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Abstract

This paper examines the structure of international Just-in-Time (JIT) supply chains. Using information about JIT supply chain management 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 JIT supply chains: They are more concentrated in space (1) and more vertically integrated both domestically and internationally (2), than their 'traditional' counterparts. I rationalize these patterns in a framework of sequential production where failure to coordinate adaptation decisions in the presence of upstream and demand shocks leads to inventory holding. In JIT supply chains, information about downstream demand conditions is shared throughout the supply chain, 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; and when they are part of the same company, so that incentives for adaptation are aligned. Guided by further predictions of the model, I present empirical evidence that these organizational complementarities depend on inventory holding costs, demand persistence, and the ability to push inventories upstream via contractual penalties. Finally, I discuss long term implications of Brexit and COVID-19 for the structure of international supply chains based on my findings.

Keywords

Just-in-time, global value chains, supply chain management, multinational firms, vertical integration

JEL Classification

F10, F14, F23, D23, L23

1 Introduction

Today’s international manufacturing supply chains provide the underpinning for affordable consumption of products with a wide variety of choice. They have also contributed to lifting millions out of poverty through participation in Global Value Chains (GVCs). Recently, however, these complex supply networks have come under increased scrutiny by the general public and politics. More salient political risk often connected to populism (Brexit, the Sino-American Trade War) and higher uncertainty due to climate change or pandemic events are raising questions that may threaten this complex and global business model: What role do supply networks play in the transmission and amplification of local shocks? Are current supply chains sufficiently resilient and do they feature enough redundancies to let us cope with the increased frequency and severity of shocks? How should we optimally adjust their structure in the long-run if we believe it requires improvement?

The answers we give depend crucially on our understanding of the highly coordinated and efficient, “just-in-time” (JIT) production networks that characterize much of modern manufacturing. More ‘traditional’ supply chains operate “make-to-stock”, where intermediates and final goods are produced and put on shelves in warehouses for customers to collect. In modern management systems – developed in Japan in the 1970s and early 1980s – these costly buffer stocks are eradicated through extreme 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.¹

Despite a sizeable body of business research on this topic, however, surprisingly little is known about the prevalence and economic importance of these JIT supply chains in the aggregate. Moreover, only case study based evidence and limited conceptual guidance is available to gauge how JIT supply chain management interacts with other margins of the organizational structure of supply chains.²

This paper makes progress on filling these important gaps. It exploits a unique data set with information about JIT supply chain participation and documents – for the first time – both the aggregate significance of JIT supply chains and how their geographic and ownership structure differs from more ‘traditional’ supply networks. To rationalize

¹In 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).

²I discuss the limited and often indirect evidence presented in previous work below.

the empirical findings it develops a novel theoretical framework based on information transmission and coordinated adaptation. Additional predictions by this model enjoy substantial empirical support and provide useful inputs for the policy debates about post-Brexit and post-COVID-19 supply chains.

To make the initial contribution of this paper, I make use of high quality survey information on JIT supply chain participation – whether or not a firm is part of a JIT supply chain or not – for more than 3,000 representative (> 20 employees) French companies in all manufacturing industries (1997-2006). I show that, perhaps surprisingly, JIT supply chain management is widespread across all sectors of manufacturing, rather than being an exclusive preoccupation for car and textile producers. Moreover, participant firms in JIT supply chains account for up to two thirds of aggregate employment and trade in France and therefore play a significant economic role.

Adding balance sheet, international trade, and worldwide ownership information, the database furthermore allows me to establish two novel stylized facts about the organizational structure of JIT supply chains. While several of their characteristics merit comprehensive research efforts, I focus on location choice and ownership/multinational production patterns in this paper. They are two of the major themes in the public discussion and academic debate: *where* stages of production are located and *who* owns the assets and goods involved has important implications for productive efficiency, shock transmission, and cross-country inequality.

First, I study location decisions by comparing the trade partner countries for international trade flows in JIT supply chains to those in ‘traditional’ ones and find that JIT supply chains are significantly more regional than their non-JIT counterparts. This pattern holds both for distance and time-to-ship as measures of proximity, at the extensive and intensive country margins, and when I control for a large number of alternative unrelated explanations. Choosing close suppliers/customers and adopting JIT supply chain management are *complementary* decisions.

Turning to ownership patterns, data on industrial activities of firms and their affiliates in my sample can be used to understand which stages of a value chain are retained within the boundaries of the (multinational) firm. I show that 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 abroad.³ This finding is not driven by the typical industry or firm level characteristics that have been shown to affect the boundaries of firms. It is also present in intra-firm trade data at the firm level – actual

³Consistent with this pattern, JIT was invented and has been very successfully employed in Japan where business groups (keiretsu) have a dominant position.

transactions, and not only assets, are more vertically integrated, too – and for intermediate inputs that create little lock-in or IPR and technology diffusion concerns for their trading partners.

The second contribution of this paper is to 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 that is shipped to a downstream buyer firm, which in turn uses it to produce its output. In an uncertain world, both companies are constantly 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. In a sequential supply setting like this, it is paramount for the two firms to make adaptation decisions in a *coordinated way*; otherwise costly inventories are needed to ensure smooth operation.

This setting naturally draws attention to three distinct frictions which inhibit coordinated adaptation and lean production, both in the stylized model and reality. First, if the supply chain operates under a ‘traditional’ regime, where no downstream information is shared with the upstream stages (“make-to-stock”), the supplier’s ability to coordinate its adaptation decisions with the buyer firm is limited due to *imperfect information*. Secondly, even if it has knowledge of demand conditions, the supplier may not have the right incentives to coordinate with the buyer when it is part of an independent company and therefore maximizes its own profits. Put differently, upstream stages may impose a *supply chain externality* on downstream ones, since the latter have to hold additional inventories not taken into account by suppliers.⁴ Thirdly, if the supplier is located far away from the buyer to take advantage of low primary factor costs and if the intermediate therefore spends substantial time in transit, even the best downstream demand signal is at risk of *obsolescence* and mis-coordination is more likely.

When the two plants pay a fixed overhead cost for a supply chain manager and adopt JIT supply chain management, real-time information about downstream demand conditions is shared between the buyer and the supplier (“make-to-order”), coordination is improved, and variable costs fall due to lower inventory holding. The key insight from this stylized framework is that the strategic decision to adopt JIT is *complementary* with both vertical integration – which ensures that the supplier uses the signal in the interest of the whole chain – and with spatial concentration – which ensures that upstream

⁴The boundary of the firm in my model is therefore determined by Transaction Cost Economics (TCE) considerations. In the taxonomy of Gibbons (2005), my mechanism features characteristics of the “adaptation” strand of the literature on vertical integration (e.g., Simon, 1951; Williamson, 1975; Forbes and Lederman, 2009; Tadelis and Williamson, 2012) I discuss other related work in Section 3.

adaptation decisions are still in line with ever changing demand.

Guided by further predictions from the model I next use my comprehensive database to investigate industry characteristics that modulate the relationships between JIT supply chain management, proximity, and vertical integration. First, the complementarities are significantly stronger when inventory costs are high, which is important evidence in favor of the mechanisms described. Secondly, the patterns are stronger when demand shocks are very persistent: since any downstream signal is particularly useful for prediction and hence valuable, the return from complementing JIT with in-house and 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 on 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 inform the political debates hinted at above, I outline the implications of the findings in this paper for how supply chains will be reorganized following two recent, prominent, and grave shocks to firms' environments, Brexit and Covid-19. Modelling Brexit as an increase of waiting times at the border, I find that while European manufacturing will become less JIT intensive and hence lose efficiency, the effect on international trade patterns will depend on the balance of two forces. Frictions at the border bias transactions towards closer partners, but a lower JIT intensity will make overall trade less sensitive to distance. Unambiguously, multinational companies will reduce their cross border activities.

Increased (perceived) uncertainty as a consequence of the COVID-19 crisis is predicted to make JIT production *more* attractive, due to its superior coordination abilities: All supply chains will become less efficient and carry higher inventories, 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 even more concentrated and dominated by a few large and powerful multinational companies.⁵

The extent of all the adjustments outlined so far will depend, however, on the specific industries involved in a supply chain, and my empirical findings above suggest three

⁵It is worth highlighting that these predictions would carry over to increased uncertainty due to climate change or worsening political instability.

useful margins – inventory costs, demand persistence, and inventory pushing – that are expected to have predictive power.

While this paper provides the first comprehensive analysis of how JIT supply chain management shapes the organization of international production, I can build upon earlier work that took first steps in this direction. Regarding the spatial impact, there are a number of industry studies on the empirical side (see, for example, [Evans and Harrigan \(2005\)](#) for textiles in the US, [McCann and Fingleton \(1996\)](#) for electronics in Scotland, and [Holl et al. \(2010\)](#) for automotive and electronics in Spain), and a few modelling approaches on the theoretical side ([McCann and Fingleton, 1996](#); [Venables, 2001](#); [Harrigan and Venables, 2006](#)). In agreement with my findings, all these studies consistently argue for a positive correlation between regionalization and JIT. This paper makes progress by showing that this pattern is present across the whole of manufacturing and therefore more important for international commerce than implied by the body of extant work. Moreover, I also show that the inventory holding cost mechanism, which provides the conceptual basis in this literature, has greater implications for the organization of supply chains than appreciated so far (e.g., multinational production).

My findings furthermore suggest 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, 2017](#)) and on gravity in general: JIT may have played an important role in explaining the distance puzzle ([Berthelon and Freund, 2008](#)), i.e., the fact that despite a continuous fall in trade costs over the second half of the 20th century ([Hummels, 2001](#)), distance is as important a barrier to trade as it was decades ago.

Regarding firm boundaries in global supply chains, the only closely related studies are [Keane and Feinberg \(2006, 2007\)](#), to the best of my knowledge. The authors present suggestive empirical evidence at the industry level that the disproportional increase in intra-firm trade between US firms and their Canadian affiliates in the late 1980s and early 1990s is attributable to advances in logistics technology and in particular to JIT supply chain management. This paper presents evidence in line with their empirical finding, but based on a direct measure of JIT and on very detailed firm level information. Importantly, I make progress by proposing a formal organizational model in the tradition of transaction cost economics to explain this pattern. Its implications receive strong support in the data, provide guidance as to which factors modulate the complementarity between JIT and vertical integration, and constitute useful inputs for policy.

More broadly, my study contributes to the literature on firm boundaries in supply chains ([Antràs and Helpman, 2004](#); [Antràs and Chor, 2013](#); [Del Prete and Rungi, 2017](#);

Berlingieri et al., 2018; Alfaro et al., 2016, 2019) as well as the firm level determinants of multinational activity (Antràs, 2003; Corcos et al., 2013) and vertical integration in general. First, it highlights that supply chain management considerations are potential drivers of integration decisions and present a fruitful area for further explorations. Secondly, it provides empirical evidence for a mechanism (coordinated adaptation and inventory holding) that shapes multinationals' decision making. Third, in conjunction with this mechanism it discovers novel characteristics of firms' environments that affect ownership patterns, namely the cost of inventory holding, demand persistence, and downstream market power to shift inventories along supply chains.⁶

In Section 2 I introduce the data, describe important characteristics of firms and industries in JIT supply chains, and establish the two stylized facts regarding their organizational structure. Section 3 is devoted to the conceptual framework that can rationalize these facts. Section 4 gives an outline of the main additional predictions derived from the model and their empirical tests. Finally, Sections 5 and 6 discuss policy implications of my findings and conclude.

2 Characterizing JIT Supply Chains Empirically

In this section I present a comprehensive characterization of JIT supply chains. I start by describing how my data set allows me to measure JIT supply chain management and illustrating its prevalence and importance. Next, I investigate the firms that participate in more 'traditional' and modern JIT supply chain arrangements. In the second part, I establish two stylized facts regarding the organizational structure of JIT supply chains: compared to 'traditional' supply chains, (1) trade is more regional and (2) production is more vertically integrated both domestically and internationally.

The ideal experiment to establish causal relationships between JIT supply chain management and other organizational patterns would be to randomly provide information about, and implement, a JIT regime on some supply chains and not on others. Subsequently, one would observe how managers restructure other aspects of their supply chains and compare the result to their untreated counterparts. Such research designs are very costly and it is nearly impossible to ensure that such experiments have no direct effect on several other organizational margins at the same time – treatment effects would be difficult to interpret even in this clean 'laboratory' setting. This observation unfortunately generalizes to natural experiments and effectively prevents an instrumental

⁶Other interesting empirical work related to JIT includes Schott et al. (2017), who show that the removal of trade policy uncertainty fosters long-term supply relationships that ensure high product quality and they describe this idea as Japanese style supply chain management.

variables strategy.

