ≤ 3 months	9	58	96	133
All	9	64	104	144

Notes: This table reports the number of intermediate products imported by French manufacturing firms, that fall in one or several of the criteria of vulnerability. "Div. $\leq 1, 2, 3$" corresponds to products sourced from fewer than one, two or three countries. "World HHI $\geq$ 0.25, 0.4" corresponds to products for which world exports are concentrated above the thresholds. "Inv. Ratio $\leq$ 1, 2, 3 months" corresponds to products sourced by firms whose input inventories at year-end cover less than one, two or three months of inputs requirements on average. See Section 4.2 for details.

Figure 5: Number of dependent products by criterion



Notes: This figure reports the number of intermediate products imported by French manufacturing firms, that fall in one or several of the criteria of vulnerability. "Div <= 2" corresponds to products sourced from fewer than two countries. "World HHI > 0.4" corresponds to products for which world exports are concentrated. "Inv. Ratio < one month" corresponds to products sourced by firms whose input inventories at year-end cover less than one month of inputs requirements on average. See Section 4.2 for details.

Conclusion

Supply chain disturbances have become more frequent and severe in recent years. Policymakers worldwide are urged to improve economic security by reducing vulnerabilities and improving the resilience of supply chains. Surprisingly, the role of inventories in strengthening resilience to supply disruptions remains relatively underexplored, especially when it comes to comparing their cost with alternative supply-chain strategies, such as multi-sourcing. This paper shows how administrative data can be leveraged to fine-tune the diagnosis of trade vulnerabilities. It provides the first descriptive statistics about the use of inventories of inputs across a large panel of firms, and uncovers a very robust and novel fact: larger firms hold relatively fewer inventories. I also provide a comprehensive study of a simple measure of supply diversification at the firm-level using customs data, the number of origin countries for an imported product. Most empirical patterns observed for this measure also hold for a range of alternative, and arguably more precise, measures, which supports using the number of countries as a valid proxy in most cases. The high granularity of the data used allows to exhibit a strong negative relationship between the use of inventories and supply diversification, at the firm-level. It suggests that these are two substitutes strategies.

These findings have implications for the assessment of trade vulnerabilities. When taking into account the fact that poorly diversified firms hold relatively more inventories, the number of products at risk is halved by a factor of two, at least regarding short-term risk. On a policy perspective, imposing a minimum level of inventories on targeted products to absorb short-term shocks may be easier to put in place and monitor than imposing diversified supply-chains. Supply-chain are famously complex, with several tiers, and as a result almost impossible to map and monitor, even for multinationals and lead firms. This suggests that the role of inventories in strengthening supply chains may be currently overlooked.

References

Aghion, Philippe, Antonin Bergeaud, Matthieu Lequien, Marc J Melitz, and Thomas Zuber, "Opposing firm-level responses to the China shock: Output competition versus input supply," *American Economic Journal: Economic Policy*, 2024, *16* (2), 249–269.

Alessandria, George, Joseph P Kaboski, and Virgiliu Midrigan, "Inventories, lumpy trade, and large devaluations," *American Economic Review*, 2010, *100* (5), 2304–2339.

_ , Shafaat Yar Khan, Armen Khederlarian, Carter Mix, and Kim J Ruhl, "The aggregate effects of global and local supply chain disruptions: 2020–2022," *Journal of International Economics*, 2023, *146*, 103788.

Antràs, Pol, Davin Chor, Thibault Fally, and Russell Hillberry, "Measuring the upstreamness of production and trade flows," *American Economic Review*, 2012, *102* (3), 412–416.

Antras, Pol, Teresa C Fort, and Felix Tintelnot, "The margins of global sourcing: Theory and evidence from us firms," *American Economic Review*, 2017, *107* (9), 2514–2564.

Atalay, Enghin, "How important are sectoral shocks?," *American Economic Journal: Macroeconomics*, 2017, *9* (4), 254–280.

Balboni, Clare, Johannes Boehm, and Mazhar Waseem, "Firm Adaptation in Production Networks: Evidence from Extreme Weather Events in Pakistan," Technical Report, mimeo 2024.

Barrot, Jean-Noël and Julien Sauvagnat, "Input specificity and the propagation of idiosyncratic shocks in production networks," *The Quarterly Journal of Economics*, 2016, *131* (3), 1543–1592.

Bergounhon, Flora, Clémence Lenoir, and Isabelle Mejean, "A guideline to French firm-level trade data," 2018.

Bernard, Andrew B, Andreas Moxnes, and Karen Helene Ulltveit-Moe, "Two-sided heterogeneity and trade," *Review of Economics and Statistics*, 2018, *100* (3), 424–439.

Blaum, Joaquin, Federico Esposito, and Sebastian Heise, "Input Sourcing under Supply Chain Risk: Evidence from US Manufacturing Firms," Technical Report, National Bureau of Economic Research 2023.

Boehm, Christoph E, Aaron Flaaen, and Nitya Pandalai-Nayar, "Input linkages and the transmission of shocks: Firm-level evidence from the 2011 Tōhoku earthquake," *Review of Economics and Statistics*, 2019, *101* (1), 60–75.

Boehm, Johannes and Ezra Oberfield, "Misallocation in the Market for Inputs: Enforcement and the Organization of Production," *The Quarterly Journal of Economics*, 2020, *135* (4), 2007–2058.

Carreras-Valle, Maria-Jose, "Increasing Inventories: The Role of Delivery Times," Technical Report, Mimeo, Penn State University 2024.

Castro-Vincenzi, Juanma, "Climate hazards and resilience in the global car industry," Technical Report, mimeo 2024.

