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# Third-Country Effects in Multinational Production Networks*

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**Abstract**

The majority of multinational firms today operate a multilateral production network. Most existing empirical analyses have, however, focused on firms' choice between producing at home and investing overseas and assumed a firm's decision to invest in a foreign country is independent of its locations in third countries. This paper extends the literature by examining the effect of existing production network on multinationals' entry decision. Using detailed French multinational subsidiary-level data, the paper finds strong evidence of horizontal and vertical interdependence across multinationals' foreign production locations. There is, however, little evidence of horizontal interdependence between home-country production and foreign investment when the third-country effects are taken into account, constituting a sharp contrast to the conventional emphasis. This result is robust to the various specifications and sensitivity analyses undertaken in the paper, and suggests the importance of investigating the causes and effects of foreign direct investment in the context of multinational production network.

Key words: multinational firm, production network, interdependence, entry decision, trade cost, input-output linkage

JEL codes: F23, D21

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# 1 Introduction

The majority of multinational corporations (MNCs) today operate a multilateral production network. An average French multinational, for example, invests in 3.8 foreign countries in 2007, with an increase of 0.93 country per firm compared to 2005. This expansion of multinational production has raised anxiety in many developed countries over the possibility of increasing job losses at home. It has also led to escalating competition in developing countries that are keen to attract foreign direct investment (FDI). In parallel to these political attention, a large economics literature has developed to address the causes and effects of FDI, with predominant emphasis on the relationship between home-country production and foreign investment. Most studies in this literature have assumed that a multinational firm's decision to invest in a foreign country is *independent* of its existing production network in third countries, an assumption that is increasingly challenged as multinationals expand their production across foreign nations.[1]

This paper addresses the above issue by examining the effect of third-country production network on multinationals' entry decisions. To achieve the goal, the paper employs a rich dataset that provides detailed information on French manufacturing firms' foreign subsidiaries in 2005 and 2007. For each subsidiary, the data reports the location, ownership status, and production activities. These information allow the paper to identify each individual firm's production network around the world and compare the structure of the network over time. They also enable the paper to establish intra-firm linkage between subsidiaries, in particular, the input-output relationship between subsidiaries' production activities. This makes it possible to distinguish the nature of interdependence between multinationals' foreign subsidiaries.

Figure 1, for example, plots the geographic distribution of Renault's global production network. Two observations emerge in this figure. First, Renault owns subsidiaries in more than 10 countries outside of France. Second, Renault segments its production across its foreign production locations by producing components in countries such as Argentina, South Korea and Spain (represented by the darker area) and performing end processes in countries such as Russia and Colombia (represented by the lighter area). These phenomenon are not exclusive to Renault, however. Figure 2 shows a similar pattern for another French multinational firm, Essilor, that specializes in lens products. In fact, our data indicates that as of 2007 French multinational firms have, on average, 0.72 upstream subsidiaries abroad (where they produce intermediate inputs that are required by the production of their final goods) and 2.49 downstream subsidiaries (where they produce the final products). It is clear that multinationals' investment decision

[1] We discuss the related literature in great detail below.

can no longer be viewed as a choice between producing at home and investing abroad; it involves instead a network of vertically linked subsidiaries.

[Figures 1-2 about here]

Our econometric evidence suggests there is a strong interdependence in multinationals' foreign production network. Existing subsidiaries in third countries exert a significant effect on multinationals' expansion decision, in both downstream and upstream production. First, MNCs are more likely to locate downstream production in countries where the cost of importing final goods from the firms' existing foreign subsidiaries is relatively high. We refer to this effect as "horizontal interdependence". Second, multinationals tend to produce the final product in countries with better access to large export markets where the MNCs do not have downstream production. We label this effect as the "market potential" factor. Third, there is a significant interaction between upstream and downstream subsidiaries. Specifically, multinationals tend to locate the final-good production in countries where the cost of importing intermediate inputs from the firms' existing foreign upstream subsidiaries is relatively low. Similarly, they are more likely to select countries with better market access to the existing downstream subsidiaries as intermediate-input production locations. We refer to this type of interaction as "vertical interdependence" and show that it is not uniform across vertically linked subsidiaries. The interdependence increases in the extent of input-output linkage between subsidiaries as well as the size of market demand in downstream production locations.

In sharp contrast to the strong interaction between MNCs' foreign production locations, there is little evidence of horizontal interdependence between multinationals' production at home and new investment abroad. We find in the paper that evidence that would support the traditional argument — on the tradeoff between foreign investment and home-country production — becomes insignificant once we take into account the third-country network factors. Instead, we observe a vertical interdependence. These results are robust to the various specifications and sensitivity analyses undertaken in the paper to address the bias of omitted variables and the potential endogeneity of network factors. This deviation from the literature suggests that assuming away the interdependence between foreign production locations is likely to give rise to biased estimates on the relationship between the performance of the home economy and FDI activities and, more generally, biased understanding of the true causes and effects of FDI. It calls for a reconsideration of the conventional specification that takes into account the effect of third-country network. The findings also convey an important message to host-country policy makers that seek to influence the inflow of foreign investment: FDI inflow to third countries can affect a country's ability to attract multinationals. The effect can be either

positive or negative dependent on the linkage of FDI flows.

This paper is closely related to a recently developed theoretical literature, led by Yeaple (2003a), Ekholm, Forslid and Markusen (2007), and Bergstrand and Egger (2008), that applies FDI modeling to a three-country framework. These studies build on the seminal work of Markusen (1984) and Helpman (1984) and influential empirical contributions by Brainard (1997), Carr, Markusen and Maskus (2001), Yeaple (2003b), Helpman, Melitz and Yeaple (2004), and Hanson, Mataloni and Slaughter (2005), who point out the two main motives for multinationals to invest abroad are market access and comparative advantage.[2] Yeaple (2003a), Ekholm, Forslid and Markusen (2007), and Bergstrand and Egger (2008) show that the combination of the market-access and comparative-advantage motives can lead to export-platform FDI, where a multinational firm invests in a host country with the intention to serve third nations via exports from the host country. This prediction suggests that multinationals' investment decision cannot be viewed as a binary choice between exporting from home and investing abroad; it engages other, third nations.

The majority of the empirical literature has, however, not taken into account the third-country effect, much less the interdependence between multinationals' foreign production locations. The following few studies took the step to examine the determinants of export-platform FDI. Head and Mayer (2004) show that third-country market demand plays a significant role in a country's ability to attract multinational firms. They find that Japanese multinationals are more likely to locate their production in regions proximate to large markets. Baltagi, Egger and Pfaffermayr (2007) consider a broader set of third-country characteristics, and find most of the characteristics affect the level of U.S. outbound FDI in seven manufacturing industries even though there is no conclusive evidence on export-platform or vertical FDI. Chen (2009) examines how a host country's preferential trade agreement with third nations can affect the country's receipt of FDI and finds that countries integrated with large markets tend to experience an increase in total and export-platform investment. She also shows that the effect is especially strong for labor-abundant countries, but at the expense of their labor-scarce preferential trading partners.

Blonigen, Davies and *et al.* (2007) is among the first that investigates cross-country interdependence in FDI. Using U.S. outbound FDI data, they examine how investments in third countries affect a country's receipt of FDI from the U.S. They find the results are highly sensitive to the sample of host countries examined: The third-country effect can be either insignificant or of reverse signs. There is some evidence of negative interdependence across proximate host countries — a result that is consistent with the

[2] See Blonigen (2005) for an excellent survey of this literature.

export-platform FDI theory — but mainly among European OECD members. They also find that including third-country FDI does not alter the estimated effect of traditional FDI determinants.

This paper examines the cross-country interdependence in individual multinationals' production networks using subsidiary-level data. The dataset employed here offers two distinct advantages relative to the aggregate data used in the literature. First, it allows us to distinguish horizontal and vertical linkage for each pair of subsidiaries at disaggregate industry level (NACE 4-digit), following the methodology introduced in Alfaro and Charlton (forthcoming). This distinction cannot be done at the aggregate industry level that has been considered in previous studies (e.g., "industrial machinery and equipment") because as Alfaro and Charlton (forthcoming) point out a large percentage of vertical FDI is intra-industry. This, to some extent, can explain the ambiguous evidence in Blonigen, Davies and *et al.* (2007) where estimates reflect a mix of horizontal and vertical interaction. Second, we examine individual multinational firms' entry decision. In contrast to aggregate sectoral FDI data that combines all individual firms, this allows us to compare the effect of traditional FDI determinants with the effect of third-country network at firm level. We find the ability to focus on intra-firm interdependence leads to sharply different findings than previous studies: The estimated horizontal interdependence between FDI and home-country exports disappears once we include third-country network variables. This departure from previous findings is not surprising given the data used there is not equivalent to an individual firm's investment decision.

