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Managing Global Production: Theory and Evidence from Just-in-Time Supply Chains

Frank Pisch

Abstract
Global value chains are highly fragmented across countries and dominated by a few large multinational firms. But the challenges of an increasingly difficult international business environment are raising the question of how these patterns will change. I study the role of international Just-in-Time (JIT) supply chains in how global production is organized and what the future may hold. Using survey and administrative data for a large panel of French manufacturers, I first document that JIT is widespread across all industries and accounts for roughly two thirds of aggregate employment and trade. Next, I establish two novel stylized facts about the structure of international JIT supply chains: (1) They are more concentrated in space and (2) more vertically integrated than their 'traditional' counterparts. I rationalize these patterns in a framework of sequential production where failure to coordinate adaptation decisions in an uncertain environment leads to inventory holding. In JIT supply chains, information about downstream demand conditions is relayed upstream, which facilitates coordination. The associated inventory saving effect is stronger when firms are close to each other, so that the supply chain reacts quickly to changes in demand. This also applies when they are part of the same company and incentives for adaptation are aligned. I validate this model by supporting empirical evidence for further predictions and discuss potential long term implications of Brexit and COVID-19 for the structure of international supply chains.

Key words: Just-in-time, global value chains, multinational firms, vertical integration
JEL Codes: F10; F14; F23; D23; L23

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Frank Pisch, University of St. Gallen, SIAW, and Centre for Economic Performance, London School of Economics.

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1 Introduction

Today's Global Value Chains (GVCs) have been shaped by advances in digital technology and liberalization efforts in goods and asset markets. They also have at least two salient and important stylized characteristics: they are highly fragmented across countries[1] and a few large multinational business groups not only account for the bulk of activity, but encompass whole segments of these value chains.[2] Both of these aspects have significant implications for, *inter alia*, productive efficiency and hence affordable consumption (for example, Blaum et al., 2018; Antràs, 2015). In recent years, however, the business environment for global supply networks has taken a turn for the worse, both in the political and in the physical sphere. Prominent sources for the rise in (perceived) uncertainty[3] and friction to global commerce[4] include a surge in protectionism in many countries, a rapidly changing world order, climate change and, last but not least, pandemic events – in 2020, The New York Times even senses "a moment of reckoning for global supply chains" (Swanson and Tankersley, 2020). One of the big questions for manufacturing and beyond is how the structure of GVCs will change, especially with respect to spatial patterns and multinational production.

The objective of this paper is to study the role of an important feature of modern production networks, namely, that at least some parts are managed in a lean, highly coordinated, just-in-time (JIT) fashion. Indeed, JIT has potentially important implications for GVCs: a supply chain's ability to coordinate tasks is shaped by its geographic set-up and the control structure in decision making. Moreover, businesses and policy makers (and occasionally even the general public) regularly voice concerns about the resilience, robustness and efficiency of highly coordinated JIT production networks. Two recent examples of this are the discussions around waiting times due to post-Brexit border checks[5] and around lock-down effects after the outbreak of COVID-19 (Miroudot, 2020). Despite these powerful reasons for investigation, so far there is only limited economic research

[1]The high degree of fragmentation is illustrated by the two facts that (1) more than half of all international trade involves intermediate goods and that (2) domestic value added has fallen to slightly more than three quarters of every dollar exported (Miroudot et al., 2009; Johnson and Noguera, 2012).

[2]For example, the vast majority of U.S. trade transactions involves a multinational company and intrafirm trade accounts for around a third of all U.S. exports and almost half of imports (Bernard et al., 2009; Ruhl, 2015).

[3]The Global Economic Policy Uncertainty Index developed by Davis (2016) averaged 80 points for the years 1997-2007, but 152 from 2008 to June 2020. Two recent spikes were related to the Sino-American conflict and COVID-19 (Altig et al., 2020).

[4]Using the Global Trade Alert, Evenett (2019) documents a dramatic increase in harmful trade related policies, including tariffs and non-tariff barriers, since 2009.

[5]In February 2018, the UK's Business, Energy and Industrial Strategy Committee stated: "The volume of manufacturers rely upon the just-in-time delivery system [...] We heard from Honda their estimate that a 15 minute delay could add around 850,000 per year in costs - a significant sum" (available at https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/379/37902.htm, accessed 21/08/2019).

on how the demands of coordination interact with the spatial and ownership structure of GVCs.

Using the example of France, this paper provides the first comprehensive empirical characterization of international just-in-time manufacturing supply chains. I propose a novel conceptual framework to rationalize the patterns documented in the data, validate it by testing some of its further predictions, and use it to guide a discussion of the future of GVCs in the aftermath of Brexit and COVID-19.

'Traditional' supply chains operate in a "make-to-stock" fashion: intermediates and final goods are produced and put on shelves in warehouses for customers to collect. Such a system works efficiently if demand forecasts are very accurate, but in complex international supply networks geared towards handling large numbers of varieties, prediction becomes difficult and inventories soar. In modern management systems by contrast – developed in Japan in the 1970s and early 1980s – such costly buffer stocks are eradicated through finely-tuned coordination of tasks, so that every production step is completed *just-in-time* for the next one to begin. To enable such a system, it has to be "make-to-order": downstream demand information is relayed to stages upstream in real-time and commencement of a task is conditional on such a signal.[6]

For the the first contribution of this paper, I use high quality survey information – the questionnaire asked for whether or not a firm participates in a JIT supply chain – for more than 3,000 representative ($>$ 20 employees) French companies in all manufacturing industries for 1997-2006. I document that JIT supply chain management is widespread across all branches of manufacturing, rather than being an exclusive preoccupation for car and textile producers. Moreover, participant firms in JIT supply chains tend to be larger and more productive than their non-JIT counterparts. As a consequence, they account for up to two thirds of aggregate employment and international trade in France and therefore play a very significant economic role.

Furthermore, international trade and worldwide ownership information allow me to examine the structure of French JIT supply networks regarding their fragmentation across countries and the role of multinational production. First, comparing the trade partner countries for international trade flows as a proxy for location, I find that JIT supply chains are significantly *more spatially concentrated* than their 'traditional' counterparts. This descriptive pattern holds for both distance and time-to-ship as measures of proximity, at the extensive and intensive country margins, and when I control for a number of alternative unrelated explanations. Moreover, firms that adopt JIT management practices during the

[6] Although JIT is sometimes viewed as a broader 'philosophy' – Schott et al. (2017) highlight stability of supply relationships, while others stress product variety and flexibility (Ohno, 1988; Schonberger, 1982) – I emphasize coordination and "make-to-order" aspects in this paper, which I believe are the most relevant for global supply chains.

sample period actively skew their international supply networks towards proximate trade partners. My estimates imply that the distance elasticity of trade in JIT supply networks is about 11 percent more negative than in 'traditional' ones (the overall gravity implied elasticity being slightly less than one in absolute value (Head and Mayer, 2015)).

Second, French firms in JIT supply chains, compared to their 'traditional' counterparts, are significantly *more likely to source any given intermediate in-house*, both domestically and from abroad. This finding is not driven by the typical industry or firm level characteristics that have been shown to affect the boundaries of multinational firms. It is present both in subsidiary ownership and intrafirm trade data at the firm level – actual transactions, and not only assets, are more vertically integrated – and the adoption of JIT is associated with more in-house production at foreign subsidiaries. Quantitatively speaking, trade is around 7 percentage points more likely to be intrafirm in JIT than in non-JIT supply chains, which is a large difference given the overall share of related party trade for France of around one third.

As a second contribution of this paper I propose a formal conceptual framework that illustrates how a single mechanism – inventory holding due to mis-coordination – can rationalize these patterns in the data. Consider a segment of a supply chain where a single upstream supplier manufactures an intermediate, which is shipped to a downstream buyer firm for further processing. In an uncertain world, both companies are continually hit by shocks, i.e., unexpected changes in their environments. Final demand may be highly unpredictable, while upstream production may, for example, experience machine break-down or sudden input price changes. While both partners in a transaction can adapt their activities to such changes, they will hold inventories to the extent that their adaptation decisions are not fully coordinated and production may be disrupted. JIT supply chain management is modelled as an information sharing technology, which ensures that signals about downstream demand are shared with the supplier to facilitate coordinated adaptation and thus reduce expensive buffer stocks.[7]

In this setting, skewing the supply network towards regional partners is a complementary strategy to JIT, in the sense that the efficiency gains of one organizational margin are amplified by the other. Even if real-time demand information is available, a remote supplier may not manage to deliver its goods in time, the composition of customer needs may have changed, and the intermediate may have become obsolete due to these long shipping times. JIT and joint ownership are complementary margins as well. Even though suppliers have better information about the downstream demand conditions under JIT, they make adaptation decisions to maximize their own local profits and thus create an

[7] In the early days of JIT in Japan, transmission of demand information took the form of little cards called "kanban" that were routed through factories and which described in great detail what inputs were needed from the next respective upstream stage (Ohno, 1988).

externality downstream if they are independent from the buyer firm. Operating as a vertically integrated firm constitutes a way of bringing adaptation incentives of individual units in line with those of the entire segment of the supply chain.[8]

I validate this conceptual framework with supporting empirical evidence for further predictions regarding industry heterogeneity in the two complementarities. First, the correlations between JIT, in-house production and proximity are significantly stronger when inventory costs are high, which is important evidence in favor of the inventory channel at the heart of the model. Second, the patterns are stronger when demand shocks are persistent: since any downstream signal is particularly useful for prediction and hence valuable, the return from complementing JIT with in-house and spatially agglomerated production is higher. Finally, if market conditions allow an independent downstream firm to force inventory costs on the supplier via contractual penalties (as in the automobile industry, for example), the complementarity between JIT and proximity is stronger: valuable demand signals due to short order lags are combined with contractual incentives for the supplier to actually use them and thus reduce (their share of) inventory costs. By contrast, the complementarity between JIT and vertical integration is weaker: pushing inventories onto the supplier is an alternative way to internalize the supply chain externality, and hence align incentives for coordination, which is particularly effective if demand information is available through the JIT system.

Finally, to illustrate the implications of my findings for how the structure of global value chains may evolve in response to a rapidly changing political and natural environment, I examine the cases of Brexit and COVID-19. Modelling Brexit as an increase of waiting times at the border, I find that European manufacturing will become less JIT intensive and hence lose efficiency. The effect on international trade patterns depends on the balance of two forces. Frictions at the border bias all trade relationships towards more proximate partners, but a lower overall JIT intensity will make trade less sensitive to distance, since 'traditional' production networks are less concentrated in space. Unambiguously, by contrast, multinational companies will reduce their cross border activities and FDI in manufacturing declines. Increased (perceived) uncertainty as a consequence of the COVID-19 outbreak is predicted to make JIT production *more* attractive due to its superior coordination abilities; all supply chains carry higher inventories and become less efficient, but this effect will be less severe in JIT systems. As a result of the complementarities documented in this paper, international trade is predicted to become more spatially concentrated and more dominated by a few large and integrated multinational companies. The extent of all adjustments varies strongly by industry and my empiri-

[8] While several mechanisms may well be at work, the conceptualization of firm boundaries I propose is a natural candidate in the context of highly coordinated production and I discuss and rule out several alternative theories like property rights or rent-seeking in Sections 2.3, 3 and 4.

cal findings suggest three margins that may be useful for forecasting – inventory costs, demand persistence and inventory pushing.

This paper expands two strands of research on the structure of international value chains and contributes to the literature on the role of management. First, relating to the spatial set-up of production networks, there is a small number of industry case studies. Evans and Harrigan (2005), for example, examine the U.S. textile business and show that fast fashion items tend to be manufactured in countries nearby.[9] The present paper expands on these findings by showing that JIT production networks are more regional across the whole of manufacturing, and that this difference compared to 'traditional' value chains is of first-order economic magnitude. Conceptually, Evans and Harrigan (2005) and Harrigan and Venables (2006) explain this economic geography fact by 'flexible production', where surprise changes in demand can be addressed by sourcing from close suppliers with low order lags. While yielding the same result, my alternative formulation of this economic problem emphasizes the role of information (cf. Steinwender, 2018) and makes the broader point that space is a friction for coordination and thus interacts with other margins of organization like firm boundaries.

More generally, this paper shows that JIT supply chain management is a relevant consideration for the broader literature on location choice in GVCs (e.g., Johnson and Noguera, 2012; Baldwin and Venables, 2013; Koopman et al., 2014; Antràs and de Gortari, 2020) and on gravity in goods trade in general. In particular, it may have played an important role in explaining the distance puzzle (Berthelon and Freund, 2008): despite a substantial fall in trade costs over the second half of the 20th century, distance is as important a barrier to trade as decades earlier (potentially because travel *times* have not been reduced commensurably).

Secondly, regarding firm boundaries in global supply chains, the only studies that examine the role of JIT are Keane and Feinberg (2006, 2007). They present suggestive empirical evidence at the industry level that the increase in intrafirm trade between US firms and their Canadian affiliates in the late 1980s and early 1990s may be attributable to advances in logistics technology and in particular to JIT supply chain management. I expand on their insights using significantly more detailed and direct firm level information to show that JIT supply chains are indeed more vertically integrated in terms of several proxies for in-house production. Moreover, I propose a novel organizational model based on coordination and inventory holding in the tradition of Transaction Cost Economics (TCE) to explain this pattern.[10]

[9] Other works include McCann and Fingleton (1996) and Holl et al. (2010), who show a similar pattern in eletronics and automobiles for Scotland and Spain.