My empirical approach throughout this paper is instead to acknowledge that the margins of JIT supply chain management, location choice, and ownership patterns are jointly determined. I isolate the covariation between them by making heavy use of control variables and fixed effects to exclude other mechanisms that may create spurious correlations in the data. Moreover, I lend additional credibility to the stylized facts by testing further predictions derived from the conceptual framework in Section 3 regarding how they should vary quantitatively with features of the environment in Section 4.

2.1 Prevalence, Importance, and Firm Characteristics

Generally speaking, information about management is hard to come by, which has prompted comprehensive data collection efforts (see, for example, Bloom and Reenen, 2007; Bloom et al., 2016). For this paper I obtained access to a rare exception to this rule: The French firm level survey Enquête sur les Changements Organisationels et l'Informatisation (COI) collected information about how firms are internally organized both from employers and their employees in 1997 and 2006.⁷ A random sample of firms with more than 50 (20 in 2006) employees was surveyed and the response rates were very high (88%, 84%), which is not unusual for France. 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.

This JIT variable has two important limitations. First, firms may misreport their true state if they do not understand what JIT means and/or do not have sufficient information to answer the question. While it is impossible to assess the extent of this problem, several arguments inspire confidence that this is not a first order concern. For one, the questionnaires contained an attachment that offered detailed explanations of a range of specific terms used in the survey, including for the JIT related questions. Companies were therefore likely to have a homogeneous and appropriate understanding of the characteristics of JIT supply chain management.⁸ Moreover, and slightly anticipating the results

⁷Other 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).

⁸The description in French and a google translate output in English is shown in Online Appendix B.

below, JIT firms did have significantly lower inventories than their non-JIT peers even within highly disaggregated industries, which is a tell-tale sign that the JIT variable is meaningful: after all, this is the main objective most companies pursue when they adopt a JIT regime. 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 by my estimates and the results in this paper are lower bounds to the true correlations.

The second limitation is that, in reality, it is a matter of *degree* just how meticulously production stages in a make-to-order supply chain are coordinated and geared towards minimizing inventories. Information on JIT in the COI survey, however, is only binary and throughout this paper I acknowledge this shortcoming by referring to JIT_{ft} as ‘JIT intensity’: since the state is discrete, the empirical patterns presented reflect differences in group averages of more and of less intensive “JITers”.

The third and final limitation is that I cannot make use of any information about which product lines are managed just-in-time or about whether a firm sources or delivers in such a way, i.e., the direction of the flow.⁹ Both aspects introduce measurement error and tend to attenuate the results.

Table 1 illustrates the prevalence and importance of JIT firms by two digit ISIC industry and averaged across the three survey years. Overall, about 45 percent of 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 31% in “wood and products of wood, except furniture” to 66% in “motor vehicles, trailers and semi-trailers”. The (fast) fashion industries with codes 17 and 18 are not unusually JIT intensive (43% and 46%). JIT firms are, however, disproportionally important economically, both in terms of employment and international trade: at the aggregate level, they account for more roughly two thirds of either.

To characterize JIT and non-JIT firms, I collect balance sheet information from FICUS, a tax return database covering the universe of French firms. In a second step, French international goods trade data is merged at the firm and year level. Based on the latter, I create an indicator that takes the value one if a firm trades in a given year, and zero otherwise. Moreover, I record the total value traded internationally.

In Table 2 I compare JIT to non-JIT firms along various dimensions. Each cell 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 sample,

⁹For the year 1997 this information is available separately by sourcing, production, 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.

Table 1: Industry Shares – JIT firms

ISIC Industry Code	Description	JIT share (in pp) of			Industry share (pp) of		
		firms	employment	int'l trade	firms	employment	int'l trade
15	food products and beverages	42	53	49	17	13	10
16	tobacco products	C	C	C	C	C	C
17	textiles	43	43	42	3.8	1.7	1.3
18	wearing apparel; dressing and dyeing of fur	46	45	47	3.2	0.9	0.7
19	leather products	40	31	31	1.5	0.9	0.6
20	wood and of products of wood and cork, except furniture	31	35	18	2.7	0.8	0.3
21	pulp, paper and paper products	56	58	59	2.9	2.4	2.9
22	publishing	39	50	62	5.7	3.1	0.5
23	coke, refined petroleum products and nuclear fuel	C	C	C	C	C	C
24	chemicals and chemical products	43	50	54	7.1	9.7	19
25	rubber and plastic products	51	74	73	5.8	6.8	4.3
26	other non-metallic mineral products	34	53	67	4.6	4.5	2.3
27	basic metals	48	59	47	3.0	4.5	8.3
28	fabricated metal products, except machinery and equipment	42	51	57	14	5.8	2.1
29	machinery and equipment n.e.c.	45	65	71	9.1	8.3	5.5
30	office machinery and computers	C	C	C	C	C	C
31	electrical machinery and apparatus n.e.c.	60	80	87	3.8	5.9	4.7
32	radio, television and communication equipment and apparatus	59	76	84	2.6	4.7	4.4
33	medical, precision and optical instruments, watches and clocks	43	58	70	3.5	3.0	1.7
34	motor vehicles, trailers and semi-trailers	66	96	98	3.2	14.5	24
35	other transport equipment	47	65	87	2.2	6.5	5.9
36	furniture; manufacturing n.e.c.	47	63	60	4.2	2.7	1.7
37	Recycling	C	C	C	C	C	C
Aggregate level		45	64	67			

"C" entries signify that firm numbers are below the publication threshold. All shares are averages across 1997, 2003, and 2006.

Table 2: JIT Premia

	JIT premium			Obs
	(1)	(2)	(3)	
log sales	0.710***	0.557***	0.075***	11,367
log employment	0.613***	0.444***		11,367
prob. international trader	0.078***	0.045***	0.009	11,367
log trade value	0.389***	0.356***	0.111***	10,318
log labour productivity	0.097***	0.113***	0.075***	11,367
log VA productivity	0.020	0.044***	0.021***	11,367
log capital intensity	0.197***	0.162***	0.077***	11,367
log intangible capital intensity	-0.018	0.070**	-0.007	11,367
log skill intensity	-0.012	0.014**	-0.004	11,367
log inventory (finals) turnover	0.240***	0.263***	0.150***	4,468
log inventory (interm.) turnover	0.150**	0.066**	0.103***	11,603
Additional covariates	None	4d Ind. × Year FE	4d Ind., × 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. Standard errors are clustered at the 4 digit industry by year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

while the estimates in columns (2) and (3) use only within industry variation (308 categories). Clearly, compared to ‘traditional’ firms, participants in JIT supply chains tend to be larger in terms of sales and employment, are more likely to trade internationally and, if they do so, trade significantly more. They are also more productive and somewhat more capital intensive. Lending further credibility to the JIT indicator, Table 2 furthermore reports that inventory turnover – the ratio of sales to the value of inventories – is substantially higher at JIT firms.

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 that are 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 advantage. I treat the JIT premia as consistent with, and as supportive evidence for, such a mechanism when I build the conceptual framework in Section 3.

2.2 Location Choice in JIT Supply Chains

Empirical Specification and Data

I compare international transactions of goods conducted by 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 the 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 the trade partner, either in terms of distance in kilometers or, often equivalently, shipping times. I estimate the following linear model, which resembles a firm level gravity equation, as the baseline specification:

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

where $ficpt$ indexes a year t trade flow of CN 8 digit product p between country c and firm f operating in 4 digit NAF¹⁰ industry i .¹¹

The two dependent variables of interest are the extensive and intensive *country margins* of trade, which reflect different trade partner locations. As in the previous subsection, firm level data on international trade comes from the universe of French customs declarations. One limitation of my firm level JIT information is that it does specify which transactions are managed JIT and which are not, so that I sum over imports and exports.

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

¹⁰NAF is the French classification of industries, which is based on the European NACE. For consistency I use the 2003 vintage throughout.

¹¹While the product dimension plays no role in the baseline and could be integrated out, I keep the data disaggregated so as to facilitate comparison when I estimate product level interactions in Section 4 below. As a robustness check I estimate specification (1) with the dependent variables summed over products, see column (4) of Online Appendix Table C.6.

is (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 be ever conducted with a JIT idea in mind. Slightly anticipating the results, this intuition is confirmed in Online Appendix Table C.3 where I include the 100 most important countries in terms of pre-sample (1996) trade volume and show that the supply chain differences related to JIT are indeed strongest for Europe.

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 keeping 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).¹²

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

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

The intensive margin is the actual value of a trade flow. This variable is heavily 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), using a scale parameter $\theta = 0.5$:

$$\text{intensive margin}_{fcpt} \equiv \sinh^{-1} \left(\frac{\theta \text{tradevalue}_{fcpt}}{\theta} \right) = \frac{\log \left\{ \theta \text{tradevalue}_{fcpt} + [(\theta^2 \text{tradevalue}_{fcpt})^2 + 1]^{\frac{1}{2}} \right\}}{\theta}.$$

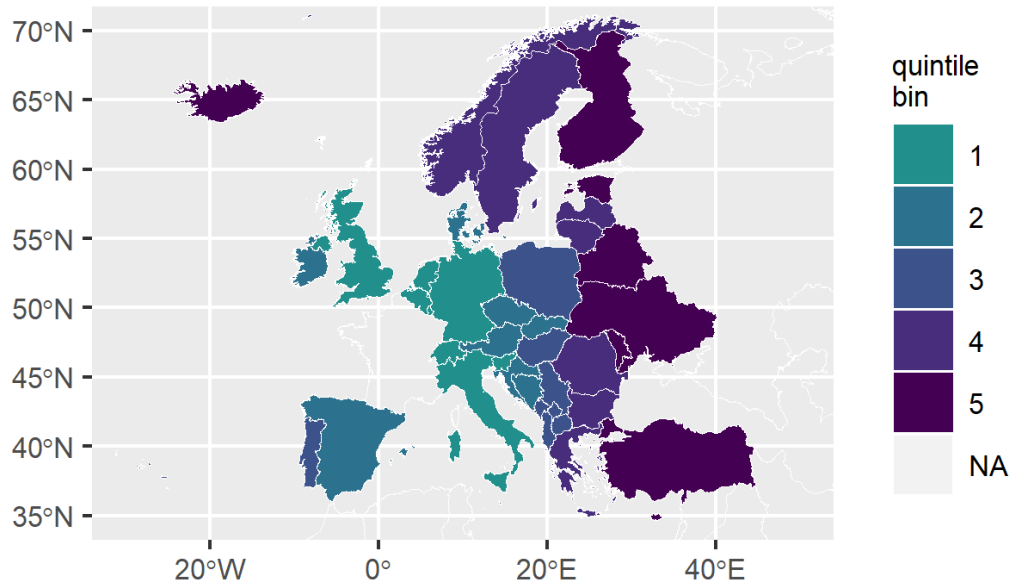
This variable is approximately normally distributed and, for high values, any coefficient obtained from estimating the preferred specification (1) can be interpreted as if the intensive margin was log transformed. For small values, the inverse hyperbolic sine does not

¹²In a robustness check reported in column (3) in Online Appendix Table C.6 below I retain the 25 most important products, which account for 96% of all French trade. The results are unchanged.

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.¹³

Panel B of Online Appendix Table C.2 provides summary statistics for both margins of interest. A firm trades its average product with 5.5 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 one million EUR in a year, but the median flow is much smaller at 38 thousand.

Figure 1: Quintiles in the distance-to-France distribution



The main regressors are a set of interactions between the JIT indicator and quantile bin dummies derived from the across country distance distribution. While shipping times are perhaps a more direct measure of the relevant spatial friction for JIT, geographic distance is a more familiar concept for most readers.¹⁴ Moreover, even the most comprehensive and reliable calculation of shipping times for France, carried out by [Berman et al. \(2013\)](#) based on marine and road transportation, has a significant number of missings. Since both measures are very highly correlated – .82 between (log) distance and (log) time-to-ship – I focus on (population-weighted) distance as provided by CEPII throughout the paper and present the baseline results with time-to-ship in Online Appendix Table C.5. The variation in the quantile variable is illustrated in Figure 1, where I present a map of

¹³The patterns I describe in the results below are fully robust to using the log of trade value as the dependent variable, i.e. fully conditioning on positive trade, as shown in column (1) of Online Appendix Table C.6.

¹⁴Panel A in Online Appendix Table C.2 presents summary statistics for both distance and time-to-ship.

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 effect is expected to be stronger for JIT firms. In other words, the distance elasticity is higher for them in absolute value.

To isolate the relationship of interest I purge the estimates from observed and unobserved confounders with a set of additional control variables, captured by 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 nor 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 for 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 in all likelihood. Furthermore, they address certain selection patterns: 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 disproportionately benefit from the same language, language proximity, or more generally cultural similarity, a good example of which is the relationship between France and 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 occur with close trade partners with a higher likelihood. 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.

I estimate the specification with OLS and cluster the standard errors at the level of the main regressor, i.e., $\text{firm} \times \text{country}$.