The rest of the paper is organized as follows. In Section 2, we use a three-country model to analyze firms' upstream and downstream location decisions given their existing production network. Based on this model, we derive several testable hypotheses and a corresponding econometric model. We then describe the econometric methodology in Section 3 and data sources in Section 4. In Section 5, we examine the geographic attributes of French MNC production networks. We present the main econometric results in Section 6 and several sensitivity analyses in Section 7. The paper concludes in Section 8.

# 2 Theoretical framework

## 2.1 Basic setup

We build a simple model to examine multinational firms' location decision. Suppose the world consists of three countries $\mathcal{N} = \{A, B, C\}$. The representative consumer in each country allocates a certain amount of her expenditure, denoted as $I_j$ ($j \in \mathcal{N}$), to the industry of differentiated products. Within this industry, the consumer has a utility

function that exhibits constant elasticity of substitution (CES). Maximizing the CES utility function subject to the consumer's expenditure level yields the consumer demand function for each representative variety $q_{ij} = Y_j p_{ij}^{-\sigma}$, where $q_{ij}$ is the quantity of the differentiated product produced by firms in country $i$ and sold to destination country $j$, $Y_j \equiv I_j / \sum_r p_{rj}^{1-\sigma}$ is the demand level in country $j$ with $r$ representing the set of varieties, $p_{ij}$ the price of this product, and $\sigma$ the constant elasticity of substitution. Note that $p_{ij} = \phi_{ij} \cdot p_i$, where $p_i$ is country $i$'s product market price and $\phi_{ij} \geqslant 1$ is the iceberg trade cost of exporting from country $i$ to country $j$ (with $\phi_{ii} = 1$).

There is a continuum of firms in each country. Each firm produces a different brand of the differentiated product. Given the interest of this paper, we assume that country $A$'s firms can produce their final good in any of the three countries while country $B$ and $C$'s firms produce only at home and serve the foreign markets via exports. Firms must pay a plant-level fixed cost $F_i$ for each final-good production location where $i$ denotes the country in which the plant is located. They must also produce one unit of intermediate input for each unit of final product.[3] Like the final product, country $A$'s firms can produce the intermediate input in any of the three countries. For simplicity, we assume that the plant-level fixed cost for intermediate-input production, $G_k$ (where $k$ denotes the country in which the upstream plant is located), is sufficiently large such that firms would build their upstream production in only one location.[4] We also assume that the upstream subsidiary will sell the inputs to the downstream subsidiaries at $m_k \phi_{ki}$, where $m_k$ is the marginal cost of producing the intermediate input and $\phi_{ki}$ is the cost of exporting the intermediate input from country $k$ to country $i$.

Now let $d_i(a)$ be an indicator variable that equals to 1 if firm $a$ locates the downstream production in country $i$ and similarly $u_i(a)$ be an indicator variable that identifies the existence of upstream production location. We can then characterize each firm's production network as $g(a) \equiv \{d_i(a), u_i(a)\}$, where $i \in \mathcal{N}$. Based on the observed production network, we define a firm as a national firm if $\max_{i \in \mathcal{N} \setminus \{A\}}[d_i(a), u_i(a)] = 0$, i.e., there is no subsidiary abroad, and a multinational if $\max_{i \in \mathcal{N} \setminus \{A\}}[d_i(a), u_i(a)] > 0$, i.e., there is at least one foreign subsidiary. We also let $\mathcal{N}_d(g(a)) = \{i \in \mathcal{N} : d_i(a) = 1\}$ denote the set of countries in which firm $a$ has downstream production and $\mathcal{N}_u(g(a)) = \{i \in \mathcal{N} : u_i(a) = 1\}$

[3] Given this paper's focus on intra-firm linkages, we do not consider here the option of purchasing intermediate inputs from unaffiliated suppliers. The latter possibility and its role in firms' location decision is an interesting reseach question in its own right and has a large scope for future empirical research. For seminal theoretical studies in this area, see, for example, Krugman and Venables (1996), Venables (1996), and Puga and Venables (1997). The empirical analysis of this paper attempts to control for these factors using host-country and firm fixed effects as firm-level data that identifies intermediate-input suppliers is largely missing.

[4] While this assumption is roughly in alignment with the data which shows French multinationals have, on average, 0.72 upstream subsidiaries abroad and 2.49 downstream subsidiaries, it is not crucial for the comparative analysis the model seeks to conduct.

the set in which $a$ has upstream production. We use $n_d(g(a))$ and $n_u(g(a))$ to represent the cardinality of the two sets respectively.

In the rest of this section, we examine firms' decision to undertake horizontal and vertical investments in a given production network. First, we note at profit maximization each firm will set the price at

$$p_i(a) = \frac{\sigma(c_i + m_k\phi_{ki})}{(\sigma - 1)}, \tag{1}$$

where $c_i$ is the marginal cost of producing the final good in country $i$. This implies that the operating profit firms will earn by producing the intermediate input in country $k$ and final good in country $i$ and selling to destination country $j$ is

$$\pi_{ij}(a) = \frac{1}{\sigma}\left(\frac{1}{c_i + m_k\phi_{ki}}\right)^{\sigma-1} {\phi_{ij}}^{-\sigma} Y_j. \tag{2}$$

It is clear that $\pi_{ij}(a)$ is an increasing function of country $j$'s demand (i.e., $Y_j$) and a decreasing function of the final good marginal cost (i.e., $c_i$) and the trade cost to ship the final good from country $i$ to country $j$ (i.e., $\phi_{ij}$). Furthermore, because production consists of two stages, $\pi_{ij}(a)$ also decreases in the marginal cost of producing the intermediate input (i.e., $m_k$) as well as the trade cost of shipping the input to the final good production location (i.e., $\phi_{ki}$).

Now suppose firms have chosen $\mathcal{N}_d(g(a))$ as the set of locations to produce the final good and country $k$ as the location to produce intermediate inputs, i.e., $\mathcal{N}_u(g(a)) = k$. The total profit function will then be

$$\begin{aligned}\Pi(g(a)) = &\sum_{i\in\mathcal{N}_d(g)} \frac{1}{\sigma}\left(\frac{1}{c_i + m_k\phi_{ki}}\right)^{\sigma-1} Y_i \\ &+ \sum_{j\in\mathcal{N}\setminus\mathcal{N}_d(g)} \max_{i\in\mathcal{N}_d(g)} \left[\frac{1}{\sigma}\left(\frac{1}{c_i + m_k\phi_{ki}}\right)^{\sigma-1} {\phi_{ij}}^{-\sigma} Y_j\right] - \sum_{i\in\mathcal{N}_d(g)} F_i - G_k.\end{aligned} \tag{3}$$

In this equation, the first term represents the operating profit firm $a$ earns from domestic sales (in countries where it has downstream production). The second term represents the operating profit from export markets (in countries where the firm does not have downstream production). Note the export profit depends on the choice of export-platform countries, i.e., the downstream production locations in $\mathcal{N}_d(g)$ from which firm $a$ exports to the other markets. We assume that firms will choose the optimal supply strategies to maximize the total profit. The last two arguments are the fixed cost of downstream and upstream production, which increases as firms expand the number of production

locations.

There are totally 21 possible location configurations. Firms will choose the optimal configuration, i.e., $g^*(a) \equiv \{d_i^*(a), u_i^*(a)\}$, that satisfies

$$\Pi\left(g^*(a)\right) \geqslant \Pi\left(g(a)\right) \quad \text{for all } g(a). \tag{4}$$

## 2.2 Downstream location decision

Given our goal to examine firms' investment decision in a given production network, suppose the current production network comprises a downstream plant in country $\widetilde{i}$ and an upstream plant in country $\widetilde{k}$, i.e., $g_0(a) = \{d_{\widetilde{i}} = 1, u_{\widetilde{k}} = 1\}$. We first look at firms' decision to build a new downstream production subsidiary in country $i$, i.e., $\Delta d_i$. Note if $\Delta d_i = 1$, firm $a$'s production network will move from $g_0(a)$ to $g_0(a) + d_i$.