_ , Gaurav Khanna, Nicolas Morales, and Nitya Pandalai-Nayar, "Weathering the storm: Supply chains and climate risk," Technical Report, National Bureau of Economic Research 2024.

Commission, European, "Strategic dependencies and capacities," Technical Report, European Commission May 2021.

Dhyne, Emmanuel, Ayumu Ken Kikkawa, Xianglong Kong, Magne Mogstad, and Felix Tintelnot, "Endogenous production networks with fixed costs," *Journal of International Economics*, 2023, *145*, 103841.

EBRD, "Transition report 2022-2023: Global Supply Chains in Turbulence," Technical Report, EBRD 2023.

Elliott, Matthew, Benjamin Golub, and Matthew V Leduc, "Supply network formation and fragility," *American Economic Review*, 2022, *112* (8), 2701–2747.

Ersahin, Nuri, Mariassunta Giannetti, and Ruidi Huang, "Supply chain risk: Changes in supplier composition and vertical integration," *Journal of International Economics*, 2024, *147*, 103854.

Ferrari, Alessandro, "Inventories, demand shocks propagation and amplification in supply chains," *ArXiv. org*, 2023, (2205.03862).

Ganapati, Sharat, Woan Foong Wong, and Oren Ziv, "Entrepot: Hubs, scale, and trade costs," Technical Report, National Bureau of Economic Research 2021.

Grossman, Gene M., Elhanan Helpman, and Hugo Lhuillier, "Supply Chain Resilience: Should Policy Promote International Diversification or Reshoring?," *Journal of Political Economy*, 2023, *131* (12), 3462–3496.

He, Chengyuan, "Inventories, production networks, and international business cycles," *Job market paper, University of Rochester*, 2023.

Khanna, Gaurav, Nicolas Morales, and Nitya Pandalai-Nayar, "Supply chain resilience: Evidence from Indian firms," Technical Report, National Bureau of Economic Research 2022.

Kropf, Andreas and Philip Sauré, "Fixed costs per shipment," *Journal of International Economics*, 2014, *92* (1), 166–184.

Lafrogne-Joussier, Raphael, Julien Martin, and Isabelle Mejean, "Supply shocks in supply chains: Evidence from the early lockdown in China," *IMF economic review*, 2023, *71* (1), 170.

Martin, Julien, Isabelle Mejean, and Mathieu Parenti, "Relationship stickiness, international trade, and economic uncertainty," *Review of Economics and Statistics*, 2023, pp. 1–45.

Mejean, Isabelle and Pierre Rousseaux, "Identifying European trade dependencies," in Beatrice Weder di Mauro Jean Pisani-Ferry and Jeromin Zettelmeyer, eds., *Europe's Economic Security*, CEPR Press, 2024, pp. 49–99.

Pankratz, Nora MC and Christoph M Schiller, "Climate change and adaptation in global supply-chain networks," *The Review of Financial Studies*, 2024, *37* (6), 1729–1777.

Peck, Helen, "Drivers of supply chain vulnerability: an integrated framework," *International journal of physical distribution & logistics management*, 2005, *35* (4), 210–232.

Pisch, Frank, "Managing global production: Theory and evidence from just-in-time supply chains," 2020.

Ramey, Valerie A and Kenneth D West, "Inventories," *Handbook of macroeconomics*, 1999, *1*, 863–923.

Rauch, James E, "Networks versus markets in international trade," *Journal of international Economics*, 1999, *48* (1), 7–35.

Vicard, Vincent and Pauline Wibaux, "EU Strategic Dependencies: A Long View," *CEPII Policy Brief*, 2023, *41*.

Appendix

A Supply-chain risk and strategies

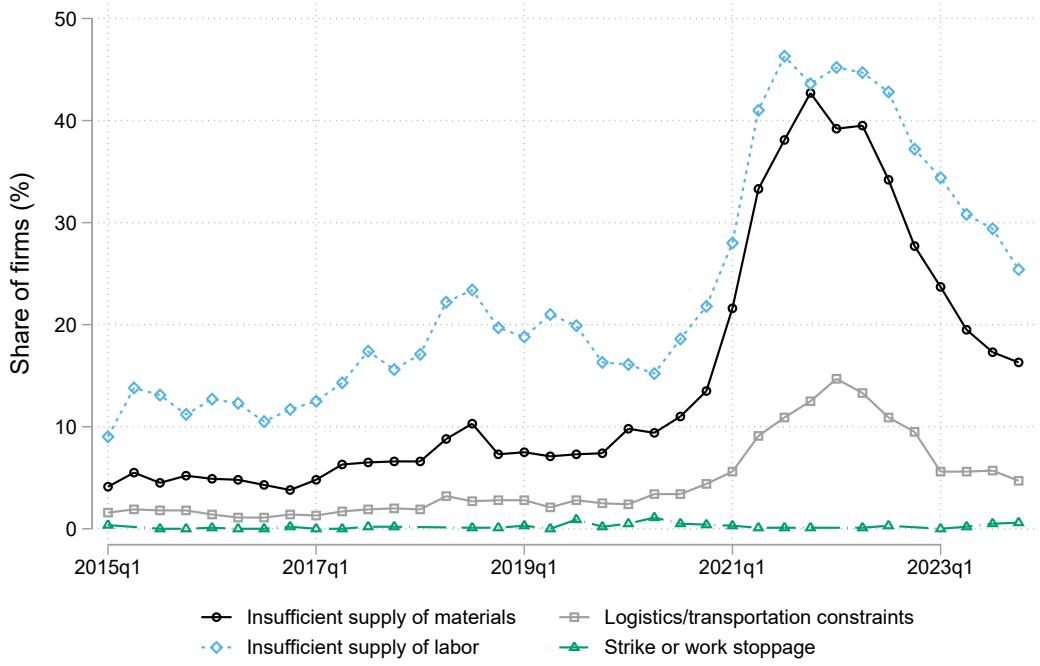
This section lists evidence of the impact of supply-chain disruptions, the importance of supply-chain risk for businesses, and of the strategies implemented by firms to cope with such risk.