Baseline Results and Robustness Checks

The coefficients of interest can be interpreted as (conditional) differences. *Relative* to very remote locations and *relative* to non-JIT firms, are JIT firms more likely to trade with a country in a low distance bin? Do they trade greater volumes with them? Figure 2 illustrates the main results from estimating the preferred specification (1) with quintile bins, where darker colors indicate larger point estimates.¹⁵ 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 more sensitive to distance than their non-JIT counterparts and JIT supply chains are more regional.¹⁶

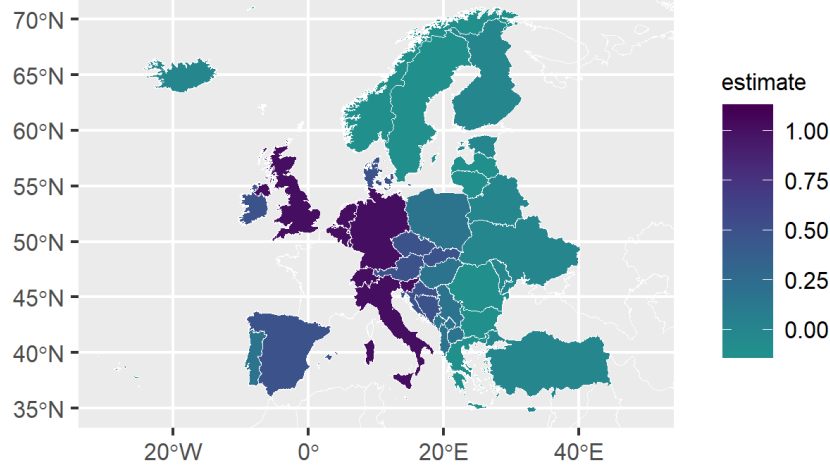
How much more “regional”? One way to illustrate the economic magnitudes of the estimated coefficients, and to see if they are of first order importance economically, is to compare them to the variation in the raw data. Across the whole sample, the average probability to trade with a country in the first distance quintile bin – which features countries like Germany – is 19.5 percent for a firm that does not participate in a JIT supply chain, while the one for the third quintile – which features countries like Hungary – is 3.7 percent. The difference in point estimates for the two quintiles in Online Appendix Table C.4 suggests that firms in modern JIT supply chains show a steeper gradient across the two categories by $(1.019 - 0.185)/(19.5 - 3.7) \approx 5.3$ percent. In the same vein, the gradient at the intensive margin for non-JIT trade flows is $4.177 - 0.737 = 3.44$, so that the baseline estimates suggest a difference between JIT and non-JIT firms of $(0.466 - 0.112)/3.440 \approx 10.3$ percent. A plausible illustration of the magnitudes is difficult due to the impossibility of estimating distance effects with data from only one country with suitable fixed effects and due to the fact the specification follows a difference-in-differences idea. The comparisons here nevertheless demonstrate that supply chain management is a first order concern for location choice in all likelihood.

¹⁵All further details for the regressions are reported in Online Appendix Table C.4.

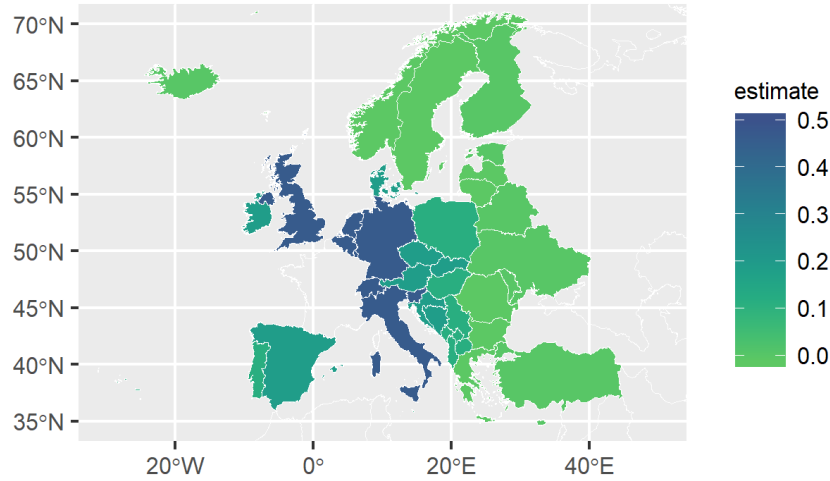
¹⁶This finding does not imply that JIT firm trade less than their non-JIT counterparts with remote locations in *absolute* terms, since the model estimated is a difference-in-differences.

Figure 2: Maps of Estimates

(a) Extensive Margin



(b) Intensive Margin



Preferred estimates based on equation (1) and shown in columns (3) and (6) of Online Appendix Table C.4: From a regression of the intensive or extensive country margins of trade on interactions of quintile dummies from the across country distance-to-France distribution with a dummy equal one if a firm is part of a just-in-time (JIT) supply chain in a year, and zero if not. Fixed effects: industry $\times$ trade partner $\times$ year; firm $\times$ year; trade partner $\times$ CN 8 digit product $\times$ year. Interacted country controls: JIT dummy interacted with 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. Standard errors clustered at firm $\times$ trade partner country level and quintile 1 + 2 (as well as 3 for intensive margin) estimates are significant at conventional levels.

Table 3: Location – Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Extensive margin										
JIT firm $\times$ 1 (distance tercile 1)	0.834*** (0.264)	0.570 (0.362)	0.721*** (0.277)	0.740*** (0.242)	0.674** (0.324)	0.628** (0.258)	0.853** (0.385)	0.428 (0.274)	-0.569** (0.275)	0.686*** (0.264)
JIT firm $\times$ 1 (distance tercile 2)	0.135 (0.180)	0.155 (0.244)	0.137 (0.189)	0.111 (0.165)	-0.055 (0.223)	0.094 (0.177)	-0.063 (0.260)	0.049 (0.185)	-0.200 (0.185)	0.134 (0.180)
Observations	2,956,338	1,636,932	2,632,707	3,824,898	2,915,946	2,956,338	1,577,136	2,768,403	2,753,520	2,956,338
R-squared	0.299	0.596	0.296	0.295	0.372	0.299	0.312	0.305	0.308	0.300
Panel B: Intensive margin										
JIT firm $\times$ 1 (distance tercile 1)	0.295*** (0.059)	0.256*** (0.080)	0.264*** (0.062)	0.271*** (0.054)	0.293*** (0.072)	0.183*** (0.057)	0.295*** (0.087)	0.174*** (0.061)	-0.114* (0.061)	0.257*** (0.059)
JIT firm $\times$ 1 (distance tercile 2)	0.062 (0.040)	0.080 (0.054)	0.060 (0.042)	0.051 (0.037)	0.030 (0.050)	0.040 (0.039)	0.029 (0.059)	0.041 (0.041)	-0.020 (0.041)	0.064 (0.040)
Observations	2,956,338	1,636,932	2,632,707	3,824,898	2,915,946	2,956,338	1,577,136	2,768,403	2,753,520	2,956,338
R-squared	0.317	0.620	0.312	0.310	0.391	0.317	0.330	0.324	0.328	0.317
Specification										
Sample	full	full	no textiles or cars	+ whole- salers	full	full	high roadshare	full	full	full
Firm $\times$ Year FE	YES		YES	YES	YES	YES	YES	YES	YES	YES
4d Industry $\times$ Country $\times$ Year FE	YES		YES	YES		YES	YES	YES	YES	YES
8d CN Product FE	YES		YES	YES	YES	YES	YES	YES	YES	YES
Baseline FEs $\times$ 8d CN Product FE		YES								
French Region $\times$ Country $\times$ 4d Industry $\times$ Year FE					YES					
Interacted country controls		YES	YES	YES	YES	YES	YES	YES	YES	YES
Contiguity										
Additional controls 1						YES		YES		
Additional controls 2						YES		YES	YES	
IT intensity									YES	YES

The dependent variables are a dummy equal to one 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; 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 controls 1: distance tercile indicators interacted with physical capital intensity; intangible capital intensity; skill intensity of firm (all in logs). Additional controls 2: distance terciles interacted with sales; employment; VA per worker of firm (all in logs). Sample size varies due to missings in variables and since singletons are dropped. Standard errors in parentheses are clustered at the firm $\times$ country level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

I now turn to a selection of important robustness checks, which I present with tercile distance dummies for clarity. In column (1) of Table 3 I repeat the baseline with terciles for comparison.

First, while the baseline set of fixed effects already addresses many sources of confounding channels that could explain the relationship between JIT and trade partner proximity as explained above, they take no account of variation in the types of products that are being traded. These differ, for example, in perishability, complexity, bulkiness, and their input requirements, all of which make them differentially likely to be traded between country and industry pairs. JIT firms may sort systematically into certain categories for non-JIT related reasons and my estimates may be confounded. 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 (2) of Table 3. Reassuringly, changes in the magnitudes of the coefficients are small, especially at the intensive margin.

Secondly, on the grounds of anecdotal evidence, one might worry that the results are mostly driven by textiles and automotive (2 digit industry codes 17, 34 and 35), two industries often associated with lean and JIT intensive production. In addition to the fact that these sectors are not very different from the average industry in terms of JIT intensity as discussed above, I conduct a more direct robustness check. When I focus on a subsample without firms that operate in these industries, the estimates are not statistically different from those based on the full sample, see column (3).

Thirdly, *indirect* importing and exporting, i.e., by means of domestic intermediaries (wholesalers), are common activities, especially for smaller firms. If they are less likely to adopt JIT due to the increasing returns nature of this technology, for example, and simultaneously tend to trade with partners very close by, my estimates capture spurious covariation. While this issue may not be a first order concern – even in the US only a small share of trade is conducted by intermediaries (Bernard et al., 2010) and international trade within Europe is relatively more straightforward – I gauge its potential impact by including wholesalers in my sample (possible for 2003 and 2006). The behavior of firms that use intermediaries should be reflected in the latters’ trade flows to some extent and some of these wholesalers offer JIT services to their customers. Column (4) of Table 3 shows that the point estimates are stable and intermediation does not seem to present a major concern.¹⁷

Fourth, several locational firm characteristics of the French traders in my sample may

¹⁷Carry-along-trade (Bernard et al., 2018) potentially causes a related problem in that my observing longer distance trade flows for smaller, non-JIT firms is hampered by intermediation. This would bias the estimates against finding a relationship, since small, non-JIT producers are likely to ‘outsource’ their long-distance trade flows to large manufacturers.

be a cause for concern. In particular, JIT firms could reside close to the borders to Germany, Belgium, or Spain to facilitate trade with partners there. Simple gravity considerations would then explain the positive correlation between JIT and proximity. In column (5) I therefore interact the γ_{ict} effects with an indicator for each of the 18 French regions, so that the estimating variation comes from comparing two firms within the same region and industry who trade with the same partner. The result in column (5) is reassuring provided that the majority of firms produces at its registry plant. In unreported regressions I confirm that this conclusion remains intact in the substantially smaller sample of firms with a single establishment.¹⁸ In column (6) I also control for the interaction between the JIT indicator and a country dummy that equals one if the trade partner shares a border with France. The estimates are once again similar to the baseline and robust to restricting the sample to single establishment firms.

Moreover, one may worry that the transportation mode for flows in JIT supply chains may be systematically different, which could cause differential freight costs to become an issue. Column (2) of Table 3 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 regionalization of JIT supply chains. Moreover, in column (7) 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.¹⁹ 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.

Fifth, 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 be confounded and larger than they should be. In column (8) of Table 3 I therefore control for interactions of the distance dummies and physical and intangible capital as well as skill intensity. The estimates are indeed smaller, but still clearly portray the main pattern of regionalization of JIT supply chains.

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. Unfortunately, as highlighted by the

¹⁸The interacted region effects also control for the local infrastructure available to firms, like highways or airports.

¹⁹I use the average over the three years 1997, 2003, 2006, and exclude the firms in my sample.

conceptual framework below, making use of the relevant firm level proxies is subject to a ‘bad controls problem’: JIT as a management technique is supposed to make firms more efficient and thus grow larger in terms of employment and sales. This very important caveat notwithstanding, I nevertheless investigate these aspects by interacting the distance dummies with value added per worker, sales, and employment for column (9). JIT firms appear to trade less with proximate partners (compared to remote partners) conditional on size and productivity. This finding, while hard to interpret given the bad controls problem just described, is consistent with the fact that the firm level proxies capture the benefits of JIT only insufficiently, so that more efficient JIT firms are compared to less efficient non-JIT ones when conditioning on observables. If more productive firms can trade with more remote locations, their distance profiles are flatter and JIT firms appear to trade relatively less with close partners.