Firms will build a downstream subsidiary in $i$ if and only if

$$\Pi\left(g_0(a) + d_i\right) > \Pi\left(g_0(a)\right). \tag{5}$$

Given equation (3), this is equivalent to

$$\left[(c_i + m_{\widetilde{k}}\phi_{\widetilde{k}i})^{1-\sigma} - (c_{\widetilde{i}} + m_{\widetilde{k}}\phi_{\widetilde{k}\widetilde{i}})^{1-\sigma}\phi_{\widetilde{i}i}{}^{-\sigma}\right] M_i > \sigma F_i, \tag{6}$$

where $M_i \equiv \sum_{j \in \mathcal{N}\setminus\mathcal{N}_d(g_0)} (\phi_{ij}{}^{-\sigma} Y_j)$ represents country $i$'s market potential, which includes country $i$'s domestic market size $Y_i$ and the size of other markets in which firm $a$ does not have downstream production. It can be further simplified to

$$c_i^{1-\sigma}(1 + \rho_{\widetilde{k}i}\phi_{\widetilde{k}i})^{1-\sigma}\left(1 - \gamma_d \phi_{\widetilde{i}i}{}^{-\sigma}\right) M_i > \sigma F_i, \tag{7}$$

where $\rho_{\widetilde{k}i} \equiv m_{\widetilde{k}}/c_i$ reflects the extent of vertical linkage between intermediate input and final good and $\gamma_d \equiv (c_{\widetilde{i}} + m_{\widetilde{k}}\phi_{\widetilde{k}\widetilde{i}})^{1-\sigma}/(c_i + m_{\widetilde{k}}\phi_{\widetilde{k}i})^{1-\sigma}$.

Note in condition (7) trade costs affect firms' investment decision in two ways. First, an increase in the cost of importing final good, i.e., $\phi_{\widetilde{i}i}$, raises firms' incentive to expand their downstream production. Second, a higher cost of importing intermediate input, i.e., $\phi_{\widetilde{k}i}$, reduces firms' motive to produce the final good in country $i$. The latter effect is especially strong when the vertical linkage between upstream and downstream production, i.e., $\rho_{\widetilde{k}i}$, is large.

Based on (7), we consider the following simplified specification:

$$\Pr\left[\Delta d_i(a)=1|g_0(a)\right]= \tag{8}$$
$$\Phi[\beta_{d,1}\ln c_i+\beta_{d,2}\ln \sigma F_i+\underbrace{\lambda_d^d\cdot d_{\widetilde{i}}(a)\cdot\ln\phi_{\widetilde{ii}}}_{horizontal}+\underbrace{\lambda_d^u\cdot u_{\widetilde{k}}(a)\cdot\ln(1+\rho_{\widetilde{ki}}\phi_{\widetilde{ki}})]}_{vertical}+\underbrace{\lambda_d^m\ln M_i}_{market\ potential}.$$

In this specification, $\Pr\left[\Delta d_i(a)=1|g_0(a)\right]$ is firm $a$'s probability to build a new downstream production location in country $i$ given its existing production network $g_0(a)$ and $\Phi[.]$ is the cumulative probability function. The terms $d_{\widetilde{i}}(a)\cdot\ln\phi_{\widetilde{ii}}$ and $u_{\widetilde{k}}(a)\cdot\ln(1+\rho_{\widetilde{ki}}\phi_{\widetilde{ki}})$ represent respectively the trade cost to import from firm $a$'s existing downstream and upstream production locations, capturing the horizontal and vertical interdependence in the network. The variable $\ln M_i\equiv\ln\sum_j(1-d_j)Y_j/\phi_{ij}$ represents country $i$'s market potential given firm $a$'s production network.

We expect, based on the model, that the effect of host-country variables satisfies $\beta_{d,1}<0$ and $\beta_{d,2}<0$. The effect of existing production network varies with the nature of the subsidiaries. We expect the effect of existing downstream network to satisfy $\lambda_d^d>0$ — that is firms are more likely to expand horizontally when the trade cost of importing final goods is relatively high. The expected effect of vertically linked subsidiaries is contrary: Firms have a greater incentive to build downstream subsidiaries when the cost of importing intermediate inputs is low, i.e., $\lambda_d^u<0$. Finally, the host-country market potential is predicted to have a positive effect, implying $\lambda_d^m>0$.

### 2.3 Upstream location decision

Now consider firms' upstream location decision. Given network $g_0(a)$ (where $d_{\widetilde{i}}=1, u_{\widetilde{k}}=1$), firms will build a new upstream production subsidiary in country $k$ and move to network $g_0(a)+u_k-u_{\widetilde{k}}$ if and only if

$$\Pi\left(g_0(a)+u_k-u_{\widetilde{k}}\right)>\Pi\left(g_0(a)\right). \tag{9}$$

Given equation (3), this is equivalent to

$$\left[(c_{\widetilde{i}}+m_k\phi_{k\widetilde{i}})^{1-\sigma}-(c_{\widetilde{i}}+m_{\widetilde{k}}\phi_{\widetilde{ki}})^{1-\sigma}\right]M_{\widetilde{i}}>\sigma\left(G_k-G_{\widetilde{k}}\right). \tag{10}$$

It can be further transformed to

$$m_k^{1-\sigma}\left[\left(\frac{1}{\rho_{k\widetilde{i}}}+\phi_{k\widetilde{i}}\right)^{1-\sigma}-\left(\frac{1}{\rho_{k\widetilde{i}}}+\gamma_u\phi_{\widetilde{ki}}\right)^{1-\sigma}\right]M_{\widetilde{i}}>\sigma\left(G_k-G_{\widetilde{k}}\right), \tag{11}$$

where $\rho_{k\widetilde{i}}\equiv m_k/c_{\widetilde{i}}$ and $\gamma_u\equiv m_{\widetilde{k}}/m_k$.

The above condition suggests that firms have greater incentives to produce the intermediate input in countries that have relatively better access to the firms' existing downstream production locations, i.e., low $\phi_{k\widetilde{i}}$. This is especially true for downstream locations with large market potential, i.e., $M_{\widetilde{i}}$. To test this hypothesis, we obtain the following simplified specification to examine firms' decision to build upstream subsidiaries:

$$\Pr\left[\Delta u_k(a)=1|g_0(a)\right]=\Phi[\beta_{u,1}\ln m_k+\beta_{u,2}\ln \sigma G_k+\underbrace{\lambda_u^d\cdot d_{\widetilde{i}}(a)\cdot\ln\phi_{k\widetilde{i}}}_{vertical}]. \tag{12}$$

In this expression, $\Pr\left[\Delta u_k(a)=1|g_0(a)\right]$ is firm $a$'s probability to build a new upstream production location in country $k$ given its existing production network $g_0(a)$. We expect, based on the model, that $\beta_{u,1}<0$ and $\beta_{u,2}<0$. Furthermore, existing downstream production locations should also exert a significant vertical effect with the expectation that $\lambda_u^d<0$. In the empirical analysis, we also explore how the vertical effect can vary with the market size of downstream locations, i.e., $M_{\widetilde{i}}$.