- Impact of disruptions: Figure S.1 shows, among US firms producing below capacity, the share of firms declaring the cause of this is an insufficient supply of materials, labor, logistics or transportation constraints, or strikes or work stoppage, according to the Quarterly Survey of Plant Capacity Utilization (2015-2023). "insufficient supply of materials" is cited half as much as "insufficient supply of labor".

- Importance of supply-chain risk: The Allianz Global Trade Survey of 2024 asks exporters what are the top risks threatening export activity in 2024, in 8 countries, including France. The second most-cited risk (50% of exporters) is the shortage of inputs and labor, and the fourth most-cited (30%) is transport risk. Ersahin et al. (2024) perform a textual analysis of earnings conference calls to construct a measure of supply chain risk faced by U.S. listed companies and shows that this measure has been increasing since the early 2000s'.

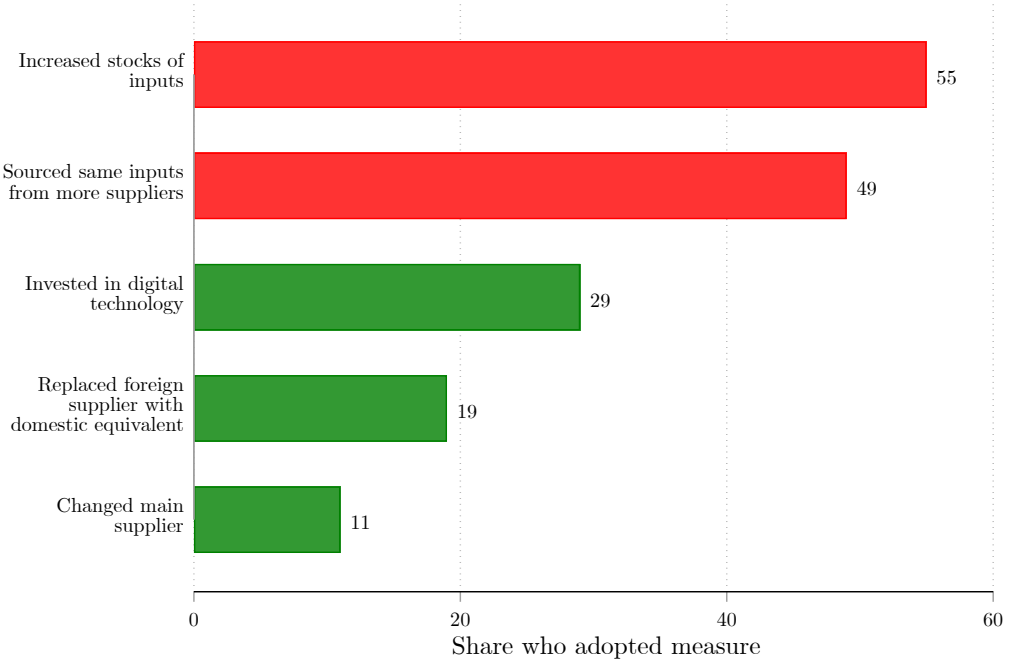
- Strategies put in place to manage supply risk: The EBRD surveyed firms participating in global value chains in 15 countries in 2022. When asked "What measures have you taken to increase the resilience of your supply-chain?", firms primarily cite an increased stock of inputs and redundancy in the supply-chain, that is sourcing the same inputs from more suppliers (Figure S.2). The ifo conducted a similar survey among German firms, with similar answers (Figure S.3).

Figure S.1: Supply reasons for actual production being below full production capability



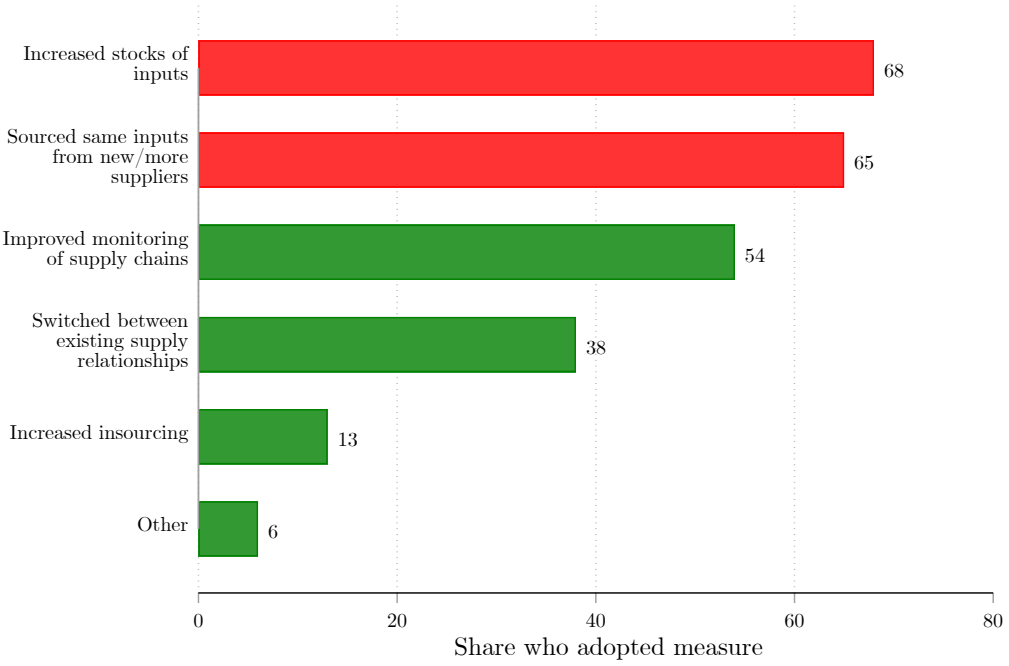
Notes: This figure displays, among firms operating below full production capability, the share of firms operating below capacity for the reason in the legend. Four such reasons are displayed. Firms can answer several reasons. Quarterly Survey of Plant Capacity Utilization Checkbox Data, 2015q1 to 2023q1, US firms.