[10] My conceptual framework builds on ideas related to Legros and Newman (2013); Alfaro et al. (2016). In contrast to their work, I micro-found conflicts of interest between parties as a multi-tasking problem

More broadly, my study has implications for the literature on firm boundaries in supply chains (Antràs, 2003; Antràs and Helpman, 2004; Antràs and Chor, 2013; Del Prete and Rungi, 2017; Berlingieri et al., 2018; Alfaro et al., 2016, 2019) and the firm level determinants of multinational activity (Corcos et al., 2013): it highlights that supply chain management considerations are potential drivers of integration decisions.

Finally, this paper contributes to the study of management practices and their implications for firms and the economy. Prominently, the World Management Survey (WMS) first presented in Bloom and Van Reenen (2007) has been used to show that better managed firms command a productivity premium and are more likely to participate in international trade (Bloom et al., forthcoming). Furthermore, consistent with my data, the WMS provides evidence that JIT practices are not ubiquitous, but usually associated with the more productive and larger companies. While the information I use in this study pertains only to French firms and their global activities, this focus makes it possible to study the international production network implications of JIT supply chain management in great detail.

2 Characterizing JIT Supply Chains Empirically

Generally speaking, information about management is hard to come by, which has prompted comprehensive data collection efforts (see, for example, Bloom and Van Reenen, 2007; Bloom et al., 2016). For this paper I obtained access to the French firm level survey Enquête sur les Changements Organisationels et l'Informatisation (COI), which collected information in two waves, 1997 and 2006, from both employers and their employees about how firms are internally organized.[11] A random sample of firms with more than 50 employees (20 in 2006) was surveyed and the response rates were very high (88%, 84%), which is not unusual for French firm surveys. The 2006 wave asked many questions for both the current year and for 2003 retrospectively, so that I can extract information for an unbalanced panel of about 3,000 manufacturing firms (ISIC Rev. 3 codes 15-37) for three individual years spanning the decade between the mid 1990s and the mid 2000s.

Based on JIT related questions, the main variable I construct is a firm level indicator JIT_{ft} that equals one whenever a firm f in year t reports that it either sourced inputs from a supplier or shipped output to a customer using a just-in-time regime.

due to adaptation in an uncertain environment. Furthermore, I emphasize the complementarity with other organizational margins that facilitate coordination, namely the spatial set-up of supply relationships and information sharing.

[11] Other work that has used COI includes Acemoglu et al. (2007) and Janod and Saint-Martin (2004). More information can be found at `https://www.enquetecoi.net/` and in the in-depth description featured in Greenan and Mairesse (1999).

This variable has three limitations. First, firms may misreport if they do not understand what JIT means and/or do not have sufficient information to answer the question. While it is difficult to assess the extent of this problem, several arguments inspire confidence that it is not a first-order concern. For one, the questionnaires contained an attachment that offers detailed explanations of a range of specific terms used in the survey, including for the JIT related questions.[12] Moreover, and slightly anticipating the results below, JIT firms hold significantly lower inventories than their non-JIT peers even within highly disaggregated industries. Since this is the main objective most companies pursue when they adopt a JIT regime, this is a tell-tale sign that the JIT variable is meaningful. Finally, if misreporting happened for reasons unrelated to firm characteristics or the spatial and ownership structure of supply chains, the differences between JIT and non-JIT supply chains are understated and the results in this paper are lower bounds to the true correlations.

The second limitation is that coordination and other efforts to minimize inventories are a matter of degree, while my information on JIT in the COI survey is only binary. I acknowledge this shortcoming here – and refer to JIT_{ft} as 'JIT intensity' occasionally below. The empirical patterns presented therefore reflect differences in group averages of more and of less intensive "JITers".

The third and final limitation is that there is no information about which exact product lines or supply relationships are managed just-in-time.[13] Both aspects introduce measurement error and tend to attenuate the results, with the consequence that my estimates tend to understate true differences between JIT and non-JIT supply chains.

2.1 Prevalence, Importance, and Firm Characteristics

Online Appendix Table C.1 illustrates the prevalence and importance of JIT firms in terms of sheer numbers, employment, and trade shares at the 2 digit industry level (23 manufacturing industries). In the aggregate, slightly less than half of all firms report that they participate in JIT supply chains. Perhaps somewhat surprisingly, JIT firms account for a sizeable share of companies in *all* industries; their share ranges from 30% in "textiles" to 67% in "motor vehicles, trailers and semi-trailers". JIT firms are, however, disproportionally important economically: they account for an outsized share of economic activity in almost every industry and for roughly two thirds of both aggregate employment and international trade.

[12] These explanations in French and English are presented in Online Appendix A.1.

[13] For the year 1997 this information is available separately for sourcing, producing and shipping. As these activities are highly interdependent and therefore strongly correlated, however, this additional detail cannot be used to, for example, validate the survey responses further.

Examining the role of JIT supply chains in international trade in slightly more detail, it is clear that JIT firms source and produce goods that France trades intensively with other countries. Online Appendix Table C.2 shows that they account for more than 80 % of value traded in the three most important HS 2 digit products; "vehicles", "electrical machinery and equipment (without computers)", and "equipment for nuclear energy generation" (these account for a third of all French international trade). Once again, this pattern underlines the significance of JIT supply chains, at least for the French economy.

To characterize JIT and 'traditional', non-JIT firms, I use balance sheet information from FICUS, an administrative fiscal database that covers the universe of French firms, and the universe of international trade transactions provided by the French customs office DGDDI. All details on how the different variables are constructed are presented in Online Appendix A.1.

Table 1: JIT Premia

	(1)	(2)	(3)	Obs
log sales	0.766***	0.555***	0.084***	12,407
log employment	0.622***	0.434***		12,411
log labour productivity	0.145***	0.122***	0.084***	12,407
log VA productivity	0.049***	0.054***	0.031***	12,327
log capital intensity	0.251***	0.174***	0.094***	12,131
log intangible capital intensity	0.082**	0.074**	0.003	11,542
log skill intensity	0.014*	0.017***	0.001	12,408
log inventory (finals) turnover	0.296***	0.250***	0.142***	4,484
log inventory (interm.) turnover	0.087***	0.099***	0.143***	11,812
Prob. international trader	0.077***	0.049***	0.011	12,411
log total trade value	0.960***	0.729***	0.142***	10,416
log # CN products traded	0.436***	0.333***	0.047**	10,416
log mean shipment value	0.299***	0.234***	0.038*	10,416
log # transactions	0.285***	0.247***	0.109***	8,231
Additional covariates	Year FE	4d Ind. $\times$ Year FE	4d Ind. $\times$ Year FE, log empl.	

Every cell in columns (1)-(3) is the coefficient estimate of a firm $\times$ year level OLS regression of the row variable on a dummy equal to one if a firm reports being part of a JIT supply chain, possibly including the covariates reported. Common sample imposed across columns within each row. 312 industries classified according to NAF Rev. 1. Standard errors are clustered at the 4 digit industry by year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Each cell in Table 1 contains the point estimate from a regression of the row variable on the JIT indicator and I refer to them as 'JIT premia'. The results in column (1) capture raw differences in the cross-section, while the estimates in columns (2) and (3) use only within industry $\times$ year variation. Compared to 'traditional' firms, participants in JIT supply chains tend to be larger in terms of sales and employment, are more productive, and are somewhat more capital intensive. Lending further credibility to the JIT indicator, Table 1 illustrates that inventory turnover – the ratio of sales to the value of inventories – is substantially higher at JIT firms. Finally, JIT firms are more likely to trade and, if they do so, trade more; they typically transact more frequently and transact a higher number of distinct products.

To interpret these patterns, it is important to keep in mind that JIT systems typically require substantial overhead that is at least piecewise independent of the scale of operations or output. These costs include, for example, the expenditure associated with employing supply chain managers capable of running a complex and highly coordinated supply network, maintenance of common IT structures or interfaces, and joint research and development with the goal of interlocked products and processes. A plausible interpretation of the finding that JIT firms command a size and productivity premium is that only large companies are in a position to amortize these fixed overhead expenditures. In other words, firms may select into JIT supply chain participation based on a profitability or capability advantage. I treat the JIT premia as consistent with, and as supporting evidence for, such a mechanism when I build the conceptual framework in Section 3.[14]

2.2 Location Choice in JIT Supply Chains

Empirical specification and data

I compare international transactions of JIT firms to those of non-JIT ones to see if there are significant differences in how trade patterns correlate with trade partner location. In light of the particular features of JIT supply chain management and some limited empirical evidence from previous industry studies (e.g. Evans and Harrigan, 2005), I am interested in proximity as the spatial characteristic of a trade partner and estimate the following baseline model:

[14] In Schonberger (1982), page 4, the author describes several implementation related and recurring fixed expenditures associated with JIT. He concludes that "[o]f course, these developmental and administrative costs are are more easily amortized by the large volume producer."

$$y_{fcpt} = \sum_{z=1}^{Z-1} \beta_z \; JIT_{ft} \times \mathbb{1}(\text{distance}_c \in \text{quantile bin}_z) + \boldsymbol{\beta_3 X_{fct}} + \\ \gamma_{ict} + \gamma_{ft} + \gamma_p + \varepsilon_{fcpt}, \quad (1)$$

where $ficpt$ indexes a trade flow of CN 8 digit product p between country c and firm f operating in 4 digit NAF Rev. 1 industry i in year t.[15] I sum over import and export flows, since, as stated above, my firm level JIT information is silent about which transactions are managed JIT and which are not. Finally, Z denotes the total number of quantile bins used.

The two dependent variables of interest are the extensive and intensive country margins of trade. To span the product space for every firm, I keep *its* 10 most important CN 8 digit codes according to total trade value in every year. These account for 88% of the total trade volume of France with Europe. I focus on these crucial goods because they are the most likely to enter corporate supply chain considerations and because it helps keep the sample size in check without losing much information (the median firm in 2006 trades in 25 products, the one at the 75th percentile in 59).[16]

The extensive margin is defined as an indicator that equals 100 whenever a firm reports trading a given product with a given country c in year t, and zero if it reports no trade in that product with c in t:

$$\text{extensive margin}_{fcpt} \equiv \mathbb{1}(tradevalue_{fcpt} > 0) * 100.$$

A natural intensive margin measure is the Euro value of a trade flow. This variable is, however, famously right skewed and contains a very large number of zeros – a log transformation that could address the first problem would therefore imply that many observations were dropped. As an alternative I employ the inverse hyperbolic sine transformation (Burbidge et al., 1988). The resulting variable is approximately normally distributed and, for high values, all coefficient estimates can be interpreted as if the dependent variable was log transformed. For small values, the inverse hyperbolic sine does not do as good a job in approximating an elasticity, but since large flows account for the bulk of international trade, this shortcoming is of second-order importance here.[17]

For the main analysis I restrict the sample to 41 European countries for which there is

[15] I concord all flows over time to CN 1996. While the product dimension could be integrated out for the baseline, I keep the data disaggregated for further exercises below. The main patterns using the aggregated sample are robust, see Online Appendix A.2.

[16] The main results are robust to using the top 25 products, see Online Appendix A.2.

[17] The main results are similar when using the log transform, see Online Appendix A.2.

(population-weighted) distance information available in the gravity data from CEPII. The reason for this geographical focus is that I expect the differences between JIT and non-JIT to be salient in the immediate vicinity of France, while trade with Australia or Chile, to mention two arguably extreme examples, is unlikely to ever be conducted with a JIT idea in mind.[18]

Panel A of Online Appendix Table C.3 provides summary statistics for both margins of interest. A typical firm trades its average product with 8.8 countries, but the distribution is highly skewed across firms and products, which is a well known fact about international trade. Conditional on trading a good with a location, the average trade value is about 1.2 million EUR in a year, but the median flow is much smaller at 40 thousand.

The main regressors are a set of interactions between the JIT indicator and quantile bin dummies derived from the across country distance distribution.[19] The variation in the quantile variable is illustrated in Online Appendix Figure C.1, where I present a map of the European countries in my sample and their respective quintile bin.

Given that countries in the final distance quantile bin provide the reference category, the β_z coefficients are expected to be positive and decreasing in z: all firms trade more with close locations compared to remote ones as prescribed by gravity, but this pattern is expected to be stronger for JIT firms. In other words, the distance elasticity is higher for them in absolute value.

To isolate the correlation of interest I purge the estimates of observed and unobserved 'confounders' with a set of additional control variables, captured by $\boldsymbol{X}_{fct}$, and a comprehensive fixed effects strategy. Starting with the latter, the industry $\times$ trade partner country $\times$ year effects (γ_{ict}) ensure that I compare trade flows of firms that operate in the same narrow industry and trade with the same location. As a consequence, neither industry or country specific characteristics, nor selection patterns – for example in line with comparative advantage – drive my results. Similarly, historical patterns and path dependencies are removed from the variation: industries in proximate locations may have developed infrastructure or agglomerated clusters that favor JIT style operations due to policy or completely unrelated reasons, which might create an association between JIT and locational choice that may have nothing to do with supply chain management. For example, the Élysée process that began in 1963 may have led to much closer cooperation between France and Germany, which today facilitates coordinated supply chains but has nothing to do with JIT. Furthermore, these fixed effects address certain selection patterns.

[18]The main results are similar, but expectedly slightly weaker when using the top 100 trading partners worldwide, see Online Appendix A.2.

[19]In Online Appendix Table C.4 I show that the results are very similar when I use the most comprehensive and reliable estimates of shipping times for France, which were produced by Berman et al. (2013) based on marine and road transportation. This variable is highly correlated with my baseline distance measure – .82 between (log) distance and (log) time-to-ship – but has a significant number of missings.

Taking the food industry as an example, JIT firms may specialize on time-sensitive items produced only in some countries, while non-JIT firms do not. The former may thus be subject to a different distribution of shocks compared to the latter, which might be picked up by the $\hat{\beta}_z$ estimates.