# 3 Econometric framework

To estimate equations (8) and (12), we consider the following two equations:

$$\begin{aligned} downstream \quad &: \quad \Pr\left[\Delta d_t=1\right]=X_{t-1}\beta_d \qquad (13)\\ &\quad +\lambda_d^d\cdot W_{d,t-1}^d\cdot d_{t-1}+\lambda_d^u\cdot W_{d,t-1}^u\cdot u_{t-1}+\lambda_d^m\cdot\ln M_{t-1}+\epsilon_{d,t}\\ uptream \quad &: \quad \Pr\left[\Delta u_t=1\right]=X_{t-1}\beta_u+\lambda_u^d\cdot W_{u,t-1}^d\cdot d_{t-1}+\epsilon_{u,t} \qquad (14)\end{aligned}$$

In the above equations, $\Delta d_t$ and $\Delta u_t$ are two vectors of observations of the two binary dependent variables which represent, respectively, each firm's decision to build downstream and upstream subsidiary in a given country, $X_{t-1}$ is a matrix of observations of lagged exogenous variables, and $\beta_d$ and $\beta_u$ are vectors of parameters. The model also includes a number of network variables including (i) $W_{d,t-1}^d\cdot d_{t-1}$ (horizontal interdependence) where $d_{t-1}\equiv\{d_{it-1}(a)\}$ represents each firm's downstream production locations in the lagged period, (ii) $W_{d,t-1}^u\cdot u_{t-1}$ and $W_{u,t-1}^d\cdot d_{t-1}$ (vertical interdependence), where $u_{t-1}\equiv\{u_{it-1}(a)\}$ represents each firm's upstream production locations in the lagged period, and (iii) $M_{t-1}\equiv W_{d,t-1}^m\cdot(1-d_{t-1})$ (market potential). Our goal is to estimate $\lambda_d^d$, $\lambda_d^u$, $\lambda_d^m$ and $\lambda_u^d$ along with $\beta_d$ and $\beta_u$.[5]

[5] We do not consider in this paper the potential contemporaneous correlation between entries for two reasons. First, the data includes all the entries observed between 2005 and 2007 but does not record the exact time of entry. To establish the causal effect of production network, we consider only the locations that existed in 2005 when we construct the third-country network variables. Second, the data shows that only a small number of multinational firms make more than one entry between 2005 and 2007. The

We now define the four weighting matrices, $W^d_{d,t-1}$, $W^u_{d,t-1}$, $W^m_{d,t-1}$ and $W^d_{u,t-1}$, used in the model. First, consider four $N \times N$ matrices $\omega^d_{d,t-1}(a)$, $\omega^u_{d,t-1}(a)$, $\omega^m_{d,t-1}(a)$, and $\omega^d_{u,t-1}(a)$ for each firm in the sample ((where $N$ denotes the number of countries in the data).

The cells in $\omega^d_{d,t-1}(a)$ are defined based on equation (8) and given by

$$\omega^d_{d,ijt-1}(a) = \ln \phi_{jit-1}(a), \tag{15}$$

where $i, j = 1, ..., N$ and $\phi_{jit-1}(a) \geqslant 1$ is the trade cost firm $a$ would incur when importing the final good from country $j$ to country $i$. If firm $a$ indeed produces the final product in country $j$, the higher this cost, the more incentive firm $a$ has to invest in country $i$.

Similarly, the cells in $\omega^u_{d,t-1}(a)$ are given by

$$\omega^u_{d,ijt-1}(a) = \ln \left[1 + \rho_j(a) \cdot \phi_{jit-1}(a)\right], \tag{16}$$

where $\rho_j(a)$ is the input-output coefficient between the good produced by firm $a$ in country $j$ and its final good and $\phi_{jit-1}(a)$ is the trade cost for firm $a$ to import the good produced in country $j$ to country $i$. If firm $a$ indeed produces in country $j$ and the good produced serves as an intermediate input for $a$'s final good (i.e., $\rho_j(a) > 0$), a greater trade cost to import from $j$ would lower firm $a$'s incentive to locate downstream production in country $i$.

Following the definition of $M_i \equiv \sum_j (1 - d_j) Y_j / \phi_{ij}$ in section 2.2, the cells in $\omega^m_{d,t-1}(a)$ are given by

$$\omega^m_{d,ijt-1}(a) = Y_{jt-1}/\phi_{ijt-1}(a), \tag{17}$$

where $Y_{jt-1}$ is the market demand in country $j$ and $\phi_{ijt-1}(a)$ is the trade cost firm $a$ would incur when exporting the final good from country $i$ to country $j$. Each cell in $\omega^m_{d,t-1}(a)$ thus captures country $i$'s export market potential in country $j$.

Finally, the cells in $\omega^d_{u,t-1}(a)$ are defined based on equation (12):

$$\omega^d_{u,ijt-1}(a) = \ln \phi_{ijt-1}(a), \tag{18}$$

where $\phi_{ijt-1}(a)$ is the trade cost for firm $a$ to export intermediate inputs from country $i$ to country $j$. If $a$ has a downstream production location in $j$, this trade cost is negatively correlated with $a$'s incentive to produce the intermediate input in $i$.

Given $\omega^d_{d,t-1}(a)$, $\omega^u_{d,t-1}(a)$, $\omega^m_{d,t-1}(a)$ and $\omega^d_{u,t-1}(a)$, we can construct the aggregate weighting matrices, $W^d_{d,t-1}$, $W^u_{d,t-1}$, $W^m_{d,t-1}$ and $W^d_{u,t-1}$. These aggregate matrices consist of $\omega^d_{d,t-1}(a)$, $\omega^u_{d,t-1}(a)$, $\omega^m_{d,t-1}(a)$ and $\omega^d_{u,t-1}(a)$ respectively along the diagonal and 0

results were largely similar when we excluded these firms from the sample.

everywhere else. For example, $W^d_{d,t-1}$ is an $NK \times NK$ matrix given by

$$W^d_{d,t-1} = \begin{bmatrix} \frac{\omega^d_{d,t-1}(a_1)}{n_{d,t-1}(a_1)} & 0 & 0 & 0 \\ 0 & \frac{\omega^d_{d,t-1}(a_2)}{n_{d,t-1}(a_2)} & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \frac{\omega^d_{d.t-1}(a_K)}{n_{d,t-1}(a_K)} \end{bmatrix} \tag{19}$$

where $a_1, a_2, ..., a_K$ represent the set of firms in the sample (with $K = 1698$) and $N$ represents the number of host countries and equals to 99. Note we scale $\omega^d_{d,t-1}(a)$, $\omega^u_{d,t-1}(a)$ and $\omega^d_{u,t-1}(a)$ with the firm's (downstream and upstream) production network size, i.e., $n_{d,t-1}(a_1)$, $n_{u,t-1}(a_1)$ and $n_{d,t-1}(a_1)$ respectively. The purpose of doing this is to estimate average interdependence across subsidiaries. Finally, note we include a firm fixed effect throughout our empirical analysis to control for all firm-specific factors such as factor intensities.[6]

# 4 Data

We employ a dataset of French manufacturing MNCs to examine multinationals' location decision in given production networks. This dataset is obtained from BvDEP AMADEUS, a comprehensive database that contains the financial and subsidiary information of public and private European firms. AMADEUS is collected by information providers at each national official public body (e.g., Institut National de la Propriete Industrielle (National Institute for Industrial Property) in the case of France) and has a particularly good coverage for countries including France, which partly motivated the use of French firms for this analysis.

The dataset reports French multinationals' subsidiary activities in 99 host countries in 2005 and 2007.[7] It is compiled from two editions of AMADEUS that were published in 2006 and 2008 respectively.[8] For each multinational firm, the data lists not only the subsidiary locations but also the primary product, sales, assets and employment of each location.[9] There are in total 1,698 French multinational firms in the dataset. These firms invest in on average 2.88 host countries in 2005 and 3.81 countries in 2007. The

[6] To avoid the incidental parameter problem that would arise with fixed-effect Maximum Likelihood Estimators, we adopt linear-probability model in Section 6.

[7] The final sample is smaller in some specifications because of the missing values in explanatory variables.

[8] AMADEUS does not directly report time series on subsidiary data. To obtain that information, one needs to acquire different editions of AMADEUS that were published in different years.

[9] The coverage of sales, assets and employment data is not as complete as the location information.

average increase in the number of invested countries is 0.93.[10]

As discussed in Section 2, we distinguish two types of subsidiaries. To do so, we follow the methodology introduced in Alfaro and Charlton (forthcoming). First, we identify subsidiaries that engage in final-good production. To do so, we compare each subsidiary's primary product with the parent firm's primary and secondary products, all of which are reported at NACE 4-digit level.[11] If the subsidiary's primary product is listed as one of the parent firm's final products, it is considered as a downstream production location. We also identify subsidiaries that engage in upstream production. This is determined by examining the input-output relationship between the subsidiary's primary product and the parent firm's final products. A subsidiary is considered as an upstream production location if the direct requirement of the subsidiary's primary product in the parent firm's final-product production exceeds a threshold value.[12] This direct identification of downstream and upstream subsidiaries has been generally absent in the literature, with the exception of Alfaro and Charlton (forthcoming), mainly because of the lack of information on subsidiary-level activities.