Figure S.2: "What measures have you taken to increase the resilience of your supply-chain?": EBRD survey



Source: EBRD (2023). 815 firms participating in global value chains, across 15 countries.

Figure S.3: "What measures did you adopt to increase the resilience of your supply-chain?": ifo survey



Source: ifo Business Survey, 2022. 3000 manufacturing firms in Germany.

B Data description

I use a combination of several administrative data for French firms between 2012 and 2023. The first main data source is the near-universe of annual tax records of firms. The second main data source is customs records. The dataset covers each unique transaction involving a French firm and a foreign country. I link these two sources using the common firm tax identifier (SIREN). In all exercises, I discard firm×year observations with negative value-added, costs, or inventories. I restrict to manufacturing firms using the industry codes. I keep firms for which at least 4 years of observations are available between 2012 and 2023.

Firm-level balance sheet data. I use the *FARE* dataset to retrieve value-added at factor costs (`r004`), spending on material inputs (`achats_mp`), total sales, the number of workers (`redi_e001`). I augment this data with the level of inventories of inputs `stocmp` from raw balance-sheet data. This variable is seldom used in the literature, as it is absent from the usual version of fiscal forms used by researchers, the *FARE* dataset.[12] The *FARE* dataset aggregates inventories into an inventory variable encompassing stocks of finished goods, work-in-process inventories, and stocks of raw materials and inputs all together. Raw fiscal forms do have the distinction between those three types of inventories, but there is no further quality check on the variables before making them available to researchers. As such, I can evaluate the quality of this raw data by adding inventories of the three types and comparing this sum to the aggregate inventories at the firm-level from the *FARE* dataset, which has been corrected. The R^2 of the regression is above 99%, with a slope of 0.99 – see Appendix Figure S.5. I conclude that the raw variables behind the usual total inventories variable are of good quality, and so is `stocmp`, that I call S_{ft} in the main text.

Firm-level customs data. I use customs data for the universe of French firms participating in international trade. The dataset is constructed from four sets of files: import and export files, for intra-EU and extra-EU trade. All are collected by the French customs. I construct the final dataset following Bergounhon et al. (2018). The data is disaggregated at the transaction-level, from which I retrieve the partner country, product, month, import/export value and main mode of transportation. I build importer and exporter status in a given year and aggregate the data in different ways to construct measures of diversification, shift-share shocks, measures of sea shipping, and trade lumpiness.

Annual production survey *EAP*. I use the French *EAP*, corresponding to a harmonized survey aimed for industrial production statistics across European countries, to determine whether a specific

[12] *FARE* is a modified version of fiscal forms whereby some variables are selected, aggregated, and retreated for national accounting purposes. As data quality checks are performed along the way, this version of fiscal forms data is usually preferred to and more reliable than raw fiscal forms data.

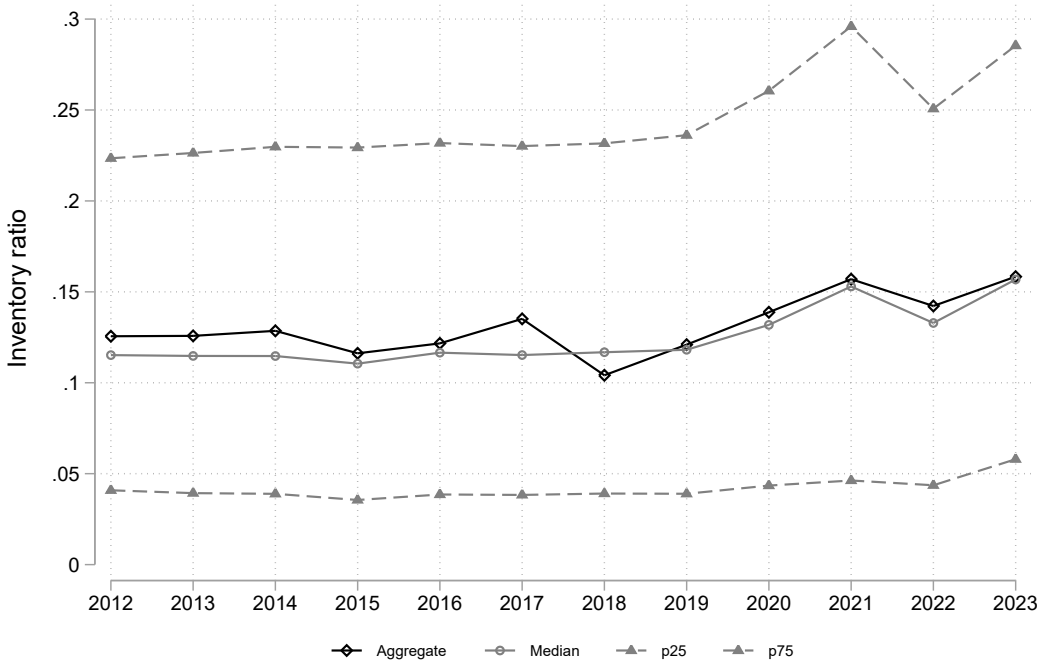
product is produced by a manufacturing firm in France. This dataset has been used recently in Aghion et al. (2024). I use the crosswalk between the survey's product classification (PRODCOM) and the CN8 to determine whether a given CN8 product is produced in France.