The final concern about firm level determinants is related to IT intensity, which may be correlated with modern supply chain management and reduces monitoring and communication costs for long distance relationships (Leuven et al., 2018). In column (10) of Table 3 I show that controlling for the interaction of distance with a firm level ICT intensity index has little effect on the estimates of interest.²⁰

2.3 Vertical Integration Patterns

Empirical Specification and Data

In this subsection I examine the relationship between JIT supply chain management and ownership: Do JIT firms retain a broader range of tasks in-house, possibly to extend their control over the supply chain? Does that constitute a potential rationale for multinational activity?

To generate econometric evidence I estimate the following model

$$y_{fijt} = \beta_1 JIT_{ft} + \beta_2 X_{ft} + \gamma_{ijt} + \varepsilon_{fijt} , \quad (2)$$

where i continues to denote the industry of French firm f in year t of my sample and j

²⁰As an alternative approach to addressing confounders at the firm level, I can employ firm $\times$ country fixed effects, which absorb all time constant characteristics of firms and their trade partners. The subsample that allows for such an exercise is smaller since only a limited number of firms appears in more than one year. Moreover, the share of ‘JIT switchers’ is low in the data, a change in a firm’s JIT status is subject to substantial measurement error due to accidental misreporting in survey data, and it may take considerable time to restructure supply chains – as a consequence, this exercise is very demanding. The estimates in column (5) of Online Appendix Table C.6 show a noisy downward slope of the same order of magnitude as the baseline at the extensive margin and there is little discernible variation across space at the intensive margin.

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 using a widely 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' ownership decisions, but still provides valuable information about technology, since the US and France are relatively similar. I base my sample on the 100 most important upstream manufacturing industries j for downstream industry i according to the direct requirement, because the 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 only count activities of foreign affiliates.²² 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.²³ Information on 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.

Table C.2 in Online Appendix C 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 firms. 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 are within the boundary of a single firm or international business group – although there are once again exceptions of large multinationals.

The main regressor of interest is the JIT_{ft} indicator. In line with anecdotal evidence in [Keane and Feinberg \(2007\)](#) that the increase in intra-firm trade between Canada and

²¹In robustness checks presented in columns (2) and (6) of Online Appendix Table 6, I show that the estimates from the baseline model (2) are somewhat smaller when I include all 310 upstream industries, but still highly statistically significant both for all and international integration. The decrease in point estimates is expected given that firms tend to vertically integrate their most important inputs ([Berlingieri et al., 2018](#)).

²²Since all firms have a primary industry i I drop all observations where $i = j$, i.e., those relationships on diagonal of the IO-table.

²³I examine other measures of integration in the robustness section below.

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 make-to-order supply chain management based on information exchange and precise coordination with asset ownership that allows for more direct control, as discussed in Section 3 below.

Specification (2) furthermore includes a set of downstream industry $\times$ upstream activity fixed effects, γ_{ij} . They are motivated by the empirical findings of a broad literature in international trade and organizational economics that examines the industry ($\times$ activity) level determinants of vertical integration (for a review see Antràs, 2015). Using only variation *within* upstream-downstream supply relationships, I remove confounders like the relative marginal investment contributions by suppliers and customers as highlighted by property rights theories 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 transaction cost economics approaches to vertical integration (e.g., Williamson, 1985). In effect, 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.

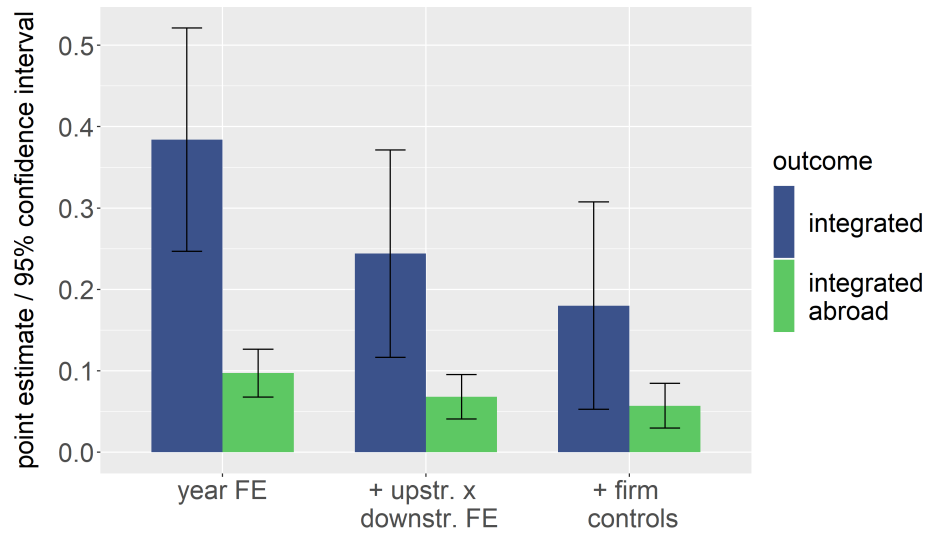
Finally, I include a set of firm level control variables (value added per employee, capital intensity, and skill intensity) which are correlated with JIT supply chain participation as shown above and may drive vertical integration (Corcos et al., 2013). I omit scale controls like employment and sales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

The model in (2) is estimated with OLS and the standard errors are clustered by firm.

Baseline Results

Figure 3 illustrates the baseline results, where the fixed effects and controls are introduced in turn, grouped by specifications that have either overall or only foreign integration as a dependent variable (Online Appendix Table C.7 contains all details for these baseline results). The JIT indicator is positive and highly significant in the preferred specification, equation (2). JIT firms are more likely to perform the average activity in-house, both in general and as a part of a more extensive multinational business group, than similar non-JIT firms. Relating the magnitudes of the estimates to the overall means of the dependent variables reveals that these differences are of first order importance: a premium of 7 and 24.5 percent, respectively, for all integration and integration abroad. In conclusion, and in line with the suggestive evidence in Keane and Feinberg (2007), ownership in modern JIT supply chains is more concentrated, more activities are controlled

Figure 3: Baseline Estimates (incl. 95% confidence intervals)



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 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). Common sample imposed and standard errors are clustered at the firm level.

directly via ownership, and these patterns are especially pronounced for multinational firms.

Different outcome variables To strengthen the credibility of these results I perform a number of robustness checks. First, the indicator variables for ownership have two shortcomings. For one, 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, may need 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 input costs. Integration of only the latter two activities conceptually means a relatively high degree, while in-house production of engines and car glass implies a lower degree of firm specialization along the value chain. In other words, the dummy variables cannot capture the *intensity* of vertical integration.

To make progress, and following standard practice to facilitate comparison, I use an index

Table 4: Vertical Integration – Additional Outcomes

VARIABLES	(1) integration index	(2) integration index abroad	(3) integration index abroad	(4) intra-firm trade share	(5) intra-firm trade share
JIT firm	0.551*** (0.201)	0.207*** (0.052)	0.116** (0.051)	6.731*** (1.874)	5.399*** (1.894)
Coeff. / mean depvar (percent)	13.7	48.6	27.2	22.2	17.8
Observations	13,484	13,484	13,484	38,599	38,599
R-squared	0.362	0.276	0.285	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
Extended 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 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; capital intensity; skill intensity (all in logs). Extended firm controls: sales; employment (all in logs). "Flow FE" refers to a dummy equal to one for export flows, and zero for import flows. Sample (1) features all firm-years from the full sample; sample (2) contains 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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

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

The result of regressing VI_{fit} (and its equivalent counting only integration abroad) on the JIT dummy, a set of firm controls, and a set of downstream industry × year fixed effects is shown in columns (1) and (2) of Table 4. Relative to the average intensities, JIT firms have a substantially higher intensity of vertical integration (premiums over means of 13.7 and 48.6 %), a difference most pronounced for multinational activity.²⁴

²⁴In unreported regressions I confirm that the results are fully robust to using either the log or the inverse

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, I examine intra-firm trade data. The French firm level survey EIIG covers a random sample of large firms with foreign affiliates in a single cross-section. It provides data on the value share of individual trade flows that was sourced within the boundary of the firm.²⁵ My alternative dependent variable is therefore “intra-firm 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. While this measure of vertical integration is only available for multinational activity, it provides direct information on whether or not a firm actually perform certain steps in the production chain in-house.

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 establish a novel insight and support my baseline findings: 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 JIT supply chains are about 7.5 percentage points more likely to happen within a multinational firm than those where the French firm operates in a ‘traditional’ way (for comparison, and consistent with aggregate data (Miroudot et al., 2009), the overall intra-firm trade share is roughly one third).²⁶

Further robustness checks

A second concern is that the stereotypically JIT industries, textiles and automotive, may be driving the results. As column (1) in Table 5 shows, this is not the case. Moreover, I may obtain confounded estimates if vertical integration leads to mixed companies that have production and (majority) sales activities, so that they are classified as wholesalers. They could be ‘proper’ manufacturing companies at heart for which supply chain management plays an important role and the estimates have limited scope when I exclude them. As the estimated coefficients on this larger sample change very little compared to

hyperbolic sine of the indices as dependent variables.

²⁵Unfortunately, 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 intra-firm trade data to the first cross-section of my JIT sample. Further information about EIIG can be found in other work that makes use of the data, for example in Carluccio and Fally (2012) or Defever and Toubal (2013).

²⁶The intra-firm trade share variable at 4 digit HS level is almost a dummy variable, so that shares can be interpreted as probabilities without loss.

the baseline, however, this does not seem to be a first order concern (see column (2) in Table 5).

In the baseline regressions I already account for several important confounding drivers of vertical integration, capital and skill intensity (Corcos et al., 2013). In the next robustness checks I furthermore explore to what extent further concerns about pure scale or selection may affect the relationship between JIT and vertical integration. Using proxies like employment or sales is not possible for domestic integration, since more vertically integrated firms tend to be bigger for mechanical reasons. For foreign integration, however, there is scope to use sales and employment *in France*.²⁷ Column (3) shows that size absorbs a large share of the difference between JIT and non-JIT and for foreign *asset* ownership the estimate is no longer significant at conventional levels. Examining scale effects using the other two outcome variables described above (vertical integration index and intra-firm trade shares), however, it is clear that the positive relationship between JIT supply chain participation and vertical integration is statistically significantly positive *conditional on size*, see columns (3) and (5) of Table 4.

Another potential mechanism that confounds the relationship between JIT and vertical integration is the degree of ICT intensity. If, for example, ICT is particularly useful for a JIT regime and improves monitoring of remote activities so that outsourcing becomes more attractive, it could introduce a spurious negative correlation in my estimate of interest. In column (4) of Table 5 I control for a firm level index of IT intensity and show that the point estimate is slightly smaller than the baseline, but still highly significantly positive. Of course, this approach suffers from the same concerns about the outcome influencing ICT adoption as size or productivity measures.

As an alternative strategy, I can rely on firm fixed effects that capture many of the unobserved characteristics that may drive the estimates. While few firms change their JIT status in my sample (and potentially for misreporting reasons only) and I have much reduced power, column (5) illustrates that many of the worrisome firm characteristics that act as confounders have little impact on the basic correlation between JIT supply chain management and vertical integration, especially for activities abroad.

Based on anecdotal evidence, JIT supply chain management is particularly important for multi-product firms with many varieties, since they have to source a larger number of specific intermediates and hence struggle more to keep inventories low – indeed, the production of highly customized varieties is a prominent reason for firms to adopt JIT in the first place (Ohno, 1988). I therefore expect the correlation between JIT and verti-

²⁷In-house activities abroad may require more domestic staff as well, so that size and vertical integration are still likely to be correlated for simultaneity reasons.

Table 5: Vertical Integration – Further Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Integrated							
JIT firm	0.140*	0.234***		0.155**	0.106	0.290***	0.075**
	(0.074)	(0.063)		(0.065)	(0.132)	(0.099)	(0.034)
Coeff. / mean depvar (percent)	5.1	9.2		6.0	4.1	9.8	6.6
Observations	878,530	1,357,087		1,048,429	1,048,429	462,270	3,250,350
R-squared	0.488	0.463		0.482	0.506	0.462	0.405
Panel B: Integrated abroad							
JIT firm	0.050***	0.073***	0.005	0.052***	0.068*	0.083***	0.024***
	(0.016)	(0.015)	(0.014)	(0.014)	(0.038)	(0.024)	(0.006)
Coeff. / mean depvar (percent)	21.0	31.1	2.1	22.3	29.2	25.7	23.8
Observations	878,530	1,357,087	1,048,429	1,048,429	1,048,429	462,270	3,250,350
R-squared	0.153	0.153	0.233	0.152	0.164	0.167	0.146
Specification							
Sample	no textiles or cars	+ whole- sellers	full	full	full	high # exp. products	all industries
Year FE	YES	YES	YES	YES	YES	YES	YES
Downstr. 4d Ind. × Upstr. 4d Ind. FE	YES	YES	YES	YES	YES	YES	YES
Firm FE					YES		
Firm controls	YES	YES	YES	YES	YES	YES	YES
Extended firm controls			YES				
IT intensity control				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 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). Extended firm controls: sales; employment (all in logs). Standard errors in parentheses are clustered at the firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

cal integration to be particularly strong whenever a downstream industry manufactures a large number of varieties. I am constrained by the fact that production data is not available to me, so that I have to rely on the number of exported CN 8 digit products. I find a highly significant and positive correlation between JIT and vertical integration – both overall and abroad – when I condition on downstream industries that export a high number of products, see column (6).