According to our definition, we find the average number of countries in which French multinationals have downstream subsidiaries is 2.49 whereas the number of countries with upstream subsidiaries is around 0.72.[13] More than 75 percent of newly established subsidiaries between 2005 and 2007 are downstream production locations, which seems to suggest firms are more inclined to expand horizontally than vertically.

Following Section 3, we use three subsidiary-level variables to construct the various weighting matrices needed to define existing network characteristics. These variables include (i) the distance between each pair of host countries (as a proxy for transport cost), (ii) the tariff rates between each pair of host countries on parent firms' final products and intermediate inputs produced overseas, and (iii) the input-output coefficient between the parent firm's final products and the subsidiary's primary good. We obtain the distance data from the CEPII distance database and tariff data from the WITS. The tariff data are applied tariff rates measured at NACE 4-digit level and reflect preferential tariff rates between host countries. We use the input-output table from the 2002 U.S. Bureau of Economic Analysis (BEA) benchmark survey. This I-O table is more disaggregate than

[10] It is worth noting that there are very few exits (i.e., subsidiary shut-downs) in the dataset. Nearly all the subsidiaries that existed in 2005 are active in 2007.

[11] AMADEUS reports both primary and secondary products for parent firms. We take into account both in our definition of downstream and upstream subsidiaries.

[12] The paper has considered different threshold values and found the results relatively similar. The results presented in the following sections are obtained based on the threshold value 0.1. We also weigh each upstream subsidiary with its input-output coefficient.

[13] Less than 20 percent of subsidiaries belong to neither cateogries and engage in activities such as wholesale distribution services. They are hence not included in the construction of downstream and upstream network variables.

the alternatives including the I-O table from the INSEE (and other available national sources).

In addition to the firm network variables, we take into account the FDI determinants that have traditionally been emphasized in the literature. First, we include several conventional variables used to capture the trade cost between home and host countries. Existing studies point out that multinationals have a greater incentive to invest in countries that require larger trade costs to export the final goods from home. To examine the importance of this motive, we include the distance between a potential host and France and tariff rates set by host countries on France in each multinational firm's primary final product category.[14] The hypothesis predicts a positive parameter on both variables: The higher the transport cost and host-country tariff for firms to export the products from home, the more likely the firm will produce the product inside the host country. In addition to the above market access variables, we also include host-country domestic market size, measured by real GDP. Multinationals that are attracted by the host-country local market size are expected to have a greater probability of investing in larger countries.

We also control for multinationals' comparative advantage motive. Specifically, we take into account host countries' marginal cost of production by including each host country's real unit labor cost. This data is aggregated from the industry level where each industry is weighed by its output share. The labor cost and output data are available from the World Bank Trade and Production Database. Furthermore, we include the tariff rate France sets on the host-country exports. The expectation is that multinationals that seek to export their products back to France would be adversely affected by this tariff.

Finally, we take into account various measures of investment costs. First, we control for host countries' tax policy using the maximum corporate tax rate, which is available from the U.S. Office of Tax Policy Research.[15] Second, we include the costs of starting a business, available from the World Development Indicators, as a proxy for entry cost. Third, we use the distance between France and the host country as a proxy for fixed cost of investment, with the expectation that subsidiaries located in remote markets are likely to require a larger fixed cost such as the cost of monitoring. Note all the explanatory variables are measured with 2005 data. Table A.1 describes the source and summary

[14] We also used the average tariff rate imposed on the firm's primary and secondary products. The results were qualitatively similar.

[15] Ideally, we would like to use the applied corporate tax rate in each host country. But this data consists of a large number of missing values for the countries in our sample.

statistics of the variables.[16]

## 5 Attributes of French MNC production networks

Before turning to the main econometric analysis, we first take a look at the geographic attributes of French MNC production networks. Figures 3 plots the distribution of French multinational firms in 2005 and 2007 by the number of countries in which investments occur. The majority of French MNCs concentrate their foreign production activities in 3 or more countries in 2007 while some spread to as many as 63. Comparing 2007 with 2005, there is a significant expansion in the size of network with an average increase of 0.93 per firm. Furthermore, as described in Section 4, a large fraction of foreign production locations comprises downstream subsidiaries. The average number of countries in which firms own downstream production is 2.49, significantly greater than the average number of countries in which firms have upstream production locations.

[Figure 3 about here]

Now we examine the geographic density of each production network. In Figure 4, we plot the level of distance between each pair of subsidiaries owned by the same French MNCs. As shown in the graph, the closest two subsidiaries are 66 kilometers apart (located in Austria and Slovakia) and the furthest pair is 19,845 kilometers apart (in Estonia and New Zealand). The majority of subsidiaries are within 6,126 kilometers, while the average distance is about 6,000. The graph also indicates that a large percentage of French MNC subsidiaries are either clustered in neighboring countries (such as EU members) or located relatively distant from each other. This is further confirmed at the multinational firm level where we calculate the average subsidiary distance for each French MNC: While a significant fraction of French multinationals have a dispersed subsidiary network, many of them concentrate their subsidiaries geographically.

We then compare the distance between downstream production locations (owned by the same French MNCs) with the distance between vertically linked subsidiaries. As shown in Figure 5, the former tends to be greater than the latter as expected. Multinationals tend to duplicate their final-product production in countries that are geographically distant from each other. But they build their upstream and downstream subsidiaries in proximate locations.

[Figures 4-5 about here]

[16] In the empirical analysis, we also consider using a country fixed effect to control for omitted host-country characteristics.

The above observations similarly apply to tariffs. In Figure 6, we plot the level of tariff between each pair of subsidiaries on the subsidiaries' primary good. It is shown that more than 30 percent of subsidiary pairs do not have tariff between each other and more than 50 percent have 7% or lower tariff rates. This is also confirmed at the parent firm level: More than 15 percent of French MNCs locate their subsidiaries in countries where tariffs have been removed for each other and 50% percent face an average of 6% or lower tariff when exporting from one subsidiary to another. This seems to suggest that French MNCs are not always driven by the tariff-jumping motive when they choose their foreign production locations; a large percentage of them invest in countries where they can export to without paying tariff. This becomes more clear when we compare, in Figure 7, the tariff between downstream production locations (on firms' final good) and the tariff of importing intermediate inputs from upstream locations. The former is significantly higher than the latter, suggesting tariffs motivate firms to expand their production horizontally but discourage them from building vertical production network.

[Figures 6-7 about here]

# 6 Empirical evidence

We now turn to the econometric analysis and examine the effect of existing production networks on multinationals' entry decision. We proceed by first estimating equations (13) and (14) with only conventional explanatory variables, i.e., excluding the effect of third-country locations and assuming $\lambda_d^d = 0$, $\lambda_d^u = 0$, $\lambda_d^m = 0$, and $\lambda_u^d = 0$.

*Excluding network effects*

The results are reported in Table 1. We find the effect of included explanatory variables is largely consistent with the existing literature when no third-country factors are taken into account.[17] First, firms exhibit a significant market-access motive that is in alignment with the literature. They are more likely to build final-good production in countries with a larger GDP. They also have a greater incentive to enter countries that set a higher tariff on the imports of their final products from France. The parameter of EU membership is also consistent. Firms are more likely to choose FDI instead of export in countries outside the EU. The effect of distance is negative, a finding that has been shown in previous studies and explained by the role of distance in raising the fixed cost of investment.

[17] The $H_0$ column in Table 1 (and the following tables) summarizes the hypotheses on the effect of explanatory variables that are predicted by either the model or the literature.

The evidence also indicates a significant comparative advantage motive. Countries with a lower unit labor cost attract more multinationals to build downstream production. Investment costs also exert a significant effect on multinationals' entry decision. A larger cost of starting business is associated with a lower probability of attracting multinational firms. The sign of the corporate tax parameter is inconsistent with expectation, however. This can be a result of the tax measure included in the paper. The corporate tax data used here reports each host country's maximum corporate tax rate and does not necessarily capture the rate applied to multinational firms. The latter information is not systematically available and would reduce the sample size substantially.