Sea distances. I use the CERDI-SeaDistance[13] database which contains bilateral maritime distances between 227 countries and territories. I combine it with the transportation mode of imports. The main transportation modes are by air, by sea, or by roads (trucks). Imports from countries outside of mainland Europe are mostly shipped by boat to Europe's main ports, before being dispatched using trucks, mainly. I thus consider that shipments from outside mainland Europe are transported by sea vessels to Europe, unless air transportation is specified. I then compute the average maritime distance of a firm's imports by computing the weighted average of sea distances to origin country of imports.

[13] Available at https://hal.science/halshs-01288748v1. See Ganapati et al. (2021) for a recent use of the database.

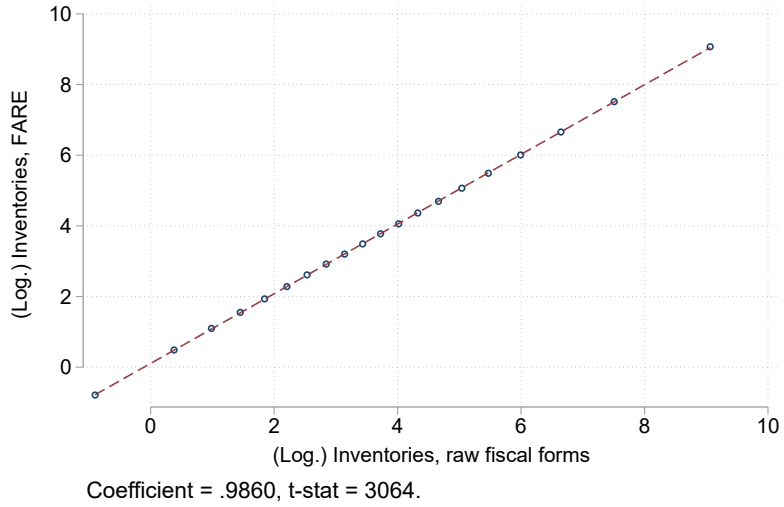
C Additional Figures

Figure S.4: Inventory ratio over time, all manufacturing firms



Notes: "Aggregate" is the inventory ratio of all firms in the manufacturing industry, computed as the sum of firms' stocks over the sum of their inputs. Median, 25th, and 75th percentile correspond to the distribution of the inventory ratio across all manufacturing. One observation per firm-year, between 2012 and 2023.

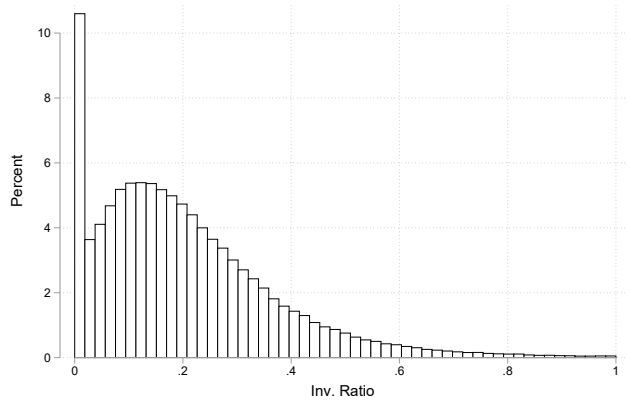
Figure S.5: Quality of the raw fiscal forms inventory data



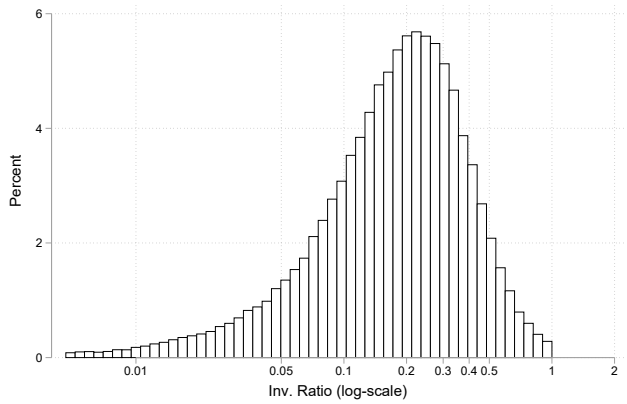
Notes: This figure is a binscatter plot of the (log. of) firm-level amount of inventories of finished goods, work-in-process, and raw material and inputs from the *FARE* dataset, against the firm-level amount of inventories reconstructed from raw fiscal forms. 2019, all firms.