Ruling out lock-in and technology diffusion as explanations

Both motivated by the substantial literature on the boundary firm in imperfect contracting environments as well as the brief discussion in [Keane and Feinberg \(2007\)](#), 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

Table 6: Vertical Integration – Lock-in and Technology Diffusion

VARIABLES	(1) integrated	(2) integrated	(3) integrated abroad	(4) integrated abroad	(5) integration index	(6) integration index abroad	(7) intra-firm trade share
JIT firm	0.213** (0.103)	0.203* (0.114)	0.061*** (0.021)	0.060** (0.030)	0.475* (0.283)	0.229*** (0.065)	6.939** (2.892)
Coeff. / mean depvar (percent)	8.0	5.6	27.7	23.0	12.1	66.4	25.3
Observations	474,745	246,179	474,745	246,179	7,767	7,767	11,390
R-squared	0.490	0.558	0.154	0.137	0.406	0.344	0.297
Sample	(1)	(2)	(1)	(2)	(3)	(3)	(4)
Year FE	YES	YES	YES	YES	YES	YES	
Downstr. 4d Ind. × Upstr. 4d Ind. FE	YES	YES	YES	YES			
Downstr. 4d Ind. × Year FE					YES	YES	
Downstr. 4d Ind. FE							YES
4d HS Product FE							YES
Flow FE							YES
Country FE							YES
Firm controls	YES	YES	YES	YES	YES	YES	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”); or 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”); or 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 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). Sample (1): Full baseline sample and restricted to downstream industries with a low lock-in index (see Online Appendix B for details; below median across downstream industries). Sample (2): Same as (1), but also restricted to upstream industries with a low lock-in index (below median across upstream industries). Sample (3): all downstream firm-years from the full sample and restricted to downstream industries with a low lock-in index (below median across downstream industries). Sample (4): all 4 digit HS trade flows associated with the firms in the full sample (1997 only) and restricted to non-differentiated 4 digit products according to Rauch (1999). Standard errors in parentheses are clustered at the firm level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

another. Such a lock-in could lead to higher quasi-rents and therefore to integration in line with a transaction costs economics rationale. To study whether this is a potential explanation, I assume 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 in Online Appendix Section B).

For the results reported in the first four columns of Table 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 es-

timates 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 intra-firm trade shares in column (7). I therefore conclude that, while lock-in effects may well be at play in JIT managed supply chains, they are not a particularly promising explanation for the integration patterns I document in this paper.²⁸

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 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, it is at least not obvious why firm boundaries protect knowledge better than contracts. Notwithstanding, the fact that JIT and vertical integration are positively correlated even for simple, homogeneous products that are straightforward to produce instills confidence that this channel is no first order concern.

3 A Conceptual Model of JIT Supply Chains

The empirical patterns are sufficiently complex to render a precise interpretation, let alone a derivation of interesting policy implications, very difficult. What is a *common* underlying mechanism that can explain the stylized facts? What are potential characteristics that modulate the observed complementarities between JIT management and the structure of supply chains? How should one think about policy implications?

In this section I propose a partial equilibrium framework to address these questions. Downstream buyers source intermediate inputs from upstream suppliers in an uncertain environment. While both partners in such a transaction can adapt to upstream and demand shocks, they will hold inventories to the extent that these adaptation decisions are not fully coordinated. JIT supply chain management is modelled as an information sharing technology, which ensures that signals about downstream demand are disseminated throughout the whole supply chain to facilitate coordinated adaptation and thus reduce expensive buffer stocks. While JIT supply chain management is typically conceived of as a broader philosophy, I emphasize coordination and ‘make-to-order’ aspects, which I believe are the most relevant for global supply chains.

Even though suppliers have better information about demand under JIT, they make adaptation decisions to maximize their own profits and thus create an externality down-

²⁸Note that instead of relying on the lock-in index, I restrict the sample to homogeneous products according to [Rauch \(1999\)](#) in column (7).

stream 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 another. The boundary of the firm in this framework is therefore defined by a Transaction Cost Economics (TCE) mechanism.²⁹

Moreover, even if real-time demand information is available, a remote supplier may not manage to deliver her goods in time to satisfy the precise needs of customers; in other words, information 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, too.³⁰

Coordinated adaptation is an important concern in JIT supply chains that may affect vertical specialization patterns of firms, but there are other forces which have the potential to shape ownership patterns, too. In particular, if JIT systems require more relationship specific investments (in either of the two senses implied by this wording), the need for coordination may give rise to hold-up on both sides of a transaction. The power to avoid intentional conflict by fiat within the boundary of the firm could be another motive for vertical integration. I offer two reasons for why I choose the route I take. From an a priori perspective, coordination failure is a salient and oft cited reason for inventory holding, the nemesis of JIT managers. By contrast, it appears much less likely that firms pay for buffer stocks to counter-act haggling inefficiencies. A posteriori, as I have shown above in Section 2.3, the main stylized fact that vertical integration and JIT are complements holds even in environments with little scope for hold-up, i.e., when parties are not locked into their relationships.

In the remainder of this section I first introduce a baseline model with JIT and without endogenous ownership or location choices to carve out the role of coordinated adaptation and information flows. Subsequently, I give firms the option to re-structure their supply chains in terms of location and ownership patterns.

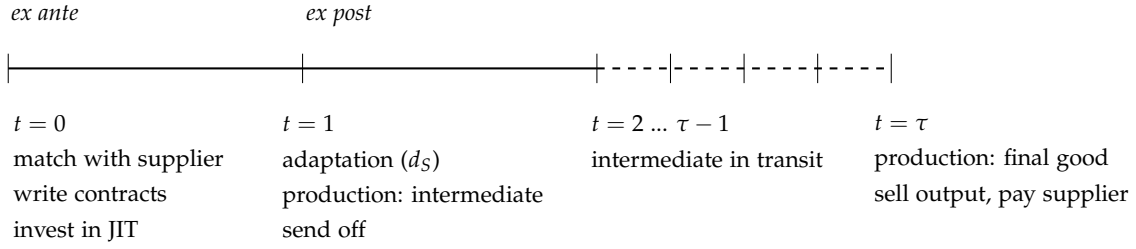
3.1 Baseline Model

Set-up

²⁹My ideas and assumptions build prominently on [Simon \(1951\)](#) and [Williamson \(1975\)](#), i.e., an adaptation theory of the boundary of the firm. From a modelling perspective I draw on [Alonso et al. \(2008, 2015\)](#).

³⁰The trade-off between primary factor costs in remote (offshore) locations and lower stocks to buffer demand shocks when shipping times are short – which will shape the geography of the supply relationship – mimics the insights from the frameworks in [Harrigan and Venables \(2006\)](#)

Figure 4: Timeline



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 by year fixed effects ensure that all estimating variation stems from differences across firms within the same sector of activity.

The final good producers each source a single intermediate input, which is specific to their own variety and which they transform into output.³¹ There is at least one supplier 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 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 intermediate 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 and τ is therefore the conceptual analogue to distance and time-to-ship in the empirical exercises.

The overall game has $\tau + 1$ stages as depicted in Figure 4. 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 under outsourcing or employment contracts under integration, and potentially

³¹To make sure that my empirical findings hold for trade in intermediates, too, I estimate the location related baseline specification on such a sample. As shown in column (2) of Online Appendix Table C.6, regionalization is at least as strong for this subset as it is for the baseline sample. All vertical integration results are based on transactions that only involve intermediates anyway.

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.

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

$$(\eta_S - d_S)^2 + w(\tau), \quad (3)$$

where η_S is a random supply shock with expectation equal to zero, a variance equal to σ_η^2 , and potentially infinite support.

The model is very general and accommodates a wide range of interpretations. For example, imagine that the intermediate input itself is manufactured using an adjustable mixture 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 by switching workers around, following the two previous examples. Clearly, if the local manager observes η_S perfectly and minimizes this expression, she adapts fully to the shock. Doing so causes excessive costs further down in the supply chain, however, if the adaptation decision conflicts with downstream interests; the downstream buyer therefore wants to sanction such behavior and thus alter the supplier’s incentives.

One of the defining features of this model is that 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 entirely new challenges, non-contractibility is a reasonable approximation to the real world. It is precisely in this sense that the present model embraces the tradition of Transaction Cost Economics: this *ex post* adaptation decision is not under anybody’s control, other than the person who holds *residual decision rights* (Simon, 1951; Hart and Holmstrom, 2010; Legros and Newman, 2013). Below, they will be formally linked to vertical integration, but in this baseline model with outsourcing every supplier’s manager chooses d_S herself.

The second part of (3), $w(\tau)$, represents the primary factor costs to produce an intermediate in locality τ , and it will be the reason for offshoring in the extended model below. I assume that $dw(\tau)/d\tau < 0$ 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, anecdotally, face ever lower labor costs in Eastern European, Arabian, and finally Asian or South American countries.³²

The supplier's objective function depends on the contract it signs with the buyer firm, which in turn governs the incentives that shape the adaptation decision d_S . 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, which are 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 by its adaptation decision for $\delta \rightarrow^+ 0$, and all of them as $\delta \rightarrow^- 1$. 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 emblematically lean automotive industry: car manufacturers/assembler-designers exert substantial market power in their input markets and push inventories on their suppliers of seats, chassis, and other component producers.

Returning to the dynamics of the model, the supplier now sends the finished input to the downstream firm's factory, where it arrives after $\tau - 2$ periods. It is now converted into the final output by the downstream manufacturer. To the extent that the intermediate does not match the period τ demand conditions due to imperfect coordination between upstream decision making and downstream demand, the buyer firm has to rely on inventories (intermediate or final) to ensure that all customers are satisfied. For illustration, suppose that the supplier decided to incorporate predominantly bright colors into the intermediate, because they happened to be relatively cheap. Demand for finals, however, happens to be skewed towards dark colors. The local adaptation decision upstream therefore causes inefficiencies downstream throughout the supply chain due to the costs of mis-coordination. Alternatively, imagine the upstream supplier's manager found that it is very 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 demand happens to be very time sensitive and the production process downstream consequently runs out of the intermediate, this temporal mis-coordination causes inefficiencies.

The value of inventories needed is assumed as

³²Evans and Harrigan (2005) model the international general equilibrium explicitly and obtain the same pattern endogenously. I abstract from such complications.

$$\gamma (\theta_\tau - d_S)^2 \quad (4)$$

where θ_t captures demand conditions; that is, for example, customers' relative preferences for certain final varieties or their time sensitivity. In this sense, θ measures the *horizontal* properties of goods demand. For simplicity, I assume that it evolves according to an AR(1) process

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

where $\rho \in (0, 1)$ is a persistence parameter and ε_t is an i.i.d. demand shock with mean zero and variance σ_ε^2 .³³ Furthermore, I normalize $\theta_0 = 0$. Realized demand conditions in period τ are therefore random and an early signal, say, 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”. Moreover, $\gamma > 0$ is most naturally interpreted as the *cost of holding inventory* relative to primary factor costs.³⁴

At this point, it would be possible to introduce a further adaptation decision for the downstream buyer firm, d_B . It could be fully non-contractible, too, and capture the buyer firm's decisions regarding the degree to which the potentially unfit intermediate is adjusted – or what extent inventories of intermediates or finals are utilized – to meet the customers' preferences. Inventories could then cover the loss due to mis-coordination between d_S and d_B and the key mechanism this model relies on, namely coordination of adaptation decisions, would be fully explicit. Since this additional endogenous choice offers little additional insight, however, I refrain from modelling the buyer's problem. Instead, I interpret θ_τ as the buyer's adaption choice in a reduced form way, so that mis-coordination between the two firms amounts to the discrepancy between d_S and θ_τ as described above.³⁵

Slightly anticipating the solution to the game, the tension between upstream supply and downstream demand shocks potentially leads to a *supply chain externality* and it is

³³An interesting – but much less tractable – generalization of the model would allow for correlation between the upstream supply shock η and the downstream demand shocks ε_t ; this is tantamount to allowing for varying the degree to which shocks are aggregate or idiosyncratic to the supply chain. Since I am interested in the long run structure of (global) supply chains, however, rather than in studying shock responses, I focus on the more specific model outlined.

³⁴I keep the inventory holding problem very stylized. The downstream firm has no economic order quantity problem, no choice about the level of demand that should be satisfied with a high probability etc. While this abstracts from many of the real life complications that face decision makers, it renders the model tractable.