[Table 1 about here]

In the fourth column of Table 1, we include a host-country fixed effect to control for all unobserved host-country characteristics. We find the effect of host-country tariff set on France remains significant and positive. This suggests controlling for country-level attributes does not change the estimated effect of the conventional market access variable. The parameter of home-country tariff also becomes significant: A higher tariff to export the final product back to France lowers multinationals' incentive to produce the good abroad. This result is consistent with the comparative advantage motive hypothesis: Some French multinationals serve their home country from foreign production location and are adversely affected by home-country tariff.

Next we examine multinationals' upstream location decision. As shown in the last columns of Table 1, the results are largely similar. Countries with a larger GDP and a higher tariff have a greater probability to attract multinationals. Those that are relatively remote from France and have a higher real unit labor cost or a higher entry cost are less likely to become upstream production locations. A result that is not expected analytically is the positive effect of French tariff. A higher tariff to export the final product back to France motivates French firms to move upstream production overseas. Again, controlling for unobserved host-country attributes with host-country dummies does not change the estimated effect of host- and home-country tariffs on each other.

*Including network effects*

Now let us take into account the potential effect of foreign production network. Table 2 reports the estimates obtained for the downstream equation in (13). The table indicates strong evidence of horizontal and vertical interdependence in multinationals' foreign production network. First, multinationals are significantly more likely to build downstream production in countries that are relatively distant from the firms' existing

downstream locations. A 100-percent increase in third-country distance raises the probability of entry by 0.6 percentage point.[18] This result similarly applies to tariff. The incentive to enter a host country rises in the tariff of importing final good from the existing locations. Export-market potential also plays a significant role. Multinationals have a greater probability to produce the final product in countries with a large export potential. This points out the significance of export-platform FDI, in which multinationals use host countries as the platform to supply third countries — in particular, the third countries where multinationals do not have downstream production activities present. These findings remain robust after we include host-country fixed effect and control for all host-country specific attributes.

[Table 2 about here]

The effect of the conventional market access variables is affected, however, by the consideration of downstream production network. As seen in Table 2, the parameter of host-country tariff on France becomes statistically insignificant when the third-country variables are taken into account. This constitutes sharp contrast with Table 1, where the evidence suggests a horizontal interdependence between foreign production and home-country exports: Market access from home has a significant effect on multinationals' location choice. This change in the results suggests that it is not adequate to focus exclusively on the home-host interdependence. As multinationals' production network expands over time, there is increasing interdependence across foreign production locations. The choice of where to invest is no longer conditional on the tradeoff between FDI and exporting from home alone; it has become a more complex decision involving third countries. Ignoring the third-country network effect is likely to give rise to biased estimates on the relationship between the performance of the home economy and FDI activities and, more generally, biased understanding of the true causes and effects of FDI.

In column (2) of Table 2, we take into account the effect of existing upstream production network. The results there show that the role of trade cost is reversed when there is a vertical linkage between foreign production locations. Multinationals are motivated to cluster vertically linked subsidiaries in proximate countries. For example, countries that are 100-percent closer to the multinationals' existing upstream locations have a 0.1-percentage-point higher probability to attract multinationals. This result suggests that upstream FDI in neighboring countries can trigger an increase in downstream FDI.

The effect of upstream production network also increases in the extent of vertical linkage, as shown in Table 3. Here, we interact the trade cost of importing intermediate inputs with the input-output coefficient with respect to the multinationals' final product.

[18] The average fitted probability of downstream entry is 0.01.

The parameters indicate that the incentive to cluster production stages is especially large when there is a strong vertical linkage. These results, again, are not sensitive to the use of host-country dummies.

[Table 3 about here]

Now we proceed to examine multinationals' upstream entry decision. As shown in Table 4, we find, again, significant evidence of vertical interdependence. Multinationals tend to build upstream production locations in countries that are relatively proximate to the existing downstream locations. This is especially true when the downstream country has a relatively large market potential. These results reflect firms' incentive to reduce intra-firm trade costs and build a geographically concentrated network of vertically linked subsidiaries.

[Table 4 about here]

# 7 Sensitivity analysis

## 7.1 Alternative weighting matrices

So far we have used distance and tariff to capture the extent of trade cost. While these two variables possibly represent the most prominent forms of trade barriers, they do not capture all the trade costs faced by multinationals. We hence consider in this section an alternative measure in the construction of weighting matrices. Specifically, we use disaggregate trade flows as a proxy for host countries' openness toward one another.

For example, when estimating firm $a$'s downstream entry decision in country $i$ given its existing downstream production location in $\widetilde{i}$, we use the import value of country $i$ from country $\widetilde{i}$ in firm $a$'s primary final product (in NACE 4-digit level) as the proxy for country $i$'s openness to country $\widetilde{i}$. Countries that are relatively open to the multinational's existing downstream locations are less likely to be selected as new hosts. We also obtain country $i$'s import from country $\widetilde{k}$ where firm $a$ has an upstream subsidiary (in the category of the subsidiary's primary good). The hypothesis here is that multinationals are more likely to produce the final product in countries that are relatively more accessible from the firms' existing upstream locations. Finally, we use country $i$'s exports to all the third countries where firm $a$ does not have downstream production (in $a$'s primary final product) to construct $i$'s export market potential. To avoid endogeneity, we use trade data in 2005 which is available from COMTRADE.[19]

[19] We also considered pre-2005 trade data and found largely similar results.

Table 5 reports the results obtained with trade-weighted network variables. The evidence indicates significant and consistent horizontal and vertical interdependence across multinationals' foreign subsidiaries. Multinationals have a particularly strong incentive to expand their downstream production in countries that import relatively less from their existing third-country downstream locations. They are also motivated to choose countries where there are large trade inflows from the firms' existing upstream subsidiaries.

[Table 5 about here]

When examining multinationals' upstream entry decision, we take into account each host country's market access to the firms' existing downstream locations. Specifically, for each multinational firm $a$ and and host country $i$, we obtain $i$'s average export value to all the third countries where firm $a$ engages in final-stage production. Ideally, we would like to use the export of the subsidiary's primary good, but this information is only observable for countries that have been selected as production locations. The counterfactual information is not available for those that were not chosen. As a result, we use each host country's average export in manufacturing industries to construct the country's market access. The results are reported in the last two columns of Table 5. There is a clear and significant motive to locate vertically linked subsidiaries in countries with close trade relationships.

### 7.2 Endogeneity of network variables

In this sub-section, we address the potential endogeneity that can arise with the network variables. So far we have used lagged location variables, i.e., $d_{t-1}$ and $u_{t-1}$, to construct measures of existing production networks. While the time lag between these variables and the dependent variables, i.e., $\Delta d_t$ and $\Delta u_t$, and the control of firm fixed effect helps establish the causal effect, the former can still be endogenous because of the serial autocorrelation in the residuals, $\epsilon_t$. To address this issue, we adopt a two-stage instrumental variable approach. In this approach, we use $W \cdot X_{t-1}$, where $W$ represents $W^d_{d,t-1}$, $W^u_{d,t-1}$, $W^m_{d,t-1}$ or $W^d_{u,t-1}$ and $X_{t-1}$ is a matrix of lagged host-country attributes, as potential instruments for the network variables.

Formally, we estimate:

$$\begin{aligned} downstream \quad &: \quad \Pr\left[\Delta d_t = 1\right] = X_{t-1}\beta_d \\ &\quad +\lambda^d_d \cdot \widehat{W^d_{d,t-1} d_{t-1}} + \lambda^u_d \cdot \widehat{W^u_{d,t-1} u_{t-1}} + \lambda^m_d \cdot \widehat{\ln M_{t-1}} + \epsilon_{d,t} \end{aligned} \tag{20}$$

$$uptream \quad : \quad \Pr\left[\Delta u_t = 1\right] = X_{t-1}\beta_u + \lambda^d_u \cdot \widehat{W^d_{u,t-1} d_{t-1}} + \epsilon_{u,t}, \tag{21}$$

where

$$\begin{aligned}
\widehat{W^d_{d,t-1}d_{t-1}} &= E\left[W^d_{d,t-1}d_{t-1}|W^d_{d,t-1}X_{t-1}\right] \\
\widehat{W^u_{d,t-1}u_{t-1}} &= E\left[W^u_{d,t-1}u_{t-1}|W^u_{d,t-1}X_{t-1}\right] \\
\widehat{\ln M_{t-1}} &= E[\ln M_{t-1}|\ln W^m_{d,t-1}X_{t-1}] \\
\widehat{W^d_{u,t-1}d_{t-1}} &= E\left[W^d_{u,t-1}u_{t-1}|W^d_{u,t-1}X_{t-1}\right].
\end{aligned} \tag{22}$$

The results are reported in Table 6. We find that most parameters remain qualitatively similar after we correct for the potential endogeneity of network variables with the exception of export market potential. We continue to observe significant horizontal and vertical interdependence across multinationals' foreign production locations.