Figure S.6: Distribution of the inventory ratio across firms

Panel A: Ratio

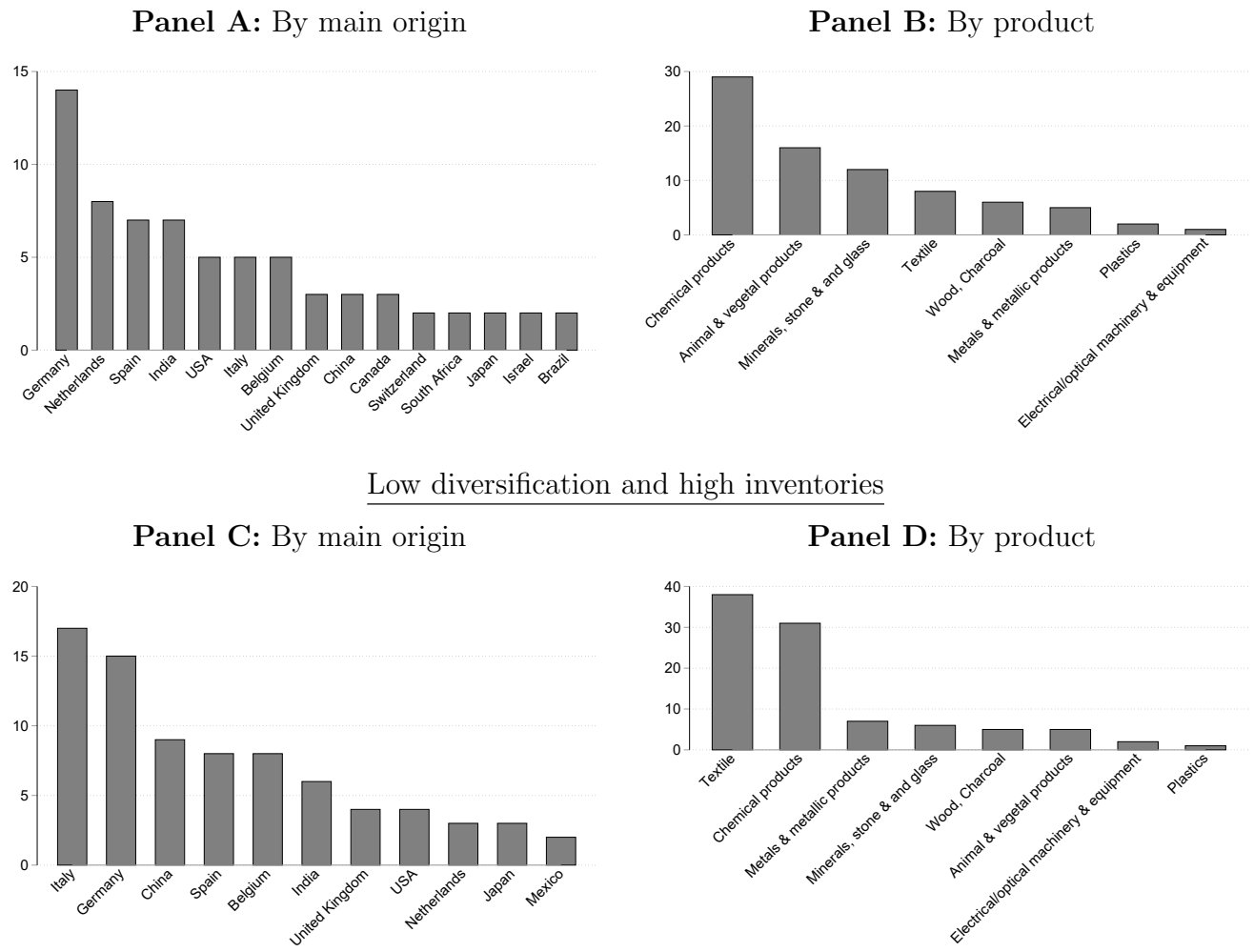


Panel B: Log. Ratio



Notes: This figure displays the histogram of inventory ratios (**Panel A**) and of the logarithm of inventory ratios (**Panel B**), across firms. One observation per firm × year.

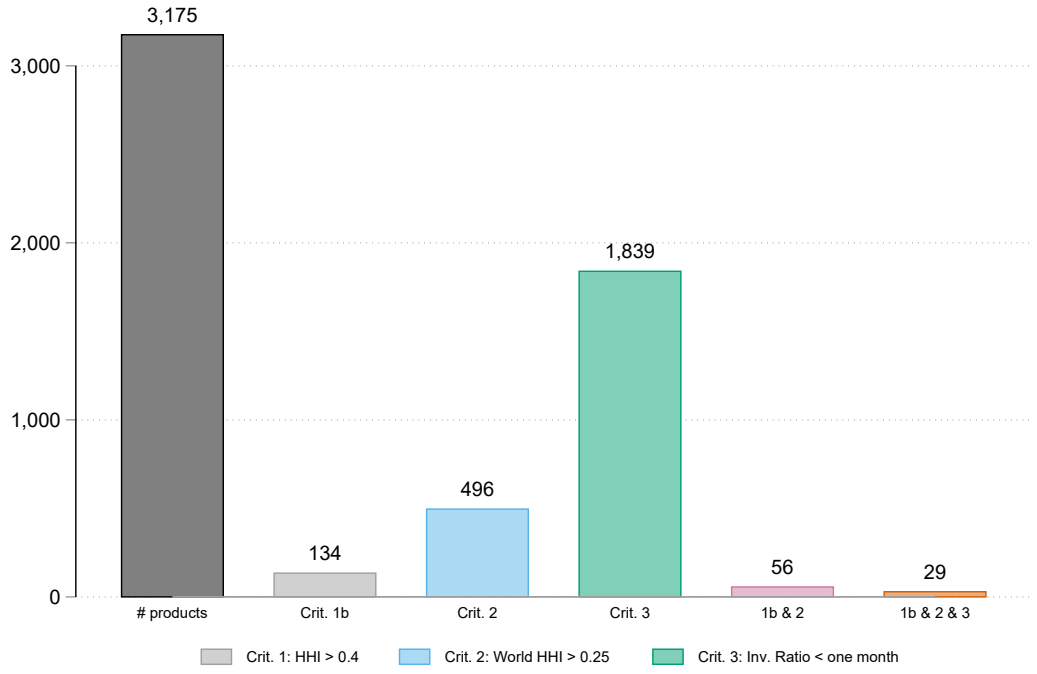
Figure S.7: Vulnerable products and the role of the inventories criterion