³⁵The model with d_B is available from the author upon request.

inherent to any sequential production process: if not properly incentivized, upstream stages may not have to take the real costs of their adaptation decisions into account. Internalization of this externality, and hence alignment of incentives, will be the driver behind vertical integration in the extended model below.

Finally, the final good producer 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 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 in terms of labor (whose price is normalised to one).

JIT and Information

To complete the exposition I present assumptions on the different information sets of the two managers (upstream and downstream) at any point in time, which depend on whether a supply relationship is managed in a traditional way or in JIT style. At the ex ante stage $t = 0$, the downstream firm has an opportunity to devote a fixed amount of resources to an information sharing technology, JIT. This proportional increase in fixed costs is denoted by $\lambda_{JIT} > 1$, so that total fixed costs for a stand-alone downstream firm become $\lambda_{JIT}f$.³⁶ As mentioned above, 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. Modelling the downside of JIT supply chain management as a fixed cost is therefore consistent with anecdotal evidence.

JIT ensures that the upstream firm receives a signal about the demand conditions in period $t = 1$ (in other words, in real-time) and, abstracting from any cheap talk considerations (in contrast to [Alonso et al., 2015](#)), I assume that the best possible signal, θ_1 is transmitted. This information exchange between the downstream and the upstream stage enables what is called a “pull” system. In a traditional supply chain, raw materials and intermediates are “pushed” through the different stages and whenever a stage needs inputs, it takes them off its supplier’s shelves – the eventual 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, if the downstream stage sends demand

³⁶The fixed costs of JIT should be interpreted as the *differential* fixed cost of running a sophisticated system on top of the regular functions in a supply chain. The exact formulation of fixed costs here is inspired by [Bustos \(2011\)](#).

information upstream, the supplier is in a better position to finish the right intermediate at the right time – hence the term “Just-in-Time”. Mis-coordination inventories, i.e., the figurative shelf-space, can be reduced substantially.³⁷ To put the same point differently, JIT causes materials and intermediates to be “pulled” through the value chain.

For a traditional “push” approach to supply chain management, I assume that the information set of the supplier is $\mathcal{I}_S^{JIT} = \{\eta_S\}$, i.e., it observes its local shock perfectly and nothing else. The buyer firm’s manager observes the final demand conditions at any point in time (perfect information), so that $\mathcal{I}_B^{JIT} = \{\theta_1, \theta_2, \dots, \theta_\tau\}$. Intuitively, 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

$$\mathcal{I}_S^{JIT} = \{\eta_S, \theta_1\}, \quad \mathcal{I}_B^{JIT} = \{\theta_1, \theta_2, \dots, \theta_\tau\},$$

i.e., the upstream firms’ manager receives a signal θ_1 , which she can take into account when she makes their adaptation decisions.

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

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

where the mode of supply chain management – decided upon ex ante – is $M = \neg JIT, JIT$ and the asterisk indicates optimal choices. $c^*(\tau, M)$ is a shorthand for the total procurement costs of one unit of the intermediate, which includes the price of the intermediate and inventory holding costs. While τ is fixed in this subsection, I make it explicit to facilitate comparability with the extended model below.

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

³⁷In a typical 1970s Japanese JIT system, small cards called “kanban” were used to transmit demand information up to previous production steps. Over time, these were first replaced by electronic data interchange (EDI) facilities and currently the internet of things (IoT) together with the 5G standard are revolutionizing this process within and between factories once again.

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

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. Evidently, 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 therefore

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

If inventories were costless ($\gamma = 0$) or if the supply contract provided no incentives for coordinated adaptation ($\delta \rightarrow^+ 0$), 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 her conditional expectation of final demand conditions, $\mathbb{E} [\theta_\tau | \mathcal{I}_S^M]$.

Note that from the perspective of the overall supply chain (i.e., first best), the supplier's incentives to adapt in a coordinated way are too weak since $\gamma\delta < \gamma$. In an outsourcing contract, the *supply chain externality* is not fully internalized. 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 downstream firm just pushes its intermediate downstream, it only adapts to the local upstream conditions. In a JIT scenario, by contrast, $\mathbb{E} [\theta_\tau | \mathcal{I}_S^M] = \rho^\tau \theta_1$, and the supplier is in a position to coordinate its adaptation decision with what happens downstream in the supply chain. For illustration, 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. This will help cut mis-coordination inventories and make the transaction more efficient.

For the downstream firm, the overall expected procurement costs incurred with a certain supply chain structure, $c^*(\tau, M)$, 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):

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

The first term in the curly brackets, $\gamma(1 - \rho^\tau)/(1 - \rho) * \sigma_\varepsilon^2$, corresponds to the inventory holdings costs due to the inevitable order lag of τ . The second term in the bracket, which is only present 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 more aligned with the buyer's interest, i.e., when the supply chain externality is lower. This insight will be at the heart of the complementarity between JIT and vertical integration in the next subsection. Finally, and quite naturally, JIT is particularly valuable if inventories are costly (high γ).

The third term in $c(\tau, M)^*$ captures two inefficiencies that arise from the coordination trade-off. First, partial adaptation to the upstream supply shock creates additional inventories downstream, which are larger when σ_η^2 is high or when the supplier puts more weight on local adaptation due a low δ . Secondly, coordinated adaptation creates productive inefficiencies upstream in the form of an inferior response to the η shock, which also increase in the variance of the upstream supply shock, σ_η^2 . In other words, the downstream firm's manager is asked to pay a higher price for the intermediate as compensation if the supplier is supposed to coordinate well with its customer.

On the ex ante stage, downstream firms decide on whether to produce, operate with traditional supply chain management, or operate using a JIT regime. Their profits take the general form

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

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

Since $c^*(\tau, \neg JIT) > c^*(\tau, JIT)$ 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 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 exactly break even is given by

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

The analogous cut-off that characterizes firms that are indifferent between producing with or without JIT supply chain management is

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

Note that nothing so far prevents that $\varphi^{\tau, \neg JIT} > \varphi^{\tau, JIT}$, in which case all active producers do so under JIT. In what follows and consistently with the data, 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

In this subsection, I allow for the downstream firm to choose its supplier’s location and whether or not that supplier is vertically integrated with the buyer firm. The spatial and ownership structure of the supply chain is therefore endogenous and free to interact with the JIT management decision.

Additional Assumptions

With regard to location choice, the buyer is free to pick an optimal location τ on the ex ante stage $t = 0$. For simplicity, there are no fixed costs of upstream market access and there are no additional trade costs. Both types of frictions can be introduced without much effort, but the additional insights regarding the interaction between supply chain management and location choice are minimal. It is therefore better to facilitate the exposition and abstract from these complications.

Furthermore, the two companies are now allowed to merge. As in [Hart and Holmstrom \(2010\)](#) and [Legros and Newman \(2013\)](#), for example, ownership confers so-called residual decision rights: In situations where incomplete contracts no longer provide any guidance as to how decisions should be made, the final say lies with the owner of the productive assets. Even if ownership and management are in different hands, the idea is that if an employee-manager takes such a residual decision in a way conflicting with the

owner's interest, the manager can be fired. To avoid the numerous complications highlighted by the vast principle agent literature, I assume that this threat is fully credible and sufficiently powerful to ensure that the owner is always – effectively – in a position to make decisions according to her discretion.

In the model at hand, this means that under non-integration or outsourcing (indexed NI), where the upstream and downstream parties are fully independent, the manager of the supplier makes decision d_S to maximize her own 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 (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. Finally, as in [Antràs and Helpman \(2004\)](#), I assume that it is costly to manage such a large firm and I denote the proportional increase of total overhead by $\lambda_{VI} > 1$, so that overall fixed costs become $\lambda_{VI}\lambda_M f$. These fixed costs can be interpreted as “bureaucracy costs” in the spirit of TCE type models ([Tadelis and Williamson, 2012](#)).³⁸

The second difference between arm's length trading and intra-firm procurement is the contractual set-up. In this framework, by assumption, the overall efficiency of the input transaction does not depend on how rents/revenues are shared within the (multinational) firm and therefore I will not make any assumptions about the employment contracts that govern the flow of funds.

Finally, the supply chain supervisor in a vertically integrated setting uses the same information when making the adaptation decision at stage $t = 1$ as do the individual managers of the separate firms in an outsourcing relationship. Her information sets are therefore

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

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

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

for JIT supply chains.

This stark assumption ensures that JIT and vertical integration are two entirely different organizational margins, where the former affects only the flow of information and the

³⁸Outsourcing certainly involves overhead expenditure, too. Typically, however, these are smaller than under vertical integration, since managers can focus on fewer functions and thus be more efficient. Indeed, the very act of outsourcing is often described as ‘turning fixed into variable costs’. In my model, $\lambda_{VI} > 1$ can thus be interpreted as the *differential* between the fixed costs of vertical integration and those of outsourcing.

latter only changes the incentive structure. It is likely that more information is exchanged among employees of the same company than among those belonging to two independent ones.³⁹ The assumption imposed here is, however, much stronger than required for my purposes. As long as vertical integration does not imply perfect information – say, the demand signal in $t = 1$ is communicated with noise – the qualitative implications of the model are unchanged. I rely on the more stylized assumption to carve out the workings of the mechanisms as clearly as possible. Moreover, the assumption is consistent with many real world contexts, where managerial overload makes it difficult for the supply chain supervisor to relay all information to all suppliers in a complex supply network.

Solution

I follow the same backward induction strategy as for the baseline model, but 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. Each branch has infinitely many strains due to the continuous location decision.

The optimal price the downstream firm charges its customers is

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

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

Focusing on the branch of the game where the transaction is carried out entirely within a (multinational) firm, the supply chain supervisor takes all decisions with the goal of minimizing the overall overall procurement costs, i.e., she solves

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

and the optimal decision is given by

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

The same 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 technology shock, since the supply chain supervisor puts more weight on coordinated

³⁹Relatedly, even if vertical integration cannot improve extensive margin of information sharing, it might affect the intensive one if it implies that strategic motives are removed, as in the case of cheap talk.

adaptation. Intuitively, vertical integration provides the right incentives for the supplier to contribute to the success of the transaction – the supply chain externality is fully internalised.

The overall procurement costs under vertical integration amount to

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

Comparing this expression to one under outsourcing, (7), there are two important differences. The first is that the gain from JIT is larger, *ceteris paribus*, since the supplier plant makes efficient use of the demand information in the sense that it puts inventory minimizing weight on coordinated adaptation. Mathematically, this 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 supplier is vertically integrated.

The second difference is that the supplier resolves the trade-off between local and coordinated adaptation more on the side of the latter and therefore inventories are lower. This gain is reflected in the smaller coefficient on σ_η^2 . Overall and *ceteris paribus*, procurement costs are lower under vertical integration due to its superior ability to align incentives along the supply chain.⁴⁰

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

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

where $\lambda_{NI} = 1$.

Solving this program with respect to τ leads to the first main proposition, which provides the conceptual grounding for the stylized fact presented in 2.2: French firms, when they operate a JIT supply chain, are more likely to have a trading relationship with closer partner countries, and then trade more in terms of value with them.⁴¹

⁴⁰There is a third and so far unmentioned difference: as the supplier puts less weight on local adaptation, productive efficiency is somewhat compromised. This effect, however, never tips the cost balance in favor of outsourcing.

⁴¹While locations are discrete in this model to make for a simple interpretation of stages in the game, I

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

Proof. See section A.1 in the Online Appendix. ■

The intuition behind the trade-offs that shape Proposition 1 can be illustrated using the cost functions (7) and (10). In a ‘traditional’ supply chain without information sharing, high time-to-ship creates inventory costs due to the fact that demand is inherently uncertain and may move away from its initial state during transit. At the same time, suppliers that operate close to final demand face higher primary factor costs, at least in the case of French manufacturing. The JIT system reduces inventories by providing the supplier with a means to predict demand more accurately and coordinate better with the downstream buyer. This reduction is, however, greater for suppliers close-by: an initial signal about demand conditions is very valuable as less time elapses between production of the intermediate and final consumption. By contrast, a remote supplier will pay little attention to the same signal, since it is of much less use for prediction. Since the marginal benefit of proximity is therefore higher in a JIT system – while the marginal costs in terms of primary factor costs remain the same – a JIT supply chain will be ‘shorter’ than its ‘traditional’ peer (*extensive margin*), *ceteris paribus*.

Defining the intensive margin of trade appropriately in the model, I can show that intermediate trade volumes are skewed towards partners nearby, too (*intensive margin*). The intuition behind this finding is that the procurement costs (7) and (10) are lower due to the complementarity between JIT and proximity. This in turn implies that a JIT firm with a given core productivity charges its downstream consumers lower final output prices, attracts more demand, and hence itself orders a larger quantity from its supplier.⁴²

I now turn to ownership and supply chain management patterns. Firms sort into different set-ups via cut-off rules in productivity, as they trade-off fixed against variable costs (both in the case of JIT and vertical integration). The cut-offs are defined by indifference conditions and take the form

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

While different parametrizations can in principle lead to a substantial number of dif-

nevertheless treat τ as continuous to abstract from mathematical complications and thus allow for a clear exposition of the main trade-offs involved.