[Table 6 about here]

# 8 Conclusion

This study is one of the first attempts to estimate the interdependence in multinationals' foreign production network. Using a detailed French multinational subsidiary dataset, the paper finds, for the first time, strong evidence of horizontal and vertical interaction between MNCs' foreign production locations. These results complement existing contributions where evidence of interdependence, obtained based on aggregate FDI data, has been ambiguous. Here we show third-country subsidiaries exert a significant effect on French multinationals' entry decision, in both downstream and upstream production. But the effect varies considerably with the linkage of subsidiaries. Multinationals are more likely to expand horizontally when the trade cost of importing final products from existing downstream subsidiaries is relatively high. But they tend to locate vertically linked subsidiaries in countries with low intra-firm trade costs, especially when there is a strong input-output relationship. These results are robust to the choice of weighting matrices in the econometric model and the control of potential endogeneity in the network variables.

Strikingly there is little evidence of horizontal interdependence between multinationals' production at home and new investment abroad once we take into account the third-country network effects. This constitutes sharp contrast to the literature where primary emphasis has been placed on the horizontal linkage between home- and host-country production. This departure can be explained by the assumption made in most previous studies that views a firm's decision to invest in a foreign country as independent of its locations in third nations even though the majority of multinationals today operate a

multilateral production network.

This paper conveys important policy implications for both FDI home and host countries: It is crucial to analyze the causes and effects of FDI in the context of global production network. As shown in the paper, assuming away the interdependence between foreign production locations is likely to over-estimate the substituting relationship between home-country production and foreign investment. It would also fail to account for the spillover effect of FDI inflows to third countries on a host country's ability to attract multinational firms. This effect can be either positive or negative dependent on the linkage between FDI flows.

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Table 1: Estimating entry decision without network factors

| Dependent variable: | $H_0$ | downstream ($\Delta d_t$) | | upstream ($\Delta u_t$) | |
|---|---|---|---|---|---|
| | | (1) | (2) | (1) | (2) |
| host-country GDP | + | 0.008*** | | 0.002*** | |
| | | (0.000) | | (0.000) | |
| host-country tariff | + | 0.005*** | 0.001* | 0.003*** | 0.001* |
| | | (0.000) | (0.000) | (0.000) | (0.000) |
| EU membership | +/– | -0.03*** | | -0.01*** | |
| | | (0.001) | | (0.001) | |
| distance to home | +/– | -0.03*** | | -0.01*** | |
| | | (0.001) | | (0.001) | |
| real unit labor cost | – | -0.03*** | | -0.02*** | |
| | | (0.002) | | (0.001) | |
| home-country tariff | – | -0.000 | -0.001*** | 0.001*** | 0.001*** |
| | | (0.000) | (0.000) | (0.000) | (0.000) |
| corporate tax | – | 0.009*** | | 0.005*** | |
| | | (0.001) | | (0.001) | |
| entry cost | – | -0.006*** | | -0.003*** | |
| | | (0.000) | | (0.000) | |
| firm fixed effect | | yes | yes | yes | yes |
| country fixed effect | | no | yes | no | yes |
| No. of observations | | 102,162 | 158,952 | 102,162 | 158,952 |
| R square | | 0.07 | 0.27 | 0.04 | 0.18 |
| Prob>F | | 0.00 | 0.00 | 0.00 | 0.00 |

Note: (i) All explanatory variables except EU membership are measured in natural logs; (ii) Standard errors are reported in the parentheses and clustered at firm level; (iii) ***, ** and * represent significance at 1%, 5% and 10%, respectively.

Table 2: Estimating downstream entry decision with network factors

| Dependent variable: | $H_0$ | downstream ($\Delta d_t$) | | |
|---|---|---|---|---|
| entry | | (1) | (2) | (3) |
| **horizontal interdependence** | | | | |
| $W^d_{d,t-1}d_{t-1}$ (dist. weighted) | + | 0.01*** | 0.01*** | 0.003*** |
| | | (0.001) | (0.001) | (0.001) |
| $W^d_{d,t-1}d_{t-1}$ (tariff weighted) | + | 0.001*** | 0.001*** | 0.003*** |
| | | (0.000) | (0.000) | (0.000) |
| **vertical interdependence** | | | | |
| $W^u_{d,t-1}u_{t-1}$ (dist. weighted) | – | | -0.14* | -0.19* |
| | | | (0.08) | (0.07) |
| $W^u_{d,t-1}u_{t-1}$ (tariff weighted) | – | | -0.06 | -0.01 |
| | | | (0.07) | (0.05) |
| **market potential** | | | | |
| $W^d_{d,t-1}(1-d_{t-1})$ (dist.) | + | 0.57*** | 0.57*** | 0.14*** |
| | | (0.01) | (0.02) | (0.03) |
| $W^d_{d,t-1}(1-d_{t-1})$ (tariff) | + | 0.02*** | 0.02*** | 0.01** |
| | | (0.005) | (0.005) | (0.004) |
| host-country GDP | + | 0.02*** | 0.02*** | |
| | | (0.005) | (0.005) | |
| host-country tariff | + | 0.001 | 0.001 | -0.002*** |
| | | (0.001) | (0.001) | (0.000) |
| EU membership | +/– | -0.02*** | -0.02*** | |
| | | (0.001) | (0.001) | |
| distance to home | +/– | -0.06*** | -0.06*** | |
| | | (0.001) | (0.001) | |
| real unit labor cost | – | -0.04*** | -0.04*** | |
| | | (0.002) | (0.002) | |
| home-country tariff | – | -0.006*** | -0.006*** | -0.002** |
| | | (0.001) | (0.001) | (0.001) |
| corporate tax | – | 0.02*** | 0.02*** | |
| | | (0.001) | (0.001) | |
| entry cost | – | -0.008*** | -0.008*** | |
| | | (0.000) | (0.000) | |
| firm fixed effect | | yes | yes | yes |
| country fixed effect | | no | no | yes |
| No. of observations | | 102,162 | 102,162 | 158,952 |
| R square | | 0.09 | 0.09 | 0.27 |
| Prob>F | | 0.00 | 0.00 | 0.00 |

Note: (i) All explanatory variables except EU membership are measured in natural logs; (ii) Standard errors are reported in the parentheses and clustered at firm level; (iii) ***, ** and * represent significance at 1%, 5% and 10%, respectively.