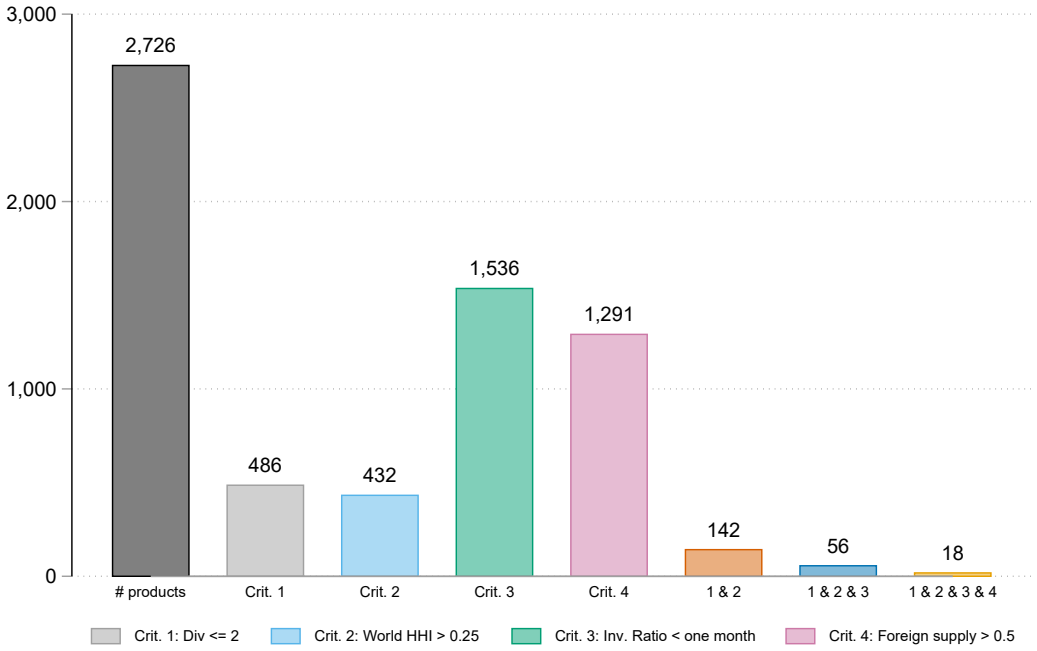
Notes: This figure reports histograms of the main origin country for the 79 identified vulnerable products (**Panel A**) and 95 products not considered vulnerable when taking inventories into account (**Panel C**), as well as histograms of the broad product categories of the 79 products (**Panel B**) and 95 products (**Panel D**).

Figure S.8: Vulnerable products: alternative criteria

Panel A: Changing diversification measure



Panel B: Adding domestic production criteria



Notes: This figure displays the vulnerable products analysis using different criteria from the baseline of Figure 5. **Panel A:** the diversification criteria is replaced by the HHI of imports greater than 0.4. **Panel B:** the three baseline criteria remain but I also condition on the product being primarily sourced from outside of France. See Section 4 for details.

D Additional Tables

Table S.1: Variance decomposition: share of between-industry variation in inventory ratios (%)

Fixed effects	2-digit	3-digit	5-digit	Obs.
Ind.	5.78	8.22	10.75	202489
Ind. × Year	7.08	9.76	12.74	202463
Ind. × Year	10.08	13.55	17.04	187174

Notes: This tables reports the share of variation in inventory ratios explained by industry fixed-effects, across importing firms. The dependent variables are inventory ratios – see Section 1 for details. Industries are 2-digit, 3-digit and 5-digit industries from the NACE Rev. 2 classification. I use one observation per firm × year. I remove observations with 0 inventories in line 3.

Table S.2: Summary statistics on alternative diversification measures

		Avg.	P10	P25	Med.	P75	P90	Obs.
All importing firms	Div.^{FR}	3.14	2	2	2.31	3.43	5.2	200,042
	Div.*	1.62	1	1	1.04	1.56	2.74	200,042
	Div. non-Diff	2.76	2	2	2.07	3	4.15	123,747
	Div. non-sticky	3.26	2	2	2.39	3.5	5.32	182,913
	HHI	.94	.85	.91	.96	1	1	200,042
Common sample	Div.^{FR}	3.55	2	2.06	2.82	3.93	5.87	121,331
	Div.*	1.86	1	1.01	1.23	1.92	3.26	121,331
	Div. non-Diff	2.77	2	2	2.09	3	4.17	121,331
	Div. non-sticky	3.57	2	2.01	2.8	3.89	5.86	121,331
	HHI	.93	.85	.9	.94	.98	1	121,331

Notes: This table displays the average and several percentiles of the distribution of diversification measures across all importing firm × year in our sample. Diversification is measured as the average number of sourcing countries per imported NC8 product in a given year – see Equation 3. Div* considers that products sourced in France are not sourced abroad, and products sourced abroad are not sourced in France. Div. non-Diff. is computed on non-differentiated products in the sense of Rauch (1999). Div. non-sticky is computed on products in the three first quartiles of relationship stickiness from (Martin et al., 2023). HHI is computed as the average HHI across imported NC8 products. Last five lines restricts to a common sample of firms importing non-differentiated products and non-sticky products.

Table S.3: Variance decomposition: share of between-industry variation in diversification (%)

Fixed effects	2-digit	3-digit	5-digit	Obs.
Ind.	5.63	7.92	11.18	202463
Ind. × Year	5.75	8.19	11.76	202463

Notes: This tables reports the share of variation in diversification explained by industry fixed-effects, across importing firms. The dependent variable is diversification – see Section 2 for details. Industries are 2-digit, 3-digit and 5-digit industries from the NACE Rev. 2 classification. One observation per firm × year.