⁴²In Online Appendix A.1 I show that there is also a price effect that shapes the intensive margin. JIT reduces mis-coordination inventories that lead to a lower price of the intermediate, too. Under realistic assumptions about the downstream demand elasticity, however, the quantity effect generated by lower downstream prices dominates this price effect on the intermediate.

ferent sorting patterns into the four tuples of ownership and management, there are only two relevant cases I have to analyze. To see this, return to the sample of supply relationships in Subsection 2.3 in the first empirical part of this paper, for which I know both whether a particular firm engages in JIT and whether that firm produces intermediates in one of 100 upstream industries, either directly or through affiliates. 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 the conceptual model. It turns out that, in 2006, out of 214 NAF downstream industries (4 digits) with both JIT and non-JIT firms, 211 (98.6%) exhibit full heterogeneity: all four possible configurations of ownership and management occur simultaneously.⁴³ I can therefore restrict my analysis to the parameter space that yields such equilibrium outcomes at the industry level from here onward. With this preliminary established, the following proposition can be derived:

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

Proof. See section A.3 in the Online Appendix. ■

First note that Proposition 2 is a statement about relative conditional frequencies within an industry: Among JIT supply relationships the share of vertically integrated ones is higher than among ‘traditional’ ones. The intuition for this finding rests on the complementarity between JIT and vertical integration.⁴⁴ Investing in a JIT system and vertically integrating both convey a variable cost advantage that is worth having even in the face of higher fixed costs, provided a firm is sufficiently productive. While the additional resources needed for managing manufacturing of intermediates in-house 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. Consequently, JIT firms require a smaller ‘increase in productivity’ to be convinced of vertical

⁴³In 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 and a comparison of ownership patterns across different supply chain management styles is not meaningful anyway. 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.

⁴⁴One may be tempted to ascribe a role to the fixed costs involved in the different set-ups. As Section A.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} (ignoring the degenerate case where all firms choose to vertically integrate and adopt a JIT system).

integration than their non-JIT counterparts. With a “regular” distribution of productivities, like the Pareto assumed in this model, the complementarity implies Proposition 2.⁴⁵

As discussed above in Subsection 2.3, this conceptual result is borne out by the data in the sense that French JIT firms report more in-house activities and more intra-firm trade than their non-JIT counterparts.

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 margins that are virtually unique to the theoretical framework presented and because I can obtain credible empirical proxies in the data. All three measures are assumed to vary primarily at the industry level, since assignment to industries is done on the basis common output characteristics and it seems plausible that these three parameters are related to features of the production technology employed. The goal is to study how these characteristics re-enforce or weaken the positive correlations between JIT supply chain management and proximity on the one hand, and between JIT and vertical integration on the other.

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 by predicting for which industries the omission of JIT supply chain management in forecasts and counterfactual analyses will be particularly problematic.

4.1 Testable Implications

Using the full model I establish the following proposition.

⁴⁵Since 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 distribution is a very 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](#)).

Proposition 3 *Ceteris paribus, in industries with*

1. *high inventory carrying costs ($\gamma \uparrow$)*
2. *high demand persistence ($\rho \uparrow$)*
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 A.4 in the Online Appendix. ■

JIT supply chain management, which reduces the level of inventory holding, obviously has a high return when stocks are costly. Reducing the value of demand information by choosing a more remote supplier or providing weak incentives to coordinate by outsourcing is therefore a particularly bad idea. 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.

For the other two comparative statics, I focus on the intuition concerning vertical integration first. First, imagine a downstream industry with very low demand persistence. Little can be gained from vertical integration with the upstream supplier, since even if it had the right incentives to take a potential demand signal due to JIT into account, uncertainty severely limits what can be achieved in terms of coordination. By contrast, when the downstream industry's demand shocks are very persistent, real-time information exchange is valuable and so is aligning the supplier's incentives with whole supply chain. Similarly, in supply relationships where upstream decision makers put little weight on coordinated adaptation since they can avoid paying for inventories (low δ), the combination of JIT and vertical integration has large coordinating benefits.

The impact of demand persistence in Proposition 3 on locational patterns is not unambiguous analytically and the direction depends on the net of two forces. On the one hand, when ρ is high, any downstream signal is particularly useful for prediction and hence valuable, so that the return from complementing JIT with spatially agglomerated production is higher. 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. Anticipating the exposition below, the latter effect,

which is strongest in the vicinity of $\rho = 1$, is expected to be second order in the light of the low levels of demand persistence documented in Online Appendix Table C.2.⁴⁶

The scope for inventory pushing only affects transactions between unrelated parties, because the identity of the plant that actually holds stocks is immaterial when both are part of the same profit maximizing unit. In outsourced trade relationships of downstream industries where the supply chain externality can easily be internalized by inventory pushing, incentives are well aligned and thus the value of a JIT regime between trade partners located in close proximity is particularly high. Since the majority of trade flows happens between unrelated partners – and especially in JIT supply chains when δ is high – the prediction in Proposition 3 is expected to hold on average in the data, even if I cannot properly distinguish between intra-firm and independent party trade.

4.2 Empirical Strategy and Results

How do these industry level predictions hold up against the data? I first describe empirical proxies for the three industry level characteristics of interest and test Proposition 3 by studying heterogeneity in my baseline estimates outlined in Section 2.

Specifications and Empirical Proxies

To capture the inventory cost parameter γ , I rely on the assumption that the purchase value of an intermediate is a key determinant. While many factors influence the cost of storing goods, like bulkiness, market prices for warehousing, or land rents, 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 working capital tied up, 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 the 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 (see Online Appendix B for details). 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. These IO coefficients describe the total value of inputs shipped from a particular upstream industry to a firm in a given downstream industry as a share of the downstream value of total output. On other words, they capture the value of intermediates sourced by a given downstream industry from one upstream industry *relative*

⁴⁶In unreported regressions I explore the convexity in the effect of ρ on the relationship between JIT and trade partner proximity and find no statistically significant evidence for a non-monotonicity.

to another – given the fixed effects strategy I employ, direct requirements are therefore an appropriate proxy for inventory holding costs.

Following the model’s assumptions closely, I measure industry level demand persistence ρ_i by the AR1 coefficient estimated on annual firm sales.⁴⁷ The summary statistics in Panel C of Online Appendix Table C.2 show that a unit shock to sales has a half-life of about $-\ln(2)/\ln(0.403) \approx 9$ months for the average 4 digit NAF industry and 95% of the industries have half-lives between roughly 4 months and two years. Compared to shipping times, the average industry loses about 4.5 percentage points of a unit shock in a single order cycle.⁴⁸ These numbers are substantial and there is considerable variation across industries. Finally, since I do not have information about demand persistence in other countries of similar quality, I resort to a sample based on imports for all distance related regressions.

Finally, a proxy for ‘inventory push-up’, i.e. the capacity for downstream firms to “force” their upstream suppliers to share in the costs of inventory holding, is needed. 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 contracting, and influences integration decisions directly. The most appealing alternative is to use observed inventories. For vertical integration regressions, I compute the ratio of average inventory holdings (as a share of sales) by the upstream industry to the same variable in the downstream one:

$$\delta_{ijt} = \log \left[\frac{1 + \frac{\text{invent}_{jt}}{\text{sales}_{jt}}}{1 + \frac{\text{invent}_{it}}{\text{sales}_{it}}} \right],$$

where j is the up-, and i is the downstream industry as before. The signal in this variable captures the burden borne by the upstream firms relative to the burden borne by the downstream ones. As Panel C in Online Appendix Table C.2 illustrates, inventory holdings tend to be roughly balanced between the upstream and the downstream sector in the average and median input supply relationship, with a slight tendency towards upstream inventory holding. For distance related regressions, where I focus on a sample of imports and have no information about upstream inventory holding, I concord CN 8 digit products to their output industries using the French data and proxy foreign inventories by French holdings in those industries.

⁴⁷Using all manufacturing firm exports from the French universe of customs data, I estimate the model $\log(\text{sales}_{fit}) = \rho_i \log(\text{sales}_{f,i,t-1}) + \gamma_t + \beta_1 \text{trend}_f + \varepsilon_{fit}$, where γ_t is a set of year fixed effects and aggregating is done using current sales as weights. All results are fully robust to using the AR1 coefficient based on exports rather than overall sales.

⁴⁸The exact calculation is $0.403(18.49/365.25) \approx 0.955$.

I interact the main regressors from the baseline specifications related to location, (1), and vertical integration, (2), with proxies for the parameters of interest. Once again I make use of quantile indicators, rather than the proxies themselves.

Results

I illustrate the results for the first part of Proposition 3 relating to the spatial structure of JIT supply chains, in a series of maps shown in Figure 5. The details for all regressions are reported in Online Appendix Table C.8 and since the patterns for the extensive and intensive margins are very similar, I focus on the latter here. The left hand side graph in each panel shows the coefficients from the baseline specification (1) when the characteristic is above the median of the relevant distribution, while on the right hand side, the characteristic is (be-)low.

To remind the reader, one would expect that, while JIT firms are embedded in more regional supply chains in general, this pattern is stronger for goods that are costly to store, when demand is very persistent, and when inventories can be pushed up to the supplier firm. The first and second prediction is very much supported in the data (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. At the same time, 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 holdings is available to me, my proxy for δ is of somewhat limited quality.

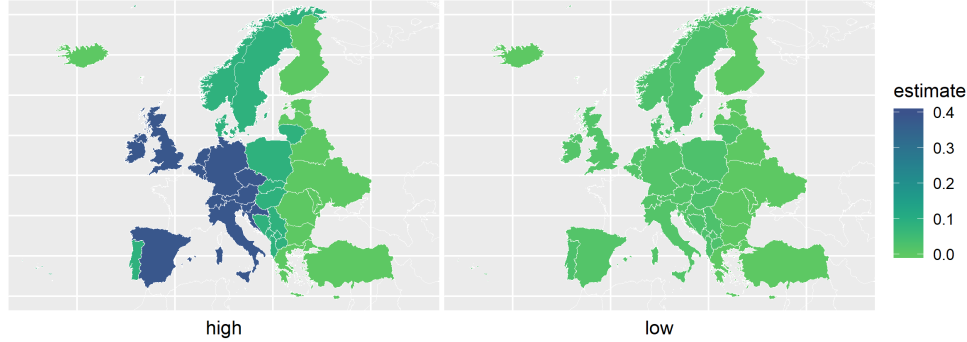
Next I examine the industry patterns of vertical integration and illustrate the results in Figure 6 – all details are reported in Online Appendix Table C.9, columns (1), (3), and (5). The dark blue bars depict the coefficient estimates on JIT from the baseline regression (2) when the characteristic depicted below the x axis is high (above median), while the light green ones relate to the characteristic being low.

All three predictions regarding vertical integration are strongly supported by the data and apply to both domestic firms and multinationals. First, JIT firms in-source more of those upstream activities where inventory holding is particularly costly, either because of the large quantity or high unit price transacted.⁴⁹ Secondly, when the downstream industry's demand is more persistent, the return to combining JIT with vertical integration is high. Finally, for both overall and foreign vertical integration, pushing inventories on upstream suppliers to internalize their externality proves to be an important substitute to

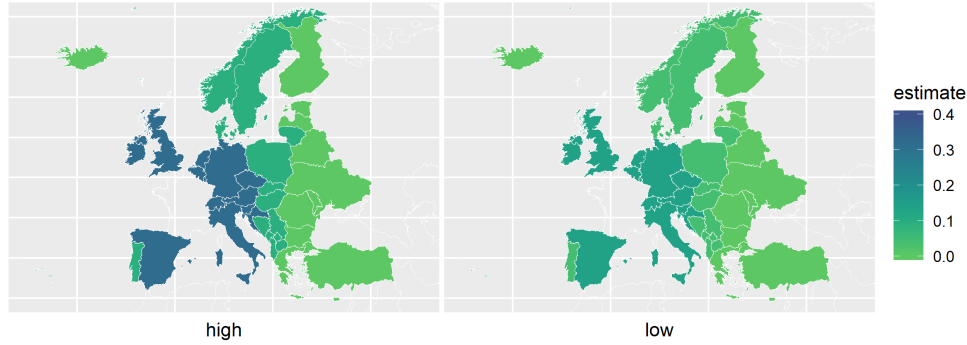
⁴⁹One may be concerned that the value transacted in a relationship drives ownership decisions as in Legros and Newman (2013) and Alfaro et al. (2016). It is not obvious, however, why JIT supply chains should respond to transaction values differently from 'traditional' ones.