Table 3: Estimating downstream entry decision with network factors: the extent of vertical linkage

| Dependent variable: | $H_0$ | downstream ($\Delta d_t$) | |
|---|---|---|---|
| entry | | (1) | (2) |
| **horizontal interdependence** | | | |
| $W^d_{d,t-1}d_{t-1}$ (dist. weighted) | + | 0.01*** | 0.003*** |
| | | (0.001) | (0.000) |
| $W^d_{d,t-1}d_{t-1}$ (tariff weighted) | + | 0.001*** | 0.003*** |
| | | (0.000) | (0.000) |
| **vertical interdependence** | | | |
| $W^u_{d,t-1}u_{t-1}$ (dist. and IO-coef. weighted) | – | -3.06*** | -3.15*** |
| | | (1.38) | (1.01) |
| $W^u_{d,t-1}u_{t-1}$ (tariff and IO-coef. weighted) | – | -1.55*** | 0.05 |
| | | (0.61) | (0.42) |
| **market potential** | | | |
| $W^d_{d,t-1}(1-d_{t-1})$ (dist.) | + | 0.58*** | 0.14*** |
| | | (0.02) | (0.03) |
| $W^d_{d,t-1}(1-d_{t-1})$ (tariff) | + | 0.02*** | 0.008* |
| | | (0.000) | (0.004) |
| host-country GDP | + | 0.02*** | |
| | | (0.005) | |
| host-country tariff | + | 0.002 | -0.002*** |
| | | (0.002) | (0.000) |
| EU membership | +/– | -0.02*** | |
| | | (0.001) | |
| distance to home | +/– | -0.06*** | |
| | | (0.001) | |
| real unit labor cost | – | -0.04*** | |
| | | (0.002) | |
| home-country tariff | – | -0.006*** | -0.002*** |
| | | (0.001) | (0.001) |
| corporate tax | – | 0.02*** | |
| | | (0.001) | |
| entry cost | – | -0.008*** | |
| | | (0.000) | |
| firm fixed effect | | yes | yes |
| country fixed effect | | no | yes |
| No. of observations | | 102,162 | 158,952 |
| R square | | 0.09 | 0.27 |
| Prob>F | | 0.00 | 0.00 |

Note: (i) All explanatory variables except EU membership are measured in natural logs; (ii) Standard errors are reported in the parentheses and clustered at firm level; (iii) ***, ** and * represent significance at 1%, 5% and 10%, respectively.

Table 4: Estimating upstream entry decision with network factors

| Dependent variable: | $H_0$ | upstream ($\Delta u_t$) | |
|---|---|---|---|
| entry | | (1) | (2) |
| **vertical interdependence** | | | |
| $W^d_{u,t-1}d_{t-1}$ (dist. weighted) | + | 6.60*** | 2.31*** |
| | | (1.29) | (0.80) |
| $W^d_{u,t-1}d_{t-1}$ (dist. and size weighted) | – | -0.28*** | -0.10*** |
| | | (0.05) | (0.03) |
| host-country GDP | + | 0.003*** | |
| | | (0.001) | |
| host-country tariff | + | 0.03*** | 0.001*** |
| | | (0.000) | (0.000) |
| EU membership | +/– | -0.01*** | |
| | | (0.001) | |
| distance to home | +/– | -0.01*** | |
| | | (0.001) | |
| real unit labor cost | – | -0.02** | |
| | | (0.001) | |
| home-country tariff | – | 0.001*** | 0.001*** |
| | | (0.000) | (0.000) |
| corporate tax | – | 0.005*** | |
| | | (0.001) | |
| entry cost | – | | |
| | | | |
| firm fixed effect | | yes | |
| country fixed effect | | no | |
| No. of observations | | 102,162 | 158,952 |
| R square | | 0.04 | 0.18 |
| Prob>F | | 0.00 | 0.00 |

Note: (i) All explanatory variables except EU membership are measured in natural logs; (ii) Standard errors are reported in the parentheses and clustered at firm level; (iii) ***, ** and * represent significance at 1%, 5% and 10%, respectively.

Table 5: Estimating downstream and upstream entry decision with network factors: trade flow weighted

| Dependent variable: | $H_0$ | downstream ($\Delta d_t$) | | upstream ($\Delta u_t$) | |
|---|---|---|---|---|---|
| entry | | (1) | (2) | (1) | (2) |
| **horizontal interdependence** | | | | | |
| $W^d_{d,t-1}d_{t-1}$ (imports weighted) | – | -0.05*** | -0.05*** | | |
| | | (0.01) | (0.01) | | |
| **vertical interdependence** | | | | | |
| $W^u_{d,t-1}u_{t-1}$ (imports weighted) | + | 0.001*** | 0.001* | | |
| | | (0.000) | (0.000) | | |
| **market potential** | | | | | |
| $W^d_{d,t-1}(1-d_{t-1})$ (exports weighted) | + | 0.006*** | 0.000 | | |
| | | (0.000) | (0.000) | | |
| **horizontal interdependence** | | | | | |
| $W^d_{u,t-1}d_{t-1}$ (exports weighted) | + | | | 0.11*** | 0.06*** |
| | | | | (0.03) | (0.01) |
| host-country GDP | + | 0.01*** | | 0.002*** | |
| | | (0.005) | | (0.001) | |
| host-country tariff | + | 0.004 | -0.001 | 0.003*** | 0.001*** |
| | | (0.004) | (0.000) | (0.000) | (0.000) |
| EU membership | +/– | -0.03*** | | -0.01*** | |
| | | (0.001) | | (0.001) | |
| distance to home | +/– | -0.03*** | | -0.01*** | |
| | | (0.001) | | (0.001) | |
| real unit labor cost | – | -0.03*** | | -0.02*** | |
| | | (0.002) | | (0.001) | |
| home-country tariff | – | -0.000 | -0.001*** | 0.001*** | 0.001*** |
| | | (0.000) | (0.000) | (0.000) | (0.000) |
| corporate tax | – | 0.007*** | | 0.005*** | |
| | | (0.001) | | (0.001) | |
| entry cost | – | -0.007*** | | -0.003*** | |
| | | (0.000) | | (0.000) | |
| firm fixed effect | | yes | yes | yes | yes |
| country fixed effect | | no | yes | no | yes |
| No. of observations | | 102,162 | 158,952 | 102,162 | 158,952 |
| R square | | 0.07 | 0.27 | 0.04 | 0.19 |
| Prob>F | | 0.00 | 0.00 | 0.00 | 0.00 |

Note: (i) All explanatory variables except EU membership are measured in natural logs; (ii) Standard errors are reported in the parentheses and clustered at firm level; (iii) ***, ** and * represent significance at 1%, 5% and 10%, respectively.

Table 6: Estimating downstream and upstream entry decision with network factors: two-stage IV (second stage)

| Dependent variable: entry | $H_0$ | downstream ($\Delta d_t$) | upstream ($\Delta u_t$) |
|---|---|---|---|
| **horizontal interdependence** | | | |
| $W^d_{d,t-1}d_{t-1}$ (imports weighted) | – | -0.06*** | |
| | | (0.02) | |
| **vertical interdependence** | | | |
| $W^u_{d,t-1}u_{t-1}$ (imports weighted) | + | 0.003*** | |
| | | (0.000) | |
| **market potential** | | | |
| $W^d_{d,t-1}(1-d_{t-1})$ (exports weighted) | + | 0.000 | |
| | | (0.000) | |
| **vertical interdependence** | | | |
| $W^d_{u,t-1}d_{t-1}$ (exports weighted) | + | | 0.10* |
| | | | (0.06) |
| host-country tariff | + | -0.000 | 0.001*** |
| | | (0.000) | (0.000) |
| home-country tariff | – | -0.001* | 0.001*** |
| | | (0.000) | (0.000) |
| firm fixed effect | | yes | yes |
| country fixed effect | | yes | yes |
| No. of observations | | 158,952 | 158,952 |
| R square | | 0.27 | 0.19 |
| Prob>F | | 0.00 | 0.00 |

Note: (i) All explanatory variables except EU membership are measured in natural logs; (ii) Standard errors are reported in the parentheses and clustered at firm level; (iii) ***, ** and * represent significance at 1%, 5% and 10%, respectively.

Table A.1: Summary statistics

| Variables | Source | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| downstream entry | AMADEUS | 0.007 | 0.08 | 0 | 1 |
| upstream entry | AMADEUS | 0.002 | 0.04 | 0 | 1 |
| GDP | WDI | 26.24 | 1.35 | 23.85 | 30.00 |
| real unit labor cost | World Bank | -2.17 | 2.17 | -15.08 | 0.18 |
| corporate tax | Office of Tax Policy Research | -1.25 | 0.29 | -2.40 | -0.91 |
| distance to home | City Distance Calculator | 7.81 | 1.19 | 5.57 | 9.73 |
| between-host distance | City Distance Calculator | 8.42 | 1.01 | 0 | 9.87 |
| EU membership | — | 0.45 | 0.49 | 0 | 1 |
| host-country tariff | WITS | 0.04 | 0.06 | 0 | 0.85 |
| home-country tariff | WITS | 0.01 | 0.02 | 0 | 0.42 |
| I-O coefficient | BEA | 0.06 | 0.06 | 0 | 0.33 |

Note: All variables except downstream/upstream entry, EU membership and I-O coefficient are measured in natural logs.