Table S.4: Pairwise correlations between measures of diversification

	Div.	Div.^{FR}	Div.*	Div. non-diff	Div. non-sticky
Div.^{FR}	.996				
Div.*	.863	.859			
Div. non-diff	.398	.388	.35		
Div. non-sticky	.928	.923	.806	.376	
HHI	-.427	-.42	-.312	-.402	-.397

Notes: This table displays the pairwise correlations between the measures of diversification across all importing firm × year in our sample. Diversification is measured as the average number of sourcing countries per imported NC8 product in a given year – see Equation 3. Div* considers that products sourced in France are not sourced abroad, and products sourced abroad are not sourced in France. Div. non-Diff. is computed on non-differentiated products in the sense of Rauch (1999). Div. non-sticky is computed on products in the three first quartiles of relationship stickiness from (Martin et al., 2023). HHI is computed as the average HHI across imported NC8 products.

Table S.5: Inventory ratio and firm size: alternative measures of size

	Inv. Ratio			
	(1)	(2)	(3)	(4)
(Log) Sales	-0.070***			
	(0.001)			
(Log) Nb. Employees		-0.013***		
		(0.001)		
(Log) V.A.			-0.032***	
			(0.001)	
(Log) V.A. per worker				-0.023***
				(0.001)
Avg.	0.190	0.190	0.190	0.190
Obs.	526,256	526,256	526,256	526,256

Notes: This table reports regressions of the inventory ratio on measures of firm size. Inv. ratio is the ratio between inventories of inputs and total available inputs in a given year. One observation per firm × year with positive inventories of inputs. All regressions include firm and industry × year fixed effects. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table S.6: Diversification and firm size: alternative measures of size

	Div.			
	(1)	(2)	(3)	(4)
(Log) Sales	0.098***			
	(0.003)			
(Log) Nb. Employees		0.066***		
		(0.003)		
(Log) V.A.			0.043***	
			(0.002)	
(Log) V.A. per worker				0.008***
				(0.002)
Obs.	195,204	195,204	195,204	195,204

Notes: This table reports regressions of diversification on measures of firm size. The dependent variable is the main measure of diversification – see Section 2.1 for details. One observation per firm × year. All regressions include firm and industry × year fixed effects. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table S.7: Determinants of diversification: alternative measures of diversification

	Div.	Div.^{FR}	Div.*	Div. non-diff.	Div. non-sticky	HHI
	(1)	(2)	(3)	(4)	(5)	(6)
(Log) Sales	0.086***	0.091***	0.071***	0.065***	0.084***	-0.035***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.002)
(Log) Nb. of imp. products	0.018***	0.020***	0.001	0.013***	0.023***	0.001
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.001)
(Log) Import share	0.034***	0.037***	0.048***	0.036***	0.034***	-0.018***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
(Log) World diversification (number)	0.047***	0.050***	0.047***	-0.094***	0.044***	
	(0.005)	(0.006)	(0.005)	(0.008)	(0.006)	
(Log) World diversification (HHI)						0.010***
						(0.002)
Obs.	196,888	196,888	196,888	121,334	179,792	196,888

Notes: The table shows regression estimates of several measures of diversification on firm size – see Section 2.1 for details on the measures. One observation per firm × year. All regressions include firm and industry × year fixed effects. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table S.8: Inventories and diversification are substitutes: Alternative measures

	Diversification measure:				
	Div.^{FR}	Div.*	Div. non-Diff.	Div. non-Sticky	HHI
	(1)	(2)	(3)	(4)	(5)
(Log.) Div.	-0.006***	0.022***	-0.009***	-0.007***	0.020***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)
(Log) Import share	0.010***	0.009***	0.016***	0.011***	0.010***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
(Log.) Nb. of imp. products	-0.008***	-0.008***	-0.005***	-0.007***	-0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
(Log) Sales	-0.075***	-0.078***	-0.070***	-0.075***	-0.076***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
(Log) Share of imports of non-diff. goods			0.003***		
			(0.000)		
(Log) Share of imports of non-sticky goods				0.003***	
				(0.000)	
Ind.*Year FE	✓	✓	✓	✓	✓
Firm FE	✓	✓	✓	✓	✓
Avg.	0.220	0.220	0.210	0.220	0.220
Obs.	182,403	182,403	116,064	167,077	182,403

Notes: This table reports the results of estimation of Equation 7. One column per measur of diversification – see Section 2.1 for details. One observation per firm × year with a positive inventory ratio. Standard errors are clustered at the firm-level. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table S.9: Product-level diversification and characteristics: using HHI

	Log. HHI_{pt}					
	(1)	(2)	(3)	(4)	(5)	(6)
Inv. Ratio	2.763***				2.518***	
	(0.282)				(0.277)	
Upstreamness		0.207***			0.116***	
		(0.026)			(0.028)	
Relationship stickiness			-0.148***		-0.121***	
			(0.033)		(0.032)	
Diff. product				-0.456***	-0.357***	
				(0.040)	(0.044)	
(Log.) World HHI						0.610***
						(0.035)
Obs.	2,841	2,841	2,841	2,841	2,841	2,841

Notes: This table reports estimation results of the OLS regression of the product-level diversification on product characteristics. Diversification if the (log.) HHI of the imports of the product across manufacturing importing firms. Inv. ratio is the average inventory ratio across firms importing the product. Variables are relative to 2015-2019. Intermediate goods. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

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