One may still be worried that it is not distance that makes certain trade partner countries more attractive for JIT supply chains, but other country characteristics. A plausible alternative mechanism is that JIT supply chains require more communication to achieve smooth operation and hence disproportionally benefit from the same language, language proximity, or more generally cultural similarity; a good example is the relationship between France and (Western-)Switzerland. Importantly, these variables are often correlated with distance. To address this concern I include interactions of the JIT indicator with appropriate proxies for these margins in the regressions. Furthermore, as the case of Brexit strikingly illustrates, regulatory conditions that facilitate speedy processing times benefit JIT supply chains disproportionately and are typically found between nearby trade partners. To address these issues I include JIT interactions with several trade agreement measures, an EU and a Euro membership indicator, a legal system indicator, and the V-Dem property rights protection index in the regressions. Finally, non-homothetic preferences may lead to greater demand for speedy transactions in richer countries, which tend to be close to France. I address this concern by controlling for interactions with income and size proxies.

Main results

Figure 1 illustrates the main results from specification (1) with quintile bins, where darker colors indicate larger point estimates – all underlying results and further details are reported in Online Appendix Table C.5. Trade with close partners is more likely, and substantially larger, in JIT supply chains than in 'traditional' ones; but this difference decreases rapidly when the trade partner is farther away. In other words, JIT trade flows are, in a descriptive sense, more sensitive to distance than their non-JIT counterparts – they are more regional.[20]

But *how much* more "regional"? One way to illustrate the economic magnitudes of the estimated coefficients, and to see if they are of first-order importance economically, is to compare them to variation in the raw data. In my estimation sample, the probability of trading a product with a country in the first distance quintile bin – which features countries like Germany – is 19.5 percent for a non-JIT firm. That for the third quintile – which features countries like Hungary – is 3.7 percent. The difference in point estimates

[20]The findings do not imply that JIT firms trade less than their non-JIT counterparts with remote locations in *absolute* terms, since the model estimated is a difference-in-differences.

for the two quintiles suggests that firms in modern JIT supply chains show a steeper gradient across the two categories by $(1.089 - 0.211)/(19.5 - 3.7) \approx 5.6$ percent. Similarly, the gradient at the intensive margin for non-JIT trade flows is $4.177 - 0.737 = 3.440$, so that the baseline estimates suggest a difference between JIT and non-JIT firms of $(0.488 - 0.120)/3.440 \approx 10.7$ percent. A plausible illustration of magnitudes is difficult in this difference-in-differences exercise, but these comparisons nevertheless demonstrate that supply chain management may be a relevant concern for location choice.

Robustness checks

Table 2 presents a selection of robustness checks. For the purpose of exposition I turn to tercile bins and column (1) repeats the baseline for comparison.

First, one may be concerned that firm characteristics other than participation in JIT supply chains drive the results. JIT firms, which tend to produce varieties that have a high capital or skill content, may have to resort to proximate trade partners, since countries that consume and specialize in such products are clustered around France. The estimates may therefore be confounded and higher than they should be. Furthermore, if JIT firms are larger and more productive, they are more likely to trade with remote locations. The estimates could thus be smaller than they would be due to the correlation between JIT and proximity alone.

The first step to address these concerns is to include firm $\times$ country fixed effects, so that the interaction coefficients are estimated using time variation in the JIT indicator. Intuitively, I examine how adoption or abandonment of JIT correlates with *changes* in the structure of supply chains in space. To ensure that there is sufficient time for such changes to take place, I limit the sample to the years 1997 and 2006. As column (2) in Table 2 shows, firms that adopt JIT supply chain practices skew their international production networks towards proximate trade partners, especially at the extensive margin.

The second step in the investigation of firm characteristics that may act as confounders is to control for interactions of the distance dummies with them directly. I add the relevant controls to the previous empirical specification in column (3), which constitutes the most demanding specification I investigate. While the point estimates fall slightly and lose their statistical significance at conventional levels, the changes are economically small and the order of magnitude is retained. At the extensive margin, the adopter coefficient is even larger than the preferred baseline estimate.

The second robustness check pertains to selection into the types of products that are being traded. They differ, for example, in perishability, complexity, bulkiness, and their input requirements, all of which make them differentially likely to be traded between dif-

Table 2: Location – Baseline Robustness

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Extensive margin						
JIT firm × $\mathbb{1}$(distance tercile 1)	0.920***	1.633**	1.299	0.625*	0.678**	0.958**
	(0.271)	(0.809)	(0.864)	(0.373)	(0.332)	(0.394)
JIT firm × $\mathbb{1}$(distance tercile 2)	0.180	0.602	0.317	0.205	-0.047	0.019
	(0.184)	(0.518)	(0.553)	(0.252)	(0.229)	(0.265)
Observations	2,994,486	2,005,443	1,849,221	1,669,833	2,954,127	1,594,527
R-squared	0.303	0.460	0.463	0.597	0.378	0.316
Panel B: Intensive margin						
JIT firm × $\mathbb{1}$(distance tercile 1)	0.311***	0.265	0.179	0.263***	0.295****	0.308***
	(0.060)	(0.172)	(0.185)	(0.082)	(0.074)	(0.089)
JIT firm × $\mathbb{1}$(distance tercile 2)	0.071*	0.059	0.005	0.090	0.034	0.042
	(0.041)	(0.110)	(0.118)	(0.055)	(0.051)	(0.059)
Observations	2,994,486	2,005,443	1,849,221	1,669,833	2,954,127	1,594,527
R-squared	0.321	0.480	0.484	0.621	0.397	0.334
Specification						
Sample	full	long difference	long difference	full	full	high roadshare
Firm × Year FE	YES	YES	YES		YES	
4d Industry × Country × Year FE	YES	YES	YES			
8d CN Product FE	YES	YES	YES			
Firm $\times Country FE		YES	YES			
Additional firm controls			YES			
Baseline FEs × 8d CN Product FE				YES		
French Region × Country × 4d Industry × Year FE					YES	

The dependent variables are a dummy equal to 100 if, in a given year, a firm-product is traded with a country, and zero if not traded with that country ("extensive margin"); or the – inverse hyperbolic sine transformed – value of such a trade flow ("intensive margin"). The regressors are a dummy equal one if a firm is part of a just-in-time (JIT) supply chain in a year, and zero if not, interacted with tercile dummies from the across country distance distribution with that JIT dummy. Interacted country controls: JIT dummy interacted with a) country dummies equal to one if French is ethnologically the main language; it is officially the same language; the partner shares a majority religion with France; the partner is landlocked; an FTA, RTA, or GSP agreement with the EU is in place; the partner's legal system is based on the Code civil; the partner is a member of the EU; the partner has the Euro; and b) (log) GDP; (log) GDP per capita; (log) land area; the V-Dem property rights protection index. Additional firm controls: distance tercile indicators interacted with physical capital intensity; intangible capital intensity; skill intensity; sales; employment; VA per worker of firm (all in logs). There are 22 regions in France. 'long difference' refers to a sample covering the years 1997 and 2006. The 'high roadshare' sample includes trade flows of firms in industries whose value share of aggregate trade shipped via roads is above the median across industries. Sample size varies due to different samples and since singletons are dropped. Standard errors in parentheses are clustered at the firm × country level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

ferent country × industry pairs. JIT firms may sort systematically into certain categories for unrelated reasons and my estimates may be confounded. Alternatively, if one believes that selection into different products is an important margin for either the adoption of JIT or for how big its efficiency gain is, it is interesting to study what share of the location patterns is driven by that. To address these issues – at the cost of a reduced sample –

I allow all relevant fixed effects to vary by 8 digit CN product, see column (4) of Table 2. Reassuringly, changes in the magnitudes of the coefficients are small, especially at the intensive margin.

The third set of robustness checks addresses concerns about firms' locations within France and their preferred means of transportation. In particular, JIT firms could simply happen to reside systematically closer to the borders with Germany, Belgium, or Spain to facilitate trade with partners there. Simple gravity considerations would then explain the positive correlation between JIT and proximity. Moreover, the baseline results could be accounted for by local infrastructure available to firms, like highways or airports. In column (5) of Table 2, I therefore interact the γ_{ict} effects with an indicator for each of the (at the time) 22 French regions, so that the estimating variation comes from comparing two firms within the same region and industry who trade with the same partner country. The result is reassuring provided that the majority of firms produces at the plant it is officially registered at. In column (1) of Online Appendix Table C.12 I confirm that the main results remain unchanged in the substantially smaller sample of firms with a single establishment.

One may also worry that the transportation mode for flows in JIT supply chains is systematically different, which could cause differential freight costs to drive the correlations. Column (4) of Table 2 shows that product characteristics do not appear to pose a major problem, so that transportation mode – to the extent that there is very little variation at the highly detailed CN 8 digit level (9.5k categories) – is unlikely to explain the spatial concentration of JIT supply chains. Moreover, in column (6) I restrict the sample to downstream industries that transport their goods almost exclusively by road, i.e., those above the across industry median of 83 percent of the total value shipped. The fact that the estimates are virtually the same in this subsample as in the full one further corroborates the conviction that differences in transportation mode do not play an important role for my findings.

I have conducted a series of so far unmentioned further robustness checks, which, for conciseness, I present in Online Appendix A.2. These include subsample analyses (dropping the most JIT intensive sectors; including wholesalers; focussing on intermediates or imports) and investigating the role of IT intensity and border effects.

2.3 Vertical Integration Patterns

Empirical specification and data

To generate econometric evidence I estimate the following model

$$y_{fijt} = \beta_1 \; JIT_{ft} + \boldsymbol{\beta_2 X_{ft}} + \gamma_{ij} + \gamma_t + \varepsilon_{fijt} \;, \tag{2}$$

where i continues to denote the industry of French firm f in year t of my sample and j denotes an (upstream) activity required for production of i.

The first dependent variable is an indicator equal to one hundred if firm f performs activity j in-house, and zero if the activity is outsourced to a third party. The second one is a similar indicator where only integration abroad is taken into account. I construct these variables following a commonly applied strategy to foster comparability with other research (e.g., Fan and Lang, 2000; Acemoglu et al., 2010; Alfaro et al., 2016): First, I use the 2002 U.S. Benchmark IO Table (concorded to ISIC Rev. 3) to obtain information about which activities or intermediate inputs a firm in industry i needs for production. This IO table is arguably very little affected by French firms' management or ownership decisions, but still provides valuable information about technology, since the U.S. and France are relatively similar. I base my measure on the 100 most important upstream manufacturing industries j for each downstream industry i according to direct requirements, because key activities are much more likely to be relevant considerations in strategic decision making.[21] In the second step, I code an activity j as "integrated" if either the firm f itself reports j as a secondary industry, or if an affiliate reports j as a primary or secondary industry. For the variable "integrated abroad" I count activities of foreign affiliates only. Since all firms have a primary industry i, I drop all observations where $i = j$, i.e., supply relationships on the diagonal of the IO-table.

This type of measure of vertical integration can be interpreted as the *potential* for a downstream firm f to source an intermediate input in-house and hence circumvent the market. Information on worldwide ownership links and industry affiliations comes from the database Liaisons financières entre sociétés (LiFi), which records information on all business groups that operate in France.

Online Appendix Table C.3 reports several summary statistics for the two main dependent variables. The overall share of integrated supply relationships $j \rightarrow i$ is 2.6 percent, but this is driven by a small number of highly vertically integrated conglomerates. Internationally, since only a small subset of firms engages in FDI, it is no surprise that a mere 0.2 percent of all upstream-downstream relationships takes place within the boundary of a single international business group. Once again, however, a few and large multinationals entertain subsidiaries that can provide them with intermediate inputs.

The main regressor of interest is the JIT_{ft} indicator. In line with anecdotal evidence

[21] The results are fully robust to using all 312 industries in my sample, see Online Appendix A.3. A slight decrease in point estimates is expected given that firms tend to vertically integrate their most important inputs (Berlingieri et al., 2018).

in Keane and Feinberg (2007) that the increase in intrafirm trade between Canada and the U.S. following CUSFTA may have been linked to JIT, its coefficient β_1 is expected to be positive: (multinational) JIT firms may try to complement their supply chain management with asset ownership that allows for more direct control, as discussed in Section 3 below.

Specification (2) furthermore includes a set of upstream $\times$ downstream industry fixed effects, γ_{ij}. They are motivated by the empirical findings of a broad literature in organizational economics and international trade that examines the determinants of vertical integration (for a review see Antràs, 2015). To the extent that they vary at the industry(-pair) level, I remove confounders like the relative marginal investment contributions by suppliers and customers as highlighted by property rights theories (PRT) of the boundary of the firm (Grossman and Hart, 1986; Antràs, 2003) or the contracting environment and relationship specificity for $j \rightarrow i$ transactions put at center stage by TCE approaches to vertical integration (e.g., Williamson, 1985). In consequence, β_1 is estimated by comparing two French firms in the same narrow industry – one a participant of a JIT supply chain, the other one not – with respect to whether the same upstream activity j is performed in-house or outsourced.

Finally, I include a set of firm level control variables (value added per employee, capital intensity, and skill intensity) which are correlated with JIT supply chain participation and may drive vertical integration (Corcos et al., 2013). I omit scale controls like employment and sales due to the mechanical relationship with vertical integration in the baseline and examine their role in the robustness checks below.

Baseline results

Columns (1)-(3) in Table 3 illustrate the baseline results, where the fixed effects and controls are introduced in turn, grouped by specifications that have either overall (Panel A) or only foreign integration (Panel B) as a dependent variable. The JIT indicator is positive and highly significant in the preferred specification in column (3): JIT firms show a higher propensity to perform the average upstream activity in-house compared to similar non-JIT firms – both in general and as a part of a multinational business group.[22] Relating the magnitudes of the estimates to the overall means of the dependent variables, shown in row "Coeff. / mean depvar (percent)", reveals that these differences are of first-order importance; the premia over sample means are 7.1 and 24.5 percent for overall integration and integration abroad, respectively.

I describe an important robustness exercise for this finding here and present others (regarding IT intensity, JIT intensive industries, and wholesalers) in Online Appendix A.3.

[22]Perhaps not coincidentally in the light of these findings, JIT was invented and has been very successfully employed in Japan, where business groups (keiretsu) have a dominant position.

Table 3: Vertical Integration – Baseline And Some Robustness

	(1)	(2)	(3)	(4)	(5)
Panel A: Integrated					
JIT firm	0.386***	0.245***	0.182***	0.041	
	(0.071)	(0.065)	(0.065)	(0.196)	
Coeff. / mean depvar (percent)	15.0	9.5	7.1	1.6	
Observations	1,048,434	1,048,434	1,048,434	699,404	
R-squared	0.000	0.482	0.482	0.509	
Panel B: Integrated abroad					
JIT firm	0.098***	0.068***	0.057***	0.122**	0.112**
	(0.015)	(0.014)	(0.014)	(0.056)	(0.055)
Coeff. / mean depvar (percent)	42.1	29.2	24.5	49.6	45.5
Observations	1,048,434	1,048,434	1,048,434	699,404	699,404
R-squared	0.000	0.153	0.154	0.178	0.178
Specification					
Sample	full	full	full	long difference	long difference
Year FE	YES	YES	YES	YES	YES
Downstr. 4d Ind. × Upstr. 4d Ind. FE		YES	YES	YES	YES
Firm FE				YES	YES
Firm controls			YES	YES	YES
Additional firm controls					YES

The dependent variables are a dummy equal to one hundred if an upstream industry is integrated in a firm/business group in a given year, and zero otherwise ("integrated"); or the same dummy where only foreign affiliations are counted ("integrated abroad"). The regressor is a dummy equal to one if a firm is part of a just-in-time (JIT) supply chain in a year, and zero if not. Firm controls: value added per worker; physical capital intensity; intangible capital intensity; skill intensity (all in logs). Additional firm controls: employment; sales (both in logs). Common sample imposed across specifications (1)-(3). Sample size varies since singletons are dropped. Standard errors in parentheses are clustered at the firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

It is well known that multinational firms are typically the largest and most productive firms, potentially because they can select into maintaining affiliates and amortize the associated overhead abroad. To avoid spurious correlation – after all, JIT firms also command a size and productivity premium as shown above – I follow two strategies. First, I include firm fixed effects in the baseline regression. Secondly, I add a firm's *domestic* employment and sales as scale covariates directly. This is only possible for foreign integration, since there is a mechanical relationship between carrying out more activities and having more employees. Once again, I exclude the year 2003 from the sample to give adopting or abandoning firms sufficient time to reorganize their supply networks.

The results are reported in columns (4) and (5) of Table 3. While the "JIT adopter" coefficient for foreign integration is economically substantial and statistically significant, the JIT coefficient for overall integration drops almost to zero. A possible conclusion from this check is that adopting JIT supply chain management is correlated with more vertical integration and that French firms adjusted their supply chains primarily abroad, potentially even substituting some domestic suppliers for foreign ones.

Different measures of vertical integration

The indicator variables for ownership have two shortcomings. First, the different upstream industries are very heterogeneous in their contributions to final output, yet enter the baseline regressions in symmetric fashion. A car manufacturer, for example, needs an engine, which accounts for a high cost share, as well as seats and car glass, which account for much less of the value of a car in terms of its input costs. Integration of only the latter two activities means a relatively low degree, while in-house production of engines and car glass implies a higher degree of vertical integration along the value chain conceptually. In other words, the indicator variable cannot capture the *intensity* of vertical integration.

Following standard practice to facilitate comparison, I use an index

$$VI_{fit} = \sum_{j \in J_{fit}} DR_{ij} * 100, \quad J_{fit} \equiv \{j \neq i | integrated_{fijt} = 1\}$$

of vertical integration as an alternative dependent variable. DR_{ij} denotes the 2002 U.S. direct requirement of industry i from upstream industry j. This index is the share of total expenditure on activities that a firm can potentially keep within its boundary.

In columns (1) and (2) of Table 4, I show the result of regressing VI_{fit} (and its equivalent counting only integration abroad) on the JIT indicator, a set of firm controls, and a set of downstream industry $\times$ year fixed effects. Relative to the sample average, JIT firms have a substantially higher intensity of vertical integration (premia over means of 12.1 and 45.7 %), a difference most pronounced for multinational activity.

The second shortcoming of the *integrated* indicator variables is that they capture asset ownership and hence only the *potential* to source inputs in-house. To understand whether actual transactions of goods are more likely to happen within the boundary of the firm, too, I examine intrafirm trade data. The French firm level survey EIIG covers a random sample of firms with foreign affiliates in a single cross-section.[23] It provides data on the

[23] Unfortunately, EIIG is only available for the year 1999, which is not part of the JIT sample from COI-TIC. I make the assumption that firms did not change their JIT status between 1997 and 1999 and match the intrafirm trade data to the first cross-section of my JIT sample. Further information about EIIG can be found

Table 4: Vertical Integration – Additional Outcomes

VARIABLES	(1) integration index	(2) integration index abroad	(3) integration index abroad	(4) intrafirm trade share	(5) intrafirm trade share
JIT firm	0.613**	0.243***	0.129**	6.731***	5.399***
	(0.250)	(0.065)	(0.063)	(1.874)	(1.894)
Coeff. / mean depvar (percent)	12.1	45.7	24.2	22.2	17.8
Observations	10,417	10,417	10,417	37,599	37,599
R-squared	0.343	0.275	0.286	0.286	0.294
Sample	(1)	(1)	(1)	(2)	(2)
Downstr. 4d Ind. × Year FE	YES	YES	YES		
Downstr. 4d Ind. FE				YES	YES
4d HS Product FE				YES	YES
Flow FE				YES	YES
Country FE				YES	YES
Firm controls	YES	YES	YES	YES	YES
Additional firm controls			YES		YES

The dependent variables are the firm level sum of all direct requirements by a firm's downstream industry from integrated upstream industries ("integration index"); or the same index counting only integration abroad ("integration index abroad"); or the – percentage point – value share of a firm's international trade flows ("intrafirm trade share"). The regressor is a dummy equal to one if a firm is part of a just-in-time (JIT) supply chain in a year, and zero if not. Firm controls: value added per worker; physical capital intensity; intangible capital intensity; skill intensity (all in logs). Additional firm controls: employment; sales (both in logs). "Flow FE" refers to a dummy equal to one for export flows, and zero for import flows. Sample (1): all downstream firm-years from the full sample. Sample (2): all 4 digit HS trade flows associated with the firms in the full sample (1997 only). Standard errors in parentheses are clustered at the firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

value share of individual trade flows that was sourced within the boundary of the firm. My alternative dependent variable is therefore "intrafirm trade share$_{fpcot}$", where p is a 4 digit HS product traded, c continues to denote the trading partner country, and o is the type of flow, i.e. either an im- or an export.

In column (4) of Table 4, I regress this variable on the JIT indicator, a set of firm controls, and on a set of downstream industry i, upstream 4 digit HS product p, and flow o fixed effects. The results from this exercise support my baseline findings and at the same time establish a novel insight: transactions along JIT supply chains are more likely to occur between related entities and, due to the prevalence of JIT, account for a large share of intrafirm trade. In particular, flows where the French party reports being embedded in a JIT supply chain are about 6.7 percentage points more likely to happen within a multinational firm than those where the French firm operates in a 'traditional'

in Online Appendix A.1.

way – for comparison, the overall intrafirm trade share is roughly one third.

Ruling out lock-in and technology diffusion as explanations

Motivated by both the literature on the boundary of the firm in imperfect contracting environments, I finally investigate to what extent the relationship between JIT and vertical integration is an outcome of relationship-specificity or "lock-in". To enable extreme levels of coordination two parties may have to share sensitive information, make substantial adjustments to their production processes, or make long-term location decisions geared toward one another. Such a lock-in could lead to higher quasi-rents and therefore to integration in line with a rent-seeking rationale. To study whether this is a potential explanation, I posit that such lock-in effects are particularly important for industries that process highly differentiated, complex goods with a substantial share of non-routine task input. By contrast, simple and easily codifiable products can be ordered fairly quickly from several sources and require little information exchange. I create a single "lock-in index" to measure these aspects based on the Rauch (1999) classification of homogeneous vs. differentiated goods, the Harvard Complexity Index for goods, and the share of non-routine tasks from Costinot et al. (2011) (details are provided in Online Appendix A.1).

For the results reported in the first four columns of Online Appendix Table C.6, I repeat the baseline specifications (2), but restrict the sample to supply relationships where the lock-in index is below the median in the downstream industry (odd columns) and, *in addition*, to those where it is below the median in the upstream industry (even columns). The point estimates are similar to the overall baseline and typically far from significantly different. These insights do not change when I use the integration intensity indices in columns (5) and (6), or intrafirm trade shares in column (7). While lock-in effects may be at play in JIT managed supply chains, I therefore conclude that they are unlikely to provide a particularly cogent explanation for the integration patterns I document in this paper.

This robustness check also speaks to the concern that JIT firms have to share more sensitive information about their technology with other parties and that the protection of such knowledge leads to vertical integration (e.g., Ethier, 1986). This channel may not be relevant even *a priori* since it is at least not obvious why firm boundaries protect knowledge better than other contracts in a world with high worker turn-over, reasonable IPR protection via patents and trademarks (enforced by an industrious legal profession), and intense networking between managers. Notwithstanding, the fact that JIT and vertical integration are positively correlated even for simple and homogeneous products instils confidence that this channel is no first-order concern.

3 A Conceptual Model of JIT Supply Chains

In this section I propose a conceptual framework to explain the patterns in the data documented above. Downstream buyers source intermediate inputs from upstream suppliers in an uncertain environment. While both partners in such a transaction can adapt to upstream and downstream shocks, they will hold inventories to the extent that these adaptation decisions are not fully coordinated and production might be disrupted. JIT supply chain management is modelled as an information sharing technology, which ensures that signals about downstream demand are shared with the supplier to facilitate coordinated adaptation and thus reduce expensive buffer stocks.

Even if real-time demand information is available, a remote supplier may not manage to deliver its goods in time to satisfy the precise needs of customers; in other words, the intermediate may have become obsolete due to long shipping times. Skewing the supply network towards regional partners, even at the price of higher primary factor costs, is therefore a complementary strategy to JIT.

Moreover, even though suppliers have better information about demand under JIT, they make adaptation decisions to maximize their own profits and thus create an externality downstream if they are independent from the buyer. Operating as a vertically integrated, multi-plant firm constitutes a way of bringing adaptation incentives of individual units in line with those of the entire segment of the supply chain. JIT and joint ownership are therefore complements in the sense that the efficiency gains of one organizational margin are amplified by the other.[24]

There are at least two other mechanisms that may play a role in explaining the vertical integration patterns in the data. First, if JIT systems require more relationship specific investments there may be scope for hold-up by either party and vertical integration is more likely. As I have shown above in Section 2.3, however, the main stylized fact holds even in environments where parties are not locked into their relationships. Second, the PRT explanation of vertical integration posits that ownership is allocated to maximize the surplus arising from a supply relationship. Asset ownership improves outside options when the relationship breaks down and hence confers incentives to invest *ex ante*. A likely prediction of this theory is that a JIT set-up works best between independent parties:

[24]Conceptually, the boundary of the firm in this framework is defined by a TCE mechanism. My ideas and assumptions build on (1) the adaptation theory of the boundary of the firm (Simon, 1951; Williamson, 1975; Forbes and Lederman, 2009) in that ownership confers residual control rights in situations where adaptation to uncertainty is not resolved by contracts; and on (2) the incentive systems theory Holmstrom and Milgrom (1991, 1994) in that ownership patterns affect decision making in a multi-tasking environment (local vs. coordinated adaptation). Furthermore, the model is closely related to Legros and Newman (2013) and Alfaro et al. (2016) in that it emphasizes coordination motives for vertical integration. In contrast to their work, I micro-found conflicts of interest between parties as a multi-tasking problem due to adaptation in an uncertain environment.

both plants must be devoted to mutual coordination and therefore *ex ante* investments by both parties are important. This implication is, however, at odds with my empirical evidence. Finally, the internal capital market of a large multinational may alleviate suppliers' concerns about financial hold-up, which may be particularly important for the close relationships that typically support JIT operations. At least in the context of France, where the overwhelming majority of suppliers are located in Europe and therefore operate in an excellent institutional environment, such concerns are arguably of second-order importance.

I first introduce a baseline model with a JIT adoption decision only and then give firms the option to re-structure their supply chains in terms of location and ownership patterns.

3.1 Baseline Model

Set-up

There is a continuum of downstream firms in a single industry who produce horizontally differentiated varieties under monopolistic competition. These are only locally consumed and *quantity* demand is derived from CES preferences,

$$x(p(\omega)) = Bp(\omega)^{-\alpha},$$

where B is a demand shifter, $p(\omega)$ is the price set by the producer of variety ω, and $\alpha > 1$ captures the price elasticity of demand. For the purpose of this paper it suffices to posit that there is a measure of potentially active downstream firms and abstract from free entry. This general set-up corresponds well to the empirical exercises in this paper, where industry $\times$ year fixed effects ensure that all estimating variation stems from differences across firms within the same sector of activity in the same year.

The final good producers each source a single intermediate input, which is specific to their own variety and which they transform into output.[25] There is at least one independent supplier firm for each intermediate and, for now, these suppliers are only resident in a single location indexed by $\tau \in \mathbb{N}^+$. To save on notation, τ captures three aspects in the model: First, it is equal to (one minus) the number of periods in the overall game between the two firms that I outline below. Secondly, it is the time it takes to ship the in-

[25] To make sure that my empirical findings hold for trade in intermediates, too, I estimate the location related baseline specification on a sample excluding final and capital goods. As shown in column (7) of Online Appendix Table C.12, regionalization is at least as strong for this subset as it is for the baseline sample. For vertical integration, it is impossible to exclude capital goods, but final goods are unlikely to play a major role in firm to firm transactions of manufacturing companies – the results are therefore based on transactions that mostly involve intermediates.

termediate from the supplier to the buyer factory (also referred to as 'order lag'). Finally, it can be interpreted as the distance covered along the way, so that τ is also the conceptual analogue to distance in the empirical exercises.[26]

The overall game has $\tau + 1$ stages as depicted in Figure 2. At the preliminary, or *ex ante* stage $t = 0$, all strategic decisions for the supply chain are made and they cannot be changed afterwards. Every final good producer matches with a supplier, writes supply contracts, and potentially invests in JIT. When I extend this baseline model to allow for vertical integration and flexible location choices below, these decisions will also be made at this stage.[27]

Technology and contracts

At the next, *ex post* stage $t = 1$ (I refer to all stages $t \geq 1$ as *ex post* since they happen after the strategic decisions have been "locked in") production of the intermediate takes place and the associated production costs are

$$(\eta_S - d_S)^2 + w(\tau), \tag{3}$$

where η_S is an i.i.d. supply shock with expectation zero and variance σ_η^2.

On an abstract level, η_S captures all uncertainties that the upstream supplier faces. More concretely, imagine that the intermediate input itself is manufactured using an adjustable mixture of colors and that the supply shock η_S is an unexpected change in their relative prices. Alternatively, η_S may capture the uncertainties surrounding the actual production process that may lead to unexpectedly early or late completion of the intermediate (e.g., machine break-down).

The manager in charge of the supplier's factory may adapt to the supply shock by choosing d_S to reduce the first term in (3). One may think of this decision as a cost minimizing choice of the color mixture, or as a quick re-organization of the production process in the factory. More generally, d_S is a catch-all representation of the multitude of adaptation decisions that can be made. Clearly, if the local manager observes η_S perfectly and minimizes this expression, they adapt fully to the shock. Doing so may cause excessive costs further down in the supply chain, however, if the adaptation decision conflicts

[26] I abstract from non-zero production times for the intermediate. While it would be possible to add them, there is little value in doing so since I do not have any corresponding information in my data set.

[27] The *ex post* part of the game is better conceptualized as the stage game of a repeated game, where, after the supply chain is set up in $t = 0$, a number of orders are issued and satisfied. I abstract from this substantial complication, since questions of corporate discounting, supply relationship duration, and optimal dynamic inventory holding are outside the scope of this paper.

with downstream conditions, as will become evident below.

The decision d_S cannot be written into a contract or observed for enforcement, or both. Especially if it needs to be taken quickly and η_S poses challenges never encountered before, non-contractibility is a reasonable approximation to the real world. As in Simon (1951), Hart and Holmstrom (2010), and Legros and Newman (2013), for example, the final say on d_S in such situations of contractual incompleteness lies with the (manager of the productive assets, who acts in the interest of the) owner.[28] It is precisely in this sense that the present model embraces the tradition of TCE type models of the boundary of the firm, since ownership creates authority to make decisions and thus influence the efficiency of a business relationship.

The second part of (3), $w(\tau)$, represents the primary factor costs to produce an intermediate in locality τ, and they will be the reason for offshoring in the extended model below. I assume that $\mathrm{d}w(\tau)/\mathrm{d}\tau < 0$ and from the perspective of any given firm this is perhaps stylized, but not too unrealistic in my setting. French companies are too small to affect factor prices in other countries and, at least anecdotally, face ever lower labor costs in Eastern European, Arabian, and finally Asian or South American countries.[29]

The supplier's objective function – and its incentives when choosing d_S – depends on the contract it signs with the buyer firm. For simplicity, I focus on contracts that reimburse the supplier for the primary factor costs incurred, $w(\tau)$, and impose a penalty for any inventory costs that are due to mis-coordination with the downstream firm (specified below). The strength of this penalty is given by a parameter $\delta \in (0, 1)$, where the supplier bears none of the costs it causes with its adaptation decision when $\delta \to^+ 0$, and all of them when $\delta \to^- 1$. I refer to this parameter as "inventory pushing", because it captures the degree to which the downstream firm can delegate costs of inventory holding to the upstream supplier. A stark example of this is the famously lean automobile industry: car manufacturers/assembler-designers exert substantial market power in their input markets and push inventories onto their suppliers of seats, chassis, and other components.

Returning to the dynamics of the model, the supplier now sends the finished input to the downstream firm's factory, where it arrives in period τ. It is now converted into the final output using labor.

Downstream demand conditions – not in terms of quantity or quality, but in terms of *horizontal* characteristics – are captured by another random variable θ_t. These may, for example, a the customer's preference for dark colors or the particular time slot during

[28]When ownership and management are in different hands, the manager can always be fired if a residual decision is taken that conflicts with the owner's interests. To avoid the numerous complications highlighted by the vast principle agent literature, I assume that this threat is fully credible and effective.

[29]Evans and Harrigan (2005) model the international general equilibrium explicitly and obtain the same pattern endogenously. I abstract from such complications, as they offer few insights regarding the role of JIT.

which arrival of the intermediate is required. For simplicity, I assume that θ_t evolves according to an AR(1) process

$$\theta_{t+1} = \rho\theta_t + \varepsilon_{t+1},$$

where $\theta_0 = 0$, $\rho \in (0,1)$ is the persistence parameter and ε_t is an i.i.d. demand shock with mean zero and variance σ_ε^2. Demand conditions in period τ are therefore random and an early signal, θ_1, provides some information about what θ_τ may turn out to be. The usefulness of such a signal for predicting future demand is higher whenever ρ is closer to 1 and I refer to this parameter as "demand persistence".

To the extent that an intermediate does not match the period τ demand conditions due to imperfect coordination, the buyer firm has to rely on inventories (intermediate or final) to ensure that all customers are satisfied. To illustrate, suppose that the supplier decided to incorporate predominantly bright colors into the intermediate, because they happened to be relatively cheap. If demand conditions are skewed towards dark colors, the local adaptation decision upstream causes inefficiencies due to mis-coordination, since customers have to be satisfied with stocked goods. Alternatively, imagine the upstream supplier's manager found that it is cost efficient to take some time with a particular stage in the production process of the intermediate and hence sends it off with a delay. If the customer specified a particular time slot that is consequently missed, the production process downstream can only continue when stocked intermediates are used.

The costs of holding inventories to cushion such disruptions are

$$\gamma\left(\theta_\tau - d_S\right)^2. \tag{4}$$

$\gamma > 0$ is most naturally interpreted as per unit inventory holding relative to primary factor costs. This inventory holding behavior is stylized, since the downstream firm has no economic order quantity problem, no explicit stock-out avoidance motives, or any dynamic optimization problem. While I abstract from these and other major real life challenges for manufacturers, my model remains tractable and delivers important insights for supply chains.[30]

It would be straightforward to introduce a non-contractible adaptation decision d_B for the downstream buyer firm at time τ, too. Inventories would cover both the loss due to mis-coordination between d_S and d_B, and the one due to imperfect local adaptation

[30] Indeed, even simple inventory models have no closed form solution and need to be simulated. This unfortunate fact is illustrated for stock-out avoidance models by Kahn (1987) and for the Economic Order Quantity model with disruptions in Choi (2014). Generally, an S,s type policy is optimal in many dynamic inventory holding settings – but the closed form expressions for S and s are elusive and approximating them is a flourishing business, at least since Federgruen and Zipkin (1984). For prominent examples of s,S type inventory model in economics, see Khan and Thomas (2007) or Alessandria et al. (2010).

between d_B and θ_τ. Such a generalization would render the key mechanism fully explicit, but adds further complexity without providing any deeper additional insights. I therefore proceed with the simpler version and θ_τ can be interpreted as the delivery target for the supplier, i.e., with all downstream adaptations already made.

Finally, the buyer converts a unit of the intermediate into φ units of output. The productivity parameter φ is heterogeneous across downstream firms and, for simplicity, follows a Pareto distribution with shape parameter $k \geq 1$ and lower bound 1. Moreover, production downstream requires machines and overhead labor in the form of managers, accountants, and other staff. These costs are lumped into a single fixed cost parameter f, denoted in terms of labor (whose price is normalized to one).

JIT and information

At the *ex ante* stage $t = 0$, the downstream firm has an opportunity to devote an amount of resources to adopt JIT. Following Bustos (2011), I model these as a proportional increase in fixed costs, so that total fixed costs for a stand-alone downstream firm become $\lambda_{JIT} f$ with $\lambda_{JIT} > 1$. JIT requires additional overhead in the form of, for example, dedicated supply chain managers capable of running a complex and highly connected supply network, maintenance of common IT structures or interfaces, and joint research and development with the goal of interlocked products and processes.

In a 'traditional' supply chain, raw materials and intermediates are "pushed" through the different stages of the value chain and whenever a stage needs inputs, it takes them off its supplier's shelves – a private customer quite literally does so in a supermarket. No heed is, or can be, paid to the conditions in the downstream market and inventory holding costs are high. By contrast, in a JIT system the buyer firm shares information about downstream demand conditions in period $t = 1$ (in other words, in real-time), so that the supplier is in a better position to finish the right intermediate at the right time – hence the very term "Just-in-Time". Mis-coordination inventories, i.e., the figurative shelf-space, can be reduced substantially. To put the same point differently, JIT causes materials and intermediates to be "pulled" through the value chain.

For a "push" approach to supply chain management, I assume that the information set of the supplier is $\mathcal{I}_S^{\neg JIT} = \{\eta_S\}$, i.e., it observes its local shock perfectly, but nothing else. The buyer firm's manager observes the final demand conditions at any point in time, so that $\mathcal{I}_B^{\neg JIT} = \{\theta_t\}_{t \leq \tau}$. To build intuition, the information friction across firms could be due to a lack of a good information transmission system or due to organizational inefficiencies – the manager in charge of plant B is not instructed to channel demand information upstream, for example. Especially in a global supply network setting, it is quite plausible that a manager with a 'traditional mind-set' would not relay information upstream or that managerial overload introduces severe frictions into this process.

By contrast, in a JIT system, the information sets are

$$\mathcal{I}_S^{JIT} = \{\eta_S, \theta_1\}, \;\; \mathcal{I}_B^{JIT} = \{\theta_t\}_{t \leq \tau},$$

i.e., the upstream firms' manager receives a signal θ_1, which they can take into account when they make their adaptation decisions.[31]

Solution

I solve the model via backward induction. At stage $t = \tau$, the first order condition for optimal price setting by the downstream firm with CES demand takes the standard form

$$p^*(M) = \frac{\alpha}{\alpha - 1} \frac{c^*(M)}{\varphi}, \tag{5}$$

where the mode of supply chain management is $M = \neg JIT, JIT$ and the asterisk indicates optimal choices. $c^*(M)$ is shorthand for the total procurement costs of one unit of the intermediate, which includes the price of the intermediate and inventory holding costs.

Next, at stage $t = 1$, the supplier solves its adaptation problem

$$\min_{d_S} \; \delta \, \mathbb{E}\left[\gamma(\theta_\tau - d_S^*)^2 | \mathcal{I}_S^M\right] + (\eta_S - d_S)^2 + w(\tau).$$

The first term captures the upstream firm's share in expected mis-coordination inventory holding costs and the second term captures adaptation to the supply shock. Minimizing production costs is subject to a trade-off between coordinated and local adaptation, with the weights given by the relative costs of inventory holding and the degree to which the buyer can oblige the supplier to share in the costs of mis-coordination.

The upstream firm's optimal choice is

$$d_S^*(\tau, .) = \underbrace{\frac{1}{1 + \gamma\delta} \eta_S}_{\text{local adaptation}} + \underbrace{\frac{\gamma\delta}{1 + \gamma\delta} \mathbb{E}\left[\theta_\tau | \mathcal{I}_S^M\right]}_{\text{coordinated adaptation}}. \tag{6}$$

If inventories were costless ($\gamma = 0$) or if the supply contract provided no incentives for coordinated adaptation ($\delta \to^+ 0$), the supplier would fully adapt to its local shock. Since neither of these conditions is satisfied by assumption, the supplier strikes an individually optimal balance and adapts both to the technology shock and its conditional expectation of final demand conditions, $\mathbb{E}\left[\theta_\tau | \mathcal{I}_S^M\right]$.

[31] I abstract from cheap talk considerations about θ, since they do not contribute any additional relevant insights. Cheap talk is, however, a main theme in the related work by Alonso et al. (2015).

Note that from the perspective of the overall supply chain (segment), the supplier's incentives to adapt in a coordinated way are too weak since $\gamma\delta < \gamma$. In other words, an outsourcing contract between two independent firms implies a *supply chain externality*. This will become even clearer below when I allow the two firms to merge and align incentives along the supply chain.

In a 'traditional' system, where the upstream firm just pushes its intermediate downstream, it can only take changes in the local upstream conditions into account, since it has no information about demand, $\mathbb{E}\left[\theta_\tau|\mathcal{I}_S^M\right] = 0$. In a JIT scenario, by contrast, $\mathbb{E}\left[\theta_\tau|\mathcal{I}_S^M\right] = \rho^\tau\theta_1$, and the supplier is in a position to coordinate its adaptation decision with what happens downstream in the supply chain.

To build intuition for the role of information sharing, suppose that $\rho = 0$, which implies that no signal earlier than in period $t = \tau$ has any predictive power for the relevant demand shock θ_τ. Regardless of whether there was an *ex ante* investment in JIT technology or not, the supplier has a constant conditional expectation $\mathbb{E}[\theta_\tau|\mathcal{I}_S^M] = 0$. Only if $\rho > 0$ – which I assume throughout – is there any value to JIT: the supplier's additional information can be used to coordinate better with the downstream part of the supply chain, so that mis-coordination inventories can be cut and the transaction becomes more efficient.

For the downstream firm, the overall expected procurement costs incurred with a certain supply chain structure, $c^*(M)$, are given by the unconditional, i.e., period $t = 0$, expectation of its share in inventory holding costs plus the price of the intermediate (which itself is equal to inventory holding costs upstream and primary factor costs):

$$c(M)^* = w(\tau) + \gamma \left\{ \frac{1-\rho^\tau}{1-\rho} \underbrace{-\rho^{2(\tau-1)} \frac{\gamma}{1+\gamma} \left[1 - \left(\frac{1-\delta}{1+\gamma\delta} \right)^2 \right]}_{\text{only if JIT}} \right\} \sigma_\varepsilon^2 + \frac{\gamma}{1+\gamma} \left[1 + \gamma \left(\frac{1-\delta}{1+\gamma\delta} \right)^2 \right] \sigma_\eta^2. \quad (7)$$

The first term in the curly brackets, $\gamma(1-\rho^\tau)/(1-\rho)$, corresponds to the inventory holdings costs due to the inevitable order lag τ. The second term in the bracket, which is present only in a JIT supply chain, captures the inventory reduction from information exchange. It falls in τ, since the demand signal becomes increasingly obsolete as the intermediate spends more time in transit. Moreover, the JIT inventory reduction increases in δ, because the supplier's incentives are better aligned with the buyer's interests, i.e., when the supply chain externality is less severe. Finally, JIT is particularly valuable if inventories are costly (γ high).

The third term in $c(M)^*$ captures two inefficiencies that arise because the upstream supplier neither adapts perfectly to the local conditions, nor in a coordinated way with the rest of the supply chain. First, coordinating with downstream demand conditions creates productive inefficiencies upstream in the form of a dampened response to the η_S shock. The implied additional costs increase in σ_η^2. Secondly, partial adaptation to downstream demand conditions generates additional inventories, which have to be larger when mis-coordination is worse, i.e, when σ_η^2 is high or when δ is low.

On the *ex ante* stage, downstream firms decide on whether to produce in the first place and on whether they want to operate with 'traditional' supply chain management or under a JIT regime. Their profits take the general form

$$\pi(M) = (\alpha - 1)^{-1} B \left[c^*(M)\right]^{1-\alpha} \varphi^{\alpha-1} - \lambda_M f,$$

where $\lambda_{\neg JIT} = 1 < \lambda_{JIT}$.

Since $c^*(\neg JIT) > c^*(JIT)$ and $\lambda_{JIT} > 1$, the industry equilibrium features a standard selection pattern. Due to the fixed costs component f there is a mass of very unproductive downstream firms (low φ) who do not enter into production since they would not be efficient enough to make positive profits. The cut-off productivity with which a non-JIT buyer would break even is given by

$$\varphi_{\neg JIT} \equiv c(\neg JIT)^* B^{\frac{1}{1-\alpha}} (\alpha - 1)^{\frac{1}{\alpha-1}} f^{\frac{1}{\alpha-1}}.$$

Analogously, there is a cut-off defined by the productivity of firms that are indifferent between producing with and without JIT supply chain management:

$$\varphi_{JIT} \equiv c(JIT)^* B^{\frac{1}{1-\alpha}} (\alpha - 1)^{\frac{1}{\alpha-1}} (\lambda_{JIT} f)^{\frac{1}{\alpha-1}}.$$

Note that nothing so far prevents that $\varphi^{\neg JIT} > \varphi^{JIT}$, in which case all active producers do so under JIT. In what follows, I will posit that the fixed costs of JIT are large enough so that some firms cannot afford the modern paradigm. This assumption is fully consistent with the empirical fact documented above in Subsection 2.1 that participants in JIT supply chains are larger and more productive than their 'traditional' counterparts.

3.2 Endogenous Location Choice and Vertical Integration

Additional assumptions

The buyer is now free to pick an optimal location τ on the *ex ante* stage $t = 0$. For simplicity, I abstract from fixed costs of upstream market access and there are no additional trade costs. Although both types of frictions can be introduced without much effort, doing so creates no relevant additional insights regarding the interaction between supply chain management and location choice.

Furthermore, the two companies are now allowed to merge. Under non-integration/ outsourcing (indexed NI), where the upstream and downstream parties are fully independent, the manager of the supplier makes decision d_S to maximize their local profits – just as described in the baseline model above. By contrast, under vertical integration (indexed VI), where the two factories are owned by a single, potentially multinational entity, the decision lies in the hands of a "supply chain supervisor". This person naturally acts in the interest of the overall segment of the supply chain, i.e, the whole company. Similar to Antràs and Helpman (2004), employing this supply chain manager constitutes a fixed cost $\lambda_{VI} f > 1$.[32]

The second difference between arm's length trading and intrafirm procurement is the contractual set-up. Since the overall efficiency of the input transaction does not depend on how costs and rents are distributed within the integrated firm, I will not make any assumptions about the employment contracts that govern the flow of funds.

Importantly, the supply chain supervisor in a vertically integrated setting uses the same information when making the adaptation decision d_S at stage $t = 1$ as do the individual managers of the separate firms in an outsourcing relationship. To capture this point I assume that the information sets are

$$\mathcal{I}_{VI}^{t=1,\neg JIT} = \{\eta_S\}, \;\; \mathcal{I}_{VI}^{t=\tau,\neg JIT} = \{\theta_\tau\},$$

when the supply relationship is managed in a 'traditional' way, while they are

$$\mathcal{I}_{VI}^{t=1,JIT} = \{\eta_S, \theta_1\}, \;\; \mathcal{I}_{VI}^{t=\tau,JIT} = \{\theta_\tau\}$$

for JIT supply chains.

This stark assumption – that information exchange works equally well within and across companies – ensures that JIT and vertical integration are two entirely different organizational margins, where the former affects only the flow of information and the latter only changes the incentive or authority structure. This assumption is also much stronger

[32]These fixed costs can be interpreted more broadly as "bureaucracy costs" in the spirit of TCE type models (Tadelis and Williamson, 2012). Outsourcing certainly involves overhead expenditures, too, but these are typically smaller than under vertical integration. Indeed, the very act of outsourcing is often described as 'turning fixed into variable costs'. In this model, $\lambda_{VI} > 1$ can thus be interpreted as the *difference* between the fixed costs of vertical integration and those of outsourcing.

than required to arrive at the main insights in this model. As long as vertical integration does not imply perfect information, the qualitative implications are unchanged. I rely on the more stylized assumption to carve out the workings of the mechanisms as clearly as possible. Moreover, this setting may not be too far removed from many real world contexts, where managerial overload makes it difficult for the supply chain supervisor to ensure all information is relayed to all suppliers, especially in an international and complex production network.

Solution

I follow the same backward induction strategy as for the baseline model. There are now four broad branches in the game tree, spanned by the downstream firm's $t = 0$ decisions to vertically integrate with the supplier and to engage in JIT supply chain management. In addition, each branch has several leaves due to the supplier location decision.

The optimal price the downstream firm charges its customers is

$$p^*(\tau, Int, M) = \frac{\alpha}{\alpha - 1} \frac{c(\tau^*, Int^*, M^*)}{\varphi}, \tag{8}$$

where the only difference to expression (5) is that the procurement costs are indexed by the organizational mode $Int = VI, NI$ and the supplier location τ.

Focusing on the vertical integration branch of the game, the supply chain supervisor takes all decisions with the goal of minimizing overall procurement costs, i.e., they solve

$$\min_{d_S} \; w(\tau) + (\eta_S - d_S)^2 + \gamma \, \mathbb{E}\left[(\theta_\tau - d_S)^2 | \mathcal{I}_{VI}^{t=1,M} \right],$$

and the optimal decision is given by

$$d_S^*(\tau, .) = \frac{1}{1+\gamma} \eta_S + \frac{\gamma}{1+\gamma} \mathbb{E}\left[\theta_\tau | \mathcal{I}_{VI}^{t=1,M} \right]. \tag{9}$$

The analogous expression under non-integration, (6), differs from this choice in an important way. The adaptation decision at the supplier plant is now less biased towards the local shock η_S, since the supply chain supervisor puts more weight on coordinated adaptation. Intuitively, vertical integration provides the right incentives for the supplier plant to contribute to the success of the transaction and the supply chain externality is fully internalized.

Overall procurement costs under vertical integration amount to

$$c(\tau, VI, M)^* = w(\tau) + \gamma \left\{ \frac{1-\rho^\tau}{1-\rho} \underbrace{-\rho^{2(\tau-1)} \frac{\gamma}{1+\gamma}}_{\text{only if JIT}} \right\} \sigma_\varepsilon^2 + \frac{\gamma}{1+\gamma} \sigma_\eta^2. \tag{10}$$

There are two crucial differences compared to outsourcing (cf. equation (7)). The first is that the gain from JIT is larger, since the supplier plant makes efficient use of the demand information: it puts inventory minimizing weight on coordinated adaptation, which can be seen in the larger coefficient on $\rho^{2(\tau-1)}$. From a conceptual point of view, there is a *complementarity* in the two organizational decisions, since introducing JIT leads to larger cost savings when the two plants are integrated, and vice versa.

The second difference is that the supplier resolves the trade-off between local and coordinated adaptation more on the side of the latter. As a consequence and even though the supply chain manager puts less weight on local adaptation, thereby compromising productive efficiency upstream, inventories are lower and procurement costs are reduced (this gain is reflected in the smaller coefficient on σ_η^2).

On the *ex ante* stage $t = 0$, two additional choices have to be made now compared to the baseline model: where to match with a supplier and whether it should be a stand-alone firm or a (foreign) affiliate. Formally, the buyer's problem is

$$\max_{\substack{\tau, \\ Int \in \{NI, VI\}, \\ M \in \{\neg JIT, JIT\}}} \pi(\tau, Int, M) = (\alpha - 1)^{-1} B \, c(\tau, Int, M)^{1-\alpha} \varphi^{\alpha-1} - \lambda_{Int} \lambda_M f, \tag{11}$$

where $\lambda_{NI} = 1$.

Solving this program with respect to τ leads to the first proposition, which provides the conceptual groundwork for the stylized fact presented in Subsection 2.2: French firms, when they operate a JIT supply chain, are more likely to have trading relationships with closer partner countries, and trade relatively more with them.[33]

Proposition 1 *Under mild conditions on $w(\tau)$, JIT supply chains are more spatially concentrated than 'traditional' ones along both the extensive and intensive margins of trade.*

Proof. See Online Appendix Section B.1. ■

Intuitively, when a 'traditional' downstream buyer makes its supplier location choice, it trades off inventory costs due to the order lag against primary factor costs. A remote

[33] While locations are discrete in this model to make for a simple interpretation of stages in the game, I nevertheless treat τ as continuous to abstract from mathematical complications and thus allow for a clear exposition of the main trade-offs involved.

supplier has an additional disadvantage for JIT firms, however: the coordination advantage created by sharing an early signal of demand conditions is smaller, because lengthy shipping times reduce the forecasting value of θ_1. As a result, JIT firms are willing to source from more expensive localities to make better use of their investment in JIT supply chain management (*extensive margin*).

Defining the intensive margin of trade appropriately in the model, I can show that trade volumes are skewed towards partners nearby, too (*intensive margin*). To build intuition, procurement costs are lower due to the complementarity between JIT and proximity, which implies that a JIT firm charges its downstream consumers lower final output prices, attracts more demand, and hence orders a larger quantity from its supplier.[34]

Finally, firms sort into different ownership and supply chain management configurations via cut-off rules in productivity, trading off fixed against variable costs:

$$\varphi_{Int,M} \equiv c^*[(\tau^*(Int, M), Int, M](\alpha - 1)^{\frac{1}{\alpha-1}} B^{\frac{1}{1-\alpha}} (\lambda_{Int}\lambda_M f)^{\frac{1}{\alpha-1}}. \tag{12}$$

While several different sorting patterns into the four tuples of ownership and management are possible, there are only two relevant cases I have to analyze. Returning to the sample of outsourced and integrated supply relationships used in Subsection 2.3, any such combination of a downstream firm and an upstream industry can be treated as a supply relationship with a (Int, M) configuration as in this conceptual model. In 2006, out of 214 NAF downstream industries with both JIT and non-JIT firms, 211 exhibit full heterogeneity: all four possible configurations of ownership and management occur simultaneously.[35] I can therefore restrict my analysis to the parameter space that yields such equilibrium outcomes at the industry level.

Proposition 2 *JIT supply chains are more vertically integrated than their 'traditional' counterparts.*

Proof. See Online Appendix Section B.3. ■

[34]In Online Appendix B.1 I show that there is also a price effect that shapes the intensive margin. JIT reduces mis-coordination inventories, which lowers the price of the intermediate, too. Under realistic assumptions about the downstream demand elasticity, however, the quantity effect dominates this price effect.

[35]In the three remaining industries there are some JIT firms that report no vertical integration. Two of them are recycling industries, while the remaining one is production of "other non-metallic mineral products" – overall they account for 47 firms out of a total of 3,612. Another point to note is that in 61 industries no JIT production is reported. These do not, however, contribute to my estimates due to downstream industry fixed effects. The same is true for the 20 industries that feature only JIT firms. I treat all the aforementioned industries as an insignificant exception to the rule and refrain from adding a conditionality to the propositions that follow.

The intuition for this result, which provides a potential rationale for the stylized fact presented in Section 2.3, rests on the complementarity between JIT and vertical integration.[36] While the increase in fixed costs of in-house production are proportionally the same under JIT and 'traditional' supply chain management, the additional benefit is greater under JIT due to the complementarity in inventory holding. Given the well behaved Pareto distribution of core productivities φ, vertical integration is more prevalent in JIT supply chains.[37]

4 Testing Further Predictions

In this section I derive additional predictions based on comparative statics with respect to the key parameters in the model and confront them with the data. I focus on inventory holding costs, demand persistence, and scope for inventory pushing, since they reflect key aspects in the theoretical framework presented. All three parameters are assumed to vary primarily at the industry level, since assignment to industries is done on the basis of common output characteristics and it seems plausible that these three parameters are related to features of the production technology employed. I study how these characteristics re-enforce or weaken the positive correlations between JIT supply chain management, spatial concentration, and vertical integration.

The exercise in this section serves three purposes. First, successfully testing these further predictions lends additional credibility to the main ideas captured by my theoretical framework. Secondly, I uncover novel features of the environment that shape (international) firm boundaries and location choices in supply chains via their effects on management choice JIT vs. non-JIT. Thirdly, by means of these exercises I provide direct input for the discussion of policy implications in Section 5.

4.1 Testable Implications

Proposition 3 *Ceteris paribus, in industries with*

1. *high inventory carrying costs ($\gamma \uparrow$)*

2. *high demand persistence ($\rho \uparrow$)*

[36] One may be tempted to ascribe a role to the fixed costs involved in the different set-ups. As Online Appendix B.3 shows, however, they are only relevant for the taxonomy of different sorting patterns. Proposition 2 holds irrespective of the values of λ_{JIT} and λ_{VI}.

[37] Since there is no free entry, it can be shown that the finding is overturned if the frequency distribution of productivities is highly irregular and features significant mass in certain intervals. While a theoretical possibility, the Pareto is a good approximation to the right tail of the productivity distribution – arguably the relevant part for my setting – in most industries and most countries (see, for the U.S. and France, respectively, Axtell, 2001; Eaton et al., 2011).

3. *a lot of scope for inventory pushing ($\delta \uparrow$)*

JIT supply chains are

- *particularly concentrated spatially, and*
- *more vertically integrated in cases 1 + 2, but less so in case 3.*

Proof. See section B.4 in the Online Appendix. ■

First, JIT supply chain management, which reduces the level of inventory holding, has a high return when stocks are costly. Reducing its return by choosing a remote supplier or providing weak incentives to coordinate by outsourcing are therefore particularly bad ideas. Consequently, in industries where γ is high, JIT firms are predicted to choose even closer suppliers and to rely more intensively on in-house production.

Secondly, in a downstream industry with very low demand persistence, any real-time signal sent under JIT has little value for coordination to begin with, so that spending additional resources on vertical integration to complement this system is unattractive – the complementarity will be weak. The impact of demand persistence on spatial patterns in JIT supply chains is non-monotonic. On the one hand, when ρ is high, any downstream signal is particularly useful for prediction, so that the return from complementing JIT with spatially agglomerated production is high. On the other hand, the environment is inherently less uncertain and coordination is easier. The return to JIT – and to reinforcing it by choosing proximate trade partners – is therefore smaller. While the latter effect may be a consideration for adjacent trade partners, even with short order lags, it has little empirical relevance (see Online Appendix B.4).[38]

The scope for inventory pushing has different effects on the two complementarities. If contracts can induce the upstream supplier to coordinate well, they are a substitute for vertical integration. In such an environment, the correlation between JIT and in-house production is weaker. By contrast, the same incentivizing power of inventory pushing strengthens the positive JIT – proximity correlation for trade between unrelated parties: if the supplier puts substantial weight on coordinated adaptation, any demand signal is used efficiently, a JIT system is particularly beneficial, and it pays run it with a supplier nearby.[39]

[38]For $\tau \to 1$, ρ must be larger than ≈ 0.6 for its effect to switch sign, as shown in Online Appendix B.4. Slightly anticipating the empirical analysis below, my industry level proxy for demand persistence is equal to .53 at the 75th percentile. Consequently, it is not surprising that an unreported test for a non-monotonicity in the effect of demand persistence on the correlation between JIT and proximity fails.

[39]Intrafirm trade is not affected by differences in δ. Since arm's length trade accounts for about two thirds of French international trade, however, there is hope of empirical support even if the two types of trade are not distinguishable in my customs data

4.2 Empirical Strategy and Results

To proxy for the inventory cost parameter γ, I rely on the assumption that the purchase value of an intermediate is a key determinant of how costly it is to hold stocks. While many factors may be relevant, there is little doubt that it is significantly more expensive to keep *valuable* produce on the shelf. The risk of obsolescence, the opportunity cost of tied up working capital, and the substantial expenditure on security all play important roles.

For regressions where the unit of observation is a particular trade flow at the 8 digit CN level, I measure a good's value as the median unit value within every 8 digit CN product category based on French customs data from 1996, i.e., pre-sample. For the vertical integration regressions, where variation is at the upstream-downstream industry level, I rely on direct requirements from the 2002 U.S. benchmark IO table. Since these IO coefficients capture the relative value of different upstream inputs, they are useful proxies for γ. Summary statistics for both variables can be found in Online Appendix Table C.3 and all details of how I construct these and all other variables are provided in Online Appendix A.1.

Following the model's assumptions closely, I measure industry level demand persistence ρ_i by the AR(1) coefficient estimated on annual firm sales. The summary statistics in Panel B of Online Appendix Table C.3 show that a unit shock to sales has a half-life of about $-ln(2)/ln(0.40) \approx 9$ months for the average 4 digit NAF industry and the interquartile range is about 9 months, too. These numbers are substantial and there is considerable variation across industries.

To arrive at a proxy for "inventory pushing", i.e. the capacity for downstream firms to "force" their upstream suppliers to share in the costs of inventory holding, I divide average inventories (normalized by sales) in the upstream industry by the same variable for the downstream industry.[40] The signal in this variable captures the burden borne by the upstream firms relative to the burden borne by the downstream ones. As Panel B of Online Appendix Table C.3 illustrates, pairwise relative inventory holdings tend to be roughly balanced between the upstream and the downstream sector for the median input supply relationship, with a tendency towards upstream inventory holding on average. For distance related regressions, where I have no information about inventory holding abroad, I create a weighted average measure for every downstream industry.

I interact the main regressors from the baseline specifications related to location, (1),

[40] Information about contractual provisions is very hard to come by and typically only available in industry studies. At the same time, market power – however measured – is a poor proxy, since it affects prices, depends on and affects other aspects of contracting, and influences integration decisions directly. The most appealing alternative is therefore to use observed inventories.

and vertical integration, (2), with above-median indicators based on the distributions of the proxies just described. Since I do not have information about foreign trade partners, I estimate the location related regressions on a sample based on imports only.[41]

Figure 3 illustrates the intensive margin results for the first part of Proposition 3 relating to the spatial structure of JIT supply chains in a series of maps.[42] The left hand sub-figure in each panel shows the coefficients from the baseline specification (1) when the respective characteristic is above the median of the relevant distribution, while on the right hand, the characteristic is below.

The first and second prediction of Proposition 3 is supported strongly by the data, see panels a) and b): while the maps for high characteristics on the left show substantial spatial concentration, the ones on the right show little or no differences across countries. By contrast, there is little heterogeneity when it comes to inventory pushing. One explanation for this null finding is measurement error: since no information about upstream inventory holding is available to me, my proxy for δ may be noisy.

Next, I examine the industry patterns of vertical integration and illustrate the results in Figure 4, where the dark blue bars depict the coefficient estimates on JIT from the baseline regression (2) when the characteristic depicted below the x-axis is high (above median in the relevant distribution), while the light green ones relate to the characteristic being low. All details for the underlying regressions are reported in Online Appendix Table C.9 and tests for significance of the differences are shown in Online Appendix Table C.10.

All three predictions regarding vertical integration are strongly supported by the data both for overall and multinational activity. First, JIT firms produce intermediates 'in-house' whenever stocking them is particularly costly, either because of the large quantity or high unit price transacted.[43] Secondly, when the downstream industry's demand is more persistent, JIT is more likely to be combined with vertical integration. Finally, for both overall and foreign vertical integration, pushing inventories onto upstream suppliers proves to be an important substitute to direct control via ownership in the data.

I present two sets of important robustness checks regarding industry heterogeneity in Online Appendix A.4. First, several alternative proxies for inventory holding costs generate very similar insights for both the spatial patterns and for vertical integration. Perhaps most reassuringly, industries that trade many different products show stronger complementarities between JIT and proximity or vertical integration. This pattern is consistent

[41] In column (8) of Online Appendix Table C.12, I re-estimate the baseline specification (1) on a sample of import trade flows and the coefficients are very similar to the overall sample.

[42] The underlying estimates are reported in Online Appendix Table C.7 and tests for significant differences between high and low charactistics are reported in Online Appendix Table C.8.

[43] One may be concerned that the value transacted in a relationship drives ownership decisions as in Legros and Newman (2013) and Alfaro et al. (2016). It is not obvious, however, how their mechanism causes differences in organizational structure between JIT supply chains and 'traditional' ones.

with the idea that multi-product firms, which offer a plethora of varieties and source many different intermediates to manufacture them, have to carry stocks individually for each intermediate and variety, which is costly. Such complex supply chains therefore benefit more from a spatially concentrated and vertically integrated JIT regime.

In the second set of robustness checks, I rule out alternative mechanisms that could explain the heterogeneity in vertical integration, for example related to TCE or PRT ideas regarding the boundary of the firm. The conclusion from this exercise is that even in the most demanding setting, the main insights presented in Figure 4 are robust, especially for multinational activity.

5 Policy Implications for Brexit and COVID-19

In this section I employ the conceptual framework and the empirical findings to discuss the long-run consequences of Brexit and COVID-19 for the structure of global supply chains. I focus on both the prevalence of JIT manufacturing and the organizational margins examined in this paper, location and ownership choices. Treating each crisis in turn, I first outline the way I conceptualize the fundamental changes to firms' business environments that have occurred and then discuss both how supply chains are predicted to reorganize and which industries/industry pairs would be most heavily affected.

Brexit

Especially during the discussions and debates in the run-up to Brexit, many manufacturers emphasized their worries about non-tariff barriers in the form of additional documentation required to meet diverging regulations in the UK and Europe as well as about associated checks being intensified at the border. Such changes would introduce friction into their highly coordinated JIT supply chains and cause substantial productivity losses. In my framework, one can conceptualize such delays as an increase in shipping time for any given location τ, so that distance becomes $X * \tau$ with $X > 1$.

Unsurprisingly, Brexit increases inventory costs in any organizational set-up, but, consistent with anecdotal evidence, JIT firms are doubly hit: in addition to holding higher base inventories for any trade relationship, their advantage of "make-to-order" production decreases. As a consequence, the share of firms who manage their supply relationship in a JIT fashion declines.

While all firms skew their supply chains more towards local trade partners as a result of longer waiting times at the border – i.e., due to higher trade costs – the reaction in JIT networks will be weaker: some relationships reduce their JIT intensity and thus lose some of their distance sensitivity, while those that retain their JITness focus less on proximate partners since the inventory cost savings of doing so are reduced. In sum, while JIT supply chains are particularly affected by Brexit, their reorganization alleviates the tendency for UK trade with remote partner countries to fall. Of course, this comes at the price of lower productive efficiency and thus higher prices for UK consumers.

The UK is one of the leading host and origin countries for FDI and multinational production in the world. My conceptual framework suggests one reason for why this position may be under threat in manufacturing. As the JIT intensity of UK and European production falls due to frictions at the border, the coordination motive for vertical integration highlighted in this paper ceases to exist for many companies. Some firms are expected to sell their stakes in foreign subsidiaries and hence FDI stocks are reduced everywhere in Europe.

The effects on international trade and on multinational production will be vastly heterogeneous across industries and industry pairs according to the additional empirical findings in Section 4. High inventory carrying costs in "other transport equipment"(ISIC Rev. 3 code 35), "motor vehicles, trailers and semi-trailers" (34), or "office machinery and computers" (30) will render Brexit delays particularly problematic for JIT and lead to a much attenuated spatial concentration effect as outlined above (see Online Appendix Table C.11). At the same time, trade with remote countries will fall more substantially in "wearing apparel; dressing and dyeing of fur" (18) or "leather products" (19), due to the loss of JIT intensity. By extension, multinational activity is expected to fall strongly in the former, and perhaps very little in the latter industries. Similar arguments can be made along the other two margins highlighted by the model; demand persistence and inventory pushing.

COVID-19

The emergence of the SARS-CoV-2 virus can be thought of as a shock to (perceived) uncertainty, either because COVID-19 might become a normal, and perhaps seasonal illness with recurring outbreaks (as of the time of writing), or because the risk of pandemics has become more salient after having been underestimated. In my conceptual framework, depending on the position of an industry in the value chain, the increase in uncertainty takes the form of a larger variance of the upstream shock η_S or of the downstream shock ε_t (but typically both to different degrees).[44]

The main insight afforded by the theoretical model is that all supply chains, irre-

[44] The COVID-19 crisis had severe short run consequences due to a complete lock-down of many economic activities in virtually all countries. While it is important to understand how JIT supply chains contributed to the transmission and amplification of these shocks, the conceptual framework in this paper is not well suited to address such questions.

spective of their organizational set-up, experience an increase in inventory holding and therefore in procurement costs. Importantly, however, this negative shock is less severe for supply chains with superior coordination capabilities, i.e., for all production networks inside (international) business groups and even more so for those operating a JIT system in addition. Consequently, both multinational production and JIT supply chains are predicted to become *more* prevalent.

These effects have direct implications for international trade, which is expected to see an increase in spatial concentration. This tendency towards regionalization would, however, be entirely unrelated to the recent wave of renewed protectionism and it is important to make a clear distinction between these two forces pushing a reorganization of GVCs. Moreover, spatial concentration may not take the form of "re-shoring", i.e., shifting previously off-shored production stages from countries like China back to Europe or North America. Local JIT supply networks in China and South-East Asia are also expected to deal very efficiently with increased uncertainty. It is therefore more likely that international commerce will move back towards trade in final goods or at least towards more complex intermediate parts and components closer to the end-product.

As in the case of Brexit, these patterns are, however, expected to be stronger in some, and weaker in other industries in line with the heterogeneities described in Section 4. Moreover, the conceptual framework implies similar reactions to any other increase in uncertainty, be it due to a new virus, climate change, or political instability.

6 Conclusion

JIT supply chains are prevalent and constitute an important margin in the organization of economic activity. Much of their significance is driven by the fact that it is the larger and more productive companies that rely on them. Compared to their more 'traditional' counterparts, JIT supply networks are also spatially more concentrated and more vertically integrated. To give a structural interpretation to these patterns in the data, this paper proposes a stylized conceptual framework. It illustrates that additional downstream information that is disseminated throughout the supply network in a JIT regime is particularly valuable for coordination if all parties have strong incentives to react to it in the right way, i.e., if they belong to the same firm, and when order lags are short due to proximity. As a consequence, all three organizational margins complement each other. To lend further credibility to the framework, I show that additional predictions regarding how these complementarities vary in strength with features of the (market) environment receive significant empirical support. Finally, the model and my empirical findings provide important inputs for policy. For example, the increase in uncertainty following the

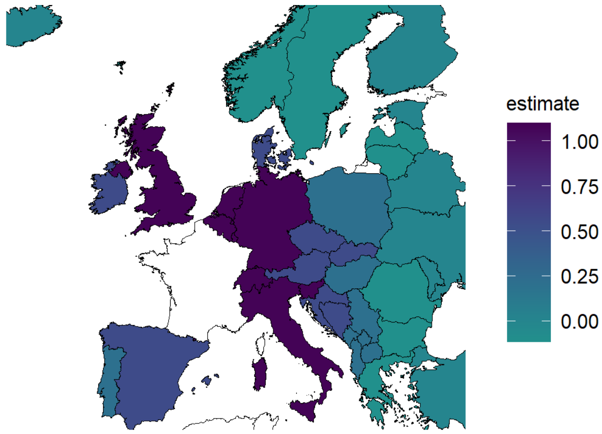
COVID-19 crisis is likely to make regional JIT supply chains – controlled by large multinationals – relatively more common as they have superior abilities for coordinated, and therefore efficient adaptation.

Not least by showing the prevalence and economic importance of JIT supply chains, this paper encourages several lines of further research at the intersection of supply chain management and international trade in general. First, how will the ICT revolution change the patterns of global production? The conceptual mechanism I propose may contribute to understanding the impact of modern digital technologies – like high performance 5G networks or the Internet of Things – which transform how information is shared among different tasks in value chains. Not only are JIT supply chains likely to benefit from such innovations and will be more widely adopted; this paper suggests that, perhaps contrary to common perception, global supply networks may become *more* concentrated in terms of space and ownership due to the complementarities highlighted (for a similar point, see Venables, 2001). Secondly, how are shocks transmitted across countries and industries? Is there amplification through supply networks? JIT supply chain management may play a crucial role for these and related questions. Altomonte et al. (2013), for example, document that the Great Trade Collapse was much more rapid for intrafirm trade than for trade between unrelated parties. This finding is fully consistent with the view that highly coordinated supply chains with fluid information sharing, low inventories, and common ownership imply agile response patterns. Testing and elaborating on this and similar ideas related to JIT is a promising way forward to understand resilience and shock propagation in a globalized world economy – especially in times of increased uncertainty both in the physical realm, owing to climate change and new diseases, and in the policy realm owing to an increasingly divided society and populism.

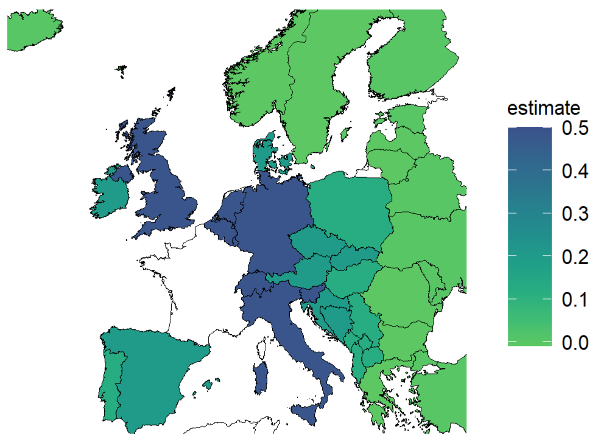
Frank Pisch is affiliated with the University of St. Gallen, SIAW, and CEP.

Figure 1: Maps Of Estimates

(a) Extensive Margin



(b) Intensive Margin



Figures depict point estimates from columns (3) and (6) of Online Appendix Table C.5, which are based on specification (1). The Republic of Kosovo was not officially recognized before 2008 and is treated as part of the Republic of Serbia in this paper.

Figure 2: Timeline

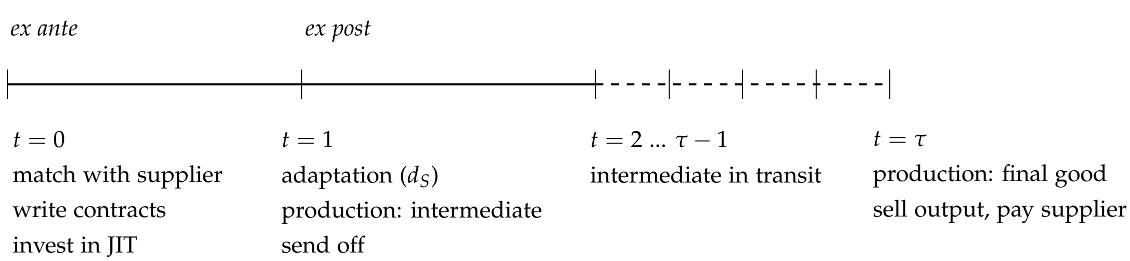
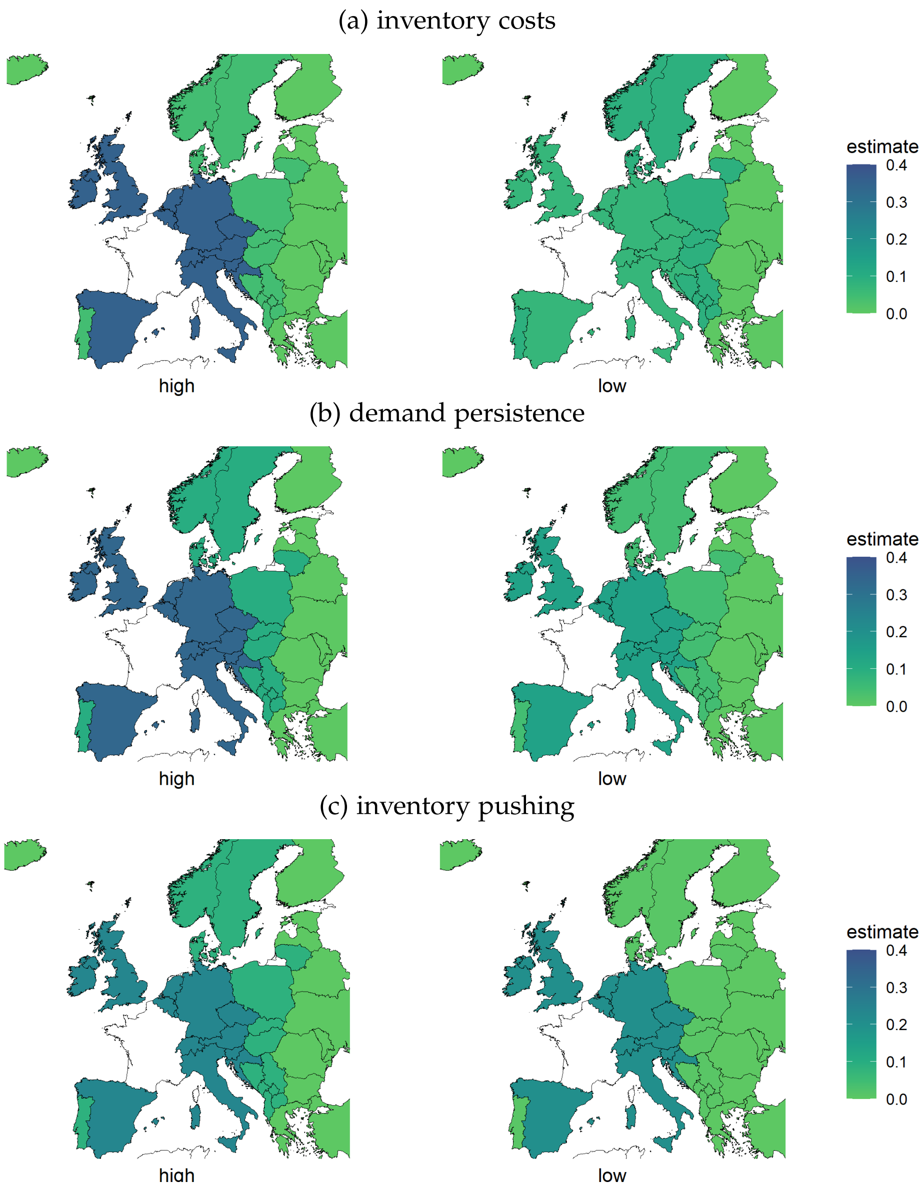


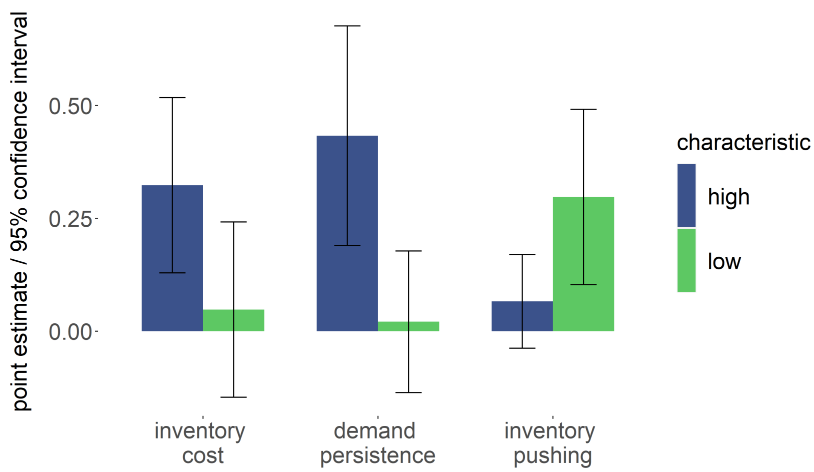
Figure 3: Heterogeneity – Intensive Margin



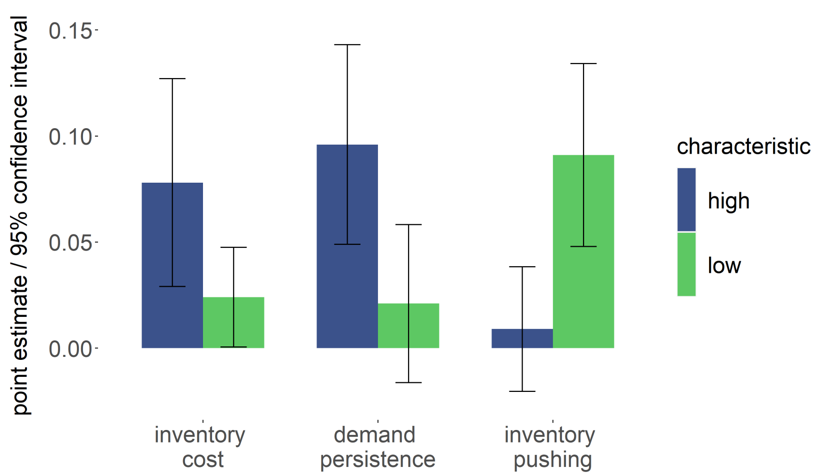
Figures depict estimates from columns (1)-(3) of Online Appendix Table C.7. Coefficients of “above median” on the left of each panel, “below median” on the right. The Republic of Kosovo was not officially recognized before 2008 and is treated as part of the Republic of Serbia in this paper.

Figure 4: Heterogeneity (Incl. 95% Confidence Intervals)

(a) all integration



(b) foreign integration



Figures depict point estimates as bars and standard errors as handle bars from columns (1)-(3) in Online Appendix Table C.9. "above median" coefficients in blue, "below median" in green.

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Tel: +44 (0)20 7955 7673 Email info@cep.lse.ac.uk
Website: http://cep.lse.ac.uk Twitter: @CEP_LSE