Figure 5: Heterogeneity – Intensive margin

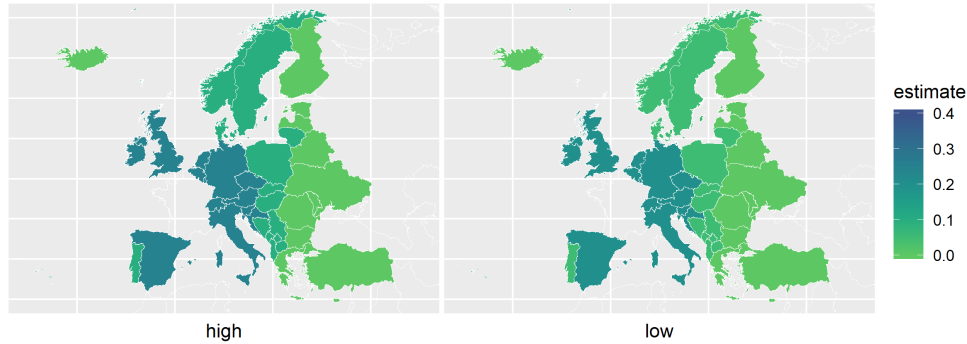
(a) inventory costs



(b) demand persistence



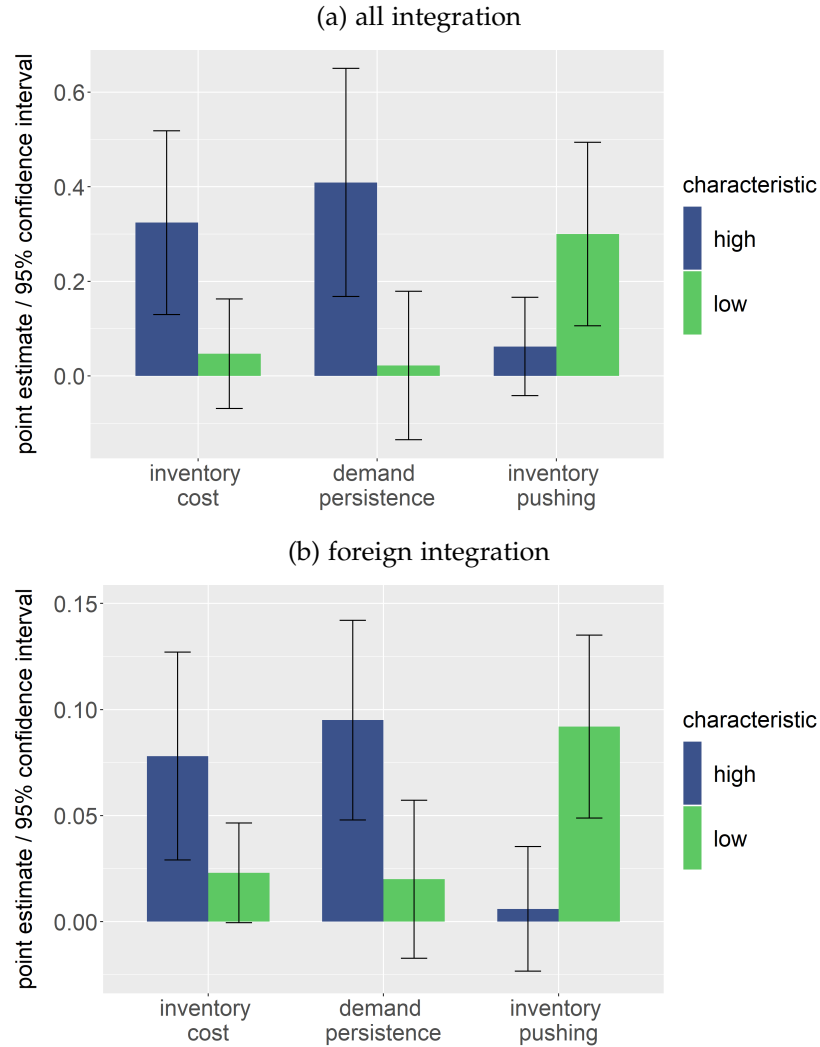
(c) inventory pushing



The dependent variables are a dummy equal to one 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 whose values are plotted in the maps are interactions of a dummy equal one if a firm is part of a JIT supply chain in a year, and zero if not, with quintile dummies from the across country time-to-ship distribution. Moreover, these variables are interacted with dummies equal to one if one of the following measures is above – left maps in panel – or below – right maps – the median of the relevant distribution: a) the pre-sample median unit value within a given 8 digit CN product; or b) the downstream industry's demand persistence; or c) the downstream industry's inventory over sales ratio. 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.

direct control via ownership in this context where coordination is the objective.

Figure 6: Heterogeneity (incl. 95% confidence intervals)



The dependent variables are a dummy equal to one hundred if an 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 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 above and below median indicators in the distribution of a) direct requirements at the upstream-downstream industry level (inventory cost); or b) sales autocorrelation coefficients at the industry level (demand persistence); or c) relative inventories at the upstream-downstream industry level (inventory pushing). Firm controls: value added per worker; physical capital intensity; intangible capital intensity; skill intensity (all in logs). Standard errors for confidence intervals are clustered at the firm level. Online Appendix Table C.9 reports all underlying results.

The literature on (multinational) firm boundaries and integration has discovered and established a number of industry level determinants which raise potential concerns that

my results are in fact driven by these factors. To address such reservations, I include a number of interactions between firm and industry specific characteristics in all regressions.

First, the contracting environment plays an important role in shaping the possibilities for opportunistic behavior in a supply relationship. To capture this idea empirically, I make use of the Harvard complexity index, the share of differentiated goods in exports according to the [Rauch \(1999\)](#) measure, and the share of non-routine tasks in production.⁵⁰ It is more difficult to contract over the characteristics of more “sophisticated” inputs and it is not surprising that there is strong evidence on their significance for firm boundaries (see, for example, [Costinot et al., 2011](#)). Moreover, as suggested by the workhorse model for multinational firms, the property rights theory (PRT), it is well known that intrafirm trade is shaped by the relative contribution of the upstream industry to the overall output of a supply relationship, i.e. the marginal contribution. [Antràs \(2015\)](#) surveys evidence that capital and skill intensity as proxies have significant impacts on the outsourcing decision. Moreover, [Antràs and Helpman \(2004\)](#) show that both the absolute productivity of firms as well as its dispersion within an industry matters for multinational activity due to the presence of fixed costs. These predictions were later tested successfully by [Nunn and Trefler \(2013\)](#). Consequently, I compute overall physical and intangible capital intensity, skill intensity, and value added per worker at the industry level and interact them both upstream and downstream with the JIT dummy.⁵¹ Columns (2), (4), and (6) of Online Appendix Table C.9 show that all point estimates are stable and the heterogeneities I document are not driven by the aforementioned mechanisms.

5 Policy Implications for Brexit and COVID-19

In this section I employ the conceptual framework and the additional 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 efficient JIT manufacturing and the organizational margins emphasized in this paper (location and ownership). 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 reorganized and which industries/industry pairs would be most heavily affected.

⁵⁰For details on how I construct these and all other variables, see the Online Appendix B.

⁵¹Note that due to the upstream by downstream industry fixed effects, all the variables described are absorbed in the baseline results.

5.1 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.⁵² In my framework, one may think about such delays as an increase in shipping time for any given location τ , so that perceived distance becomes $X * \tau$ with $X > 1$. Procurement cost functions are now

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

and

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

with the associated productivity cut-offs.

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 “made-to-order” production decreases. As a consequence, the share of firms who manage their supply relationship in a JIT fashion declines.

Following Proposition 1 and inspecting the first order conditions for location decisions, the difference in spatial concentration between JIT and non-JIT supply networks

⁵²In February 2018 the UK’s Business, Energy and Industrial Strategy Committee stated: “The volume manufacturers rely upon the just-in-time delivery system, under which components are delivered directly to the assembly line and there is a very limited requirement for warehousing of stock. [...] We saw at first hand the arrival of trucks to the Honda factory in Swindon every seven minutes and the seamless delivery of parts to the line. [...] We heard from Honda their estimate that a 15 minute delay could add around 850,000 per year in costs - a significant sum [...] Other companies had made similar calculations of the increased costs associated with border delays.” (available at <https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/379/37902.htm>, accessed 21/08/2019).

shrinks. Put differently, while all firms will skew their supply chains more towards local trade partners as a result of longer waiting times at the border, 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 value of JIT is lower. In sum, while JIT supply chains are particularly affected by Brexit, their reorganization alleviates the tendency for UK trade with remoter partner countries to fall. Of course, this comes at the price of lower productive efficiency and 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, however, suggests a(n additional) reason for why this position may be under threat at least in manufacturing. As the JIT intensity of UK and European production falls due to frictions at the border, more and more firms will sell their stakes in foreign subsidiaries and hence FDI stocks are reduced – after all, ‘traditional’ supply chains, where coordination is less important, can more easily be controlled using outsourcing contracts. I am not aware that this point has been highlighted in the Brexit policy discussion yet.

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 35), “motor vehicles, trailers and semi-trailers” (34), or “office machinery and computers” 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.10 for the relevant summary statistics). At the same time, trade with remote countries will fall substantially in “wearing apparel; dressing and dyeing of fur” (18) or “leather products” (19). 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.

5.2 COVID-19

Relating to the COVID-19 outbreak in 2020, business people, economists and politicians have highlighted the role of highly coordinated and lean international supply chains for the consequences of, and how the world can deal with, pandemics or similar public health emergencies. To form visions and policy stances regarding how supply chains will have to be reorganized, a sound understanding of the world after the COVID-19 crisis is required. I use both the conceptual framework and the empirical evidence presented in this paper to provide an informed discussion about some of the long run implications of

the COVID-19 crisis for the structure of global supply chains.⁵³

The emergence of the SARS-CoV-2 virus can be thought of as a shock to (perceived) uncertainty, either because COVID-19 will become a normal and perhaps seasonal illness with regular outbreaks, or because the risk of pandemics has become more salient after having been underestimated. 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 or of the downstream shock ε (but typically both to different degrees). I will view these scenarios through the lens of the model in turn.

The first observation borne out by the conceptual framework is that *vertical integration* in supply chains becomes relatively more attractive, since it improves coordination when it is most needed. Larger upstream shocks due to an increase in σ_η^2 aggravate the supply chain externality under outsourcing since they require drastic adaptation decisions upstream that make coordination with downstream demand conditions more difficult. While procurement costs increase regardless of organizational form, this negative effect is smaller for intrafirm transactions.

The complementarity of vertical integration with JIT supply chain management pushes firms towards adopting the latter and the overall share of JIT firms increases. Intuitively, the need for more control in the supply chain makes demanding systems like JIT relatively more attractive and the model in sum predicts that industries towards the downstream end of value chains will see more highly coordinated multinational production. Since such a supply chain structure also tends to be more spatially concentrated, one would furthermore expect stronger regionalism in international trade.

Alternatively, the COVID-19 crisis may be conceptualized as an increase in demand uncertainty, σ_ε^2 , especially for industries upstream in the value chain. Once again, while inventory costs increase for every organizational set-up, highly coordinated JIT supply chains tend to cope better with the situation since they imply superior coordination. This advantage is even greater for vertically integrated or multinational production, which is the form of ownership that is thus expected to become more prevalent. The complementarity between JIT and proximity, moreover, implies that trade partners will be closer to each other.

In sum, my conceptual framework provides a rationale for global supply chains to become even more highly coordinated, vertically integrated, and spatially concentrated when the world is more uncertain, since such a structure is designed to deal more effi-

⁵³The 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 shocks, the conceptual framework in this paper is not well suited to address such questions.

ciently with the enhanced requirements for adaptability than a ‘traditional’ one. As in the case of Brexit above, this pattern is, however, stronger in some, and weaker in other industries in line with the heterogeneities described in Section 4. Moreover, it applies to any shift towards more uncertainty, be it due to a new virus, climate change, or political instability and populism.

6 Conclusion

JIT supply chains are prevalent and constitute an important organizational margin 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 more concentrated in space and more vertically integrated. To give a structural interpretation to these patterns in the data, I have proposed a stylized conceptual framework. It illustrates that the additional downstream information that is disseminated throughout the supply network in a JIT regime is particularly valuable for coordination if all parties have incentives to react to it properly (vertical integration) and when order lags are short due to proximity. As a consequence, all three organizational margins are complements to each other. To lend further credibility to the framework, I show that additional predictions regarding how the 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 attractive due to their superior abilities to adapt in a coordinated, and therefore efficient way.

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 which enable 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 conception, global supply networks may become even more concentrated in term 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 intra-firm 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 to shocks. 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.

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A Online Appendix

The Online Appendix can be found on the author's webpage or here:

<https://drive.google.com/open?id=1ClB05BHBb1vaiTQsMCD7le0iESB0CvW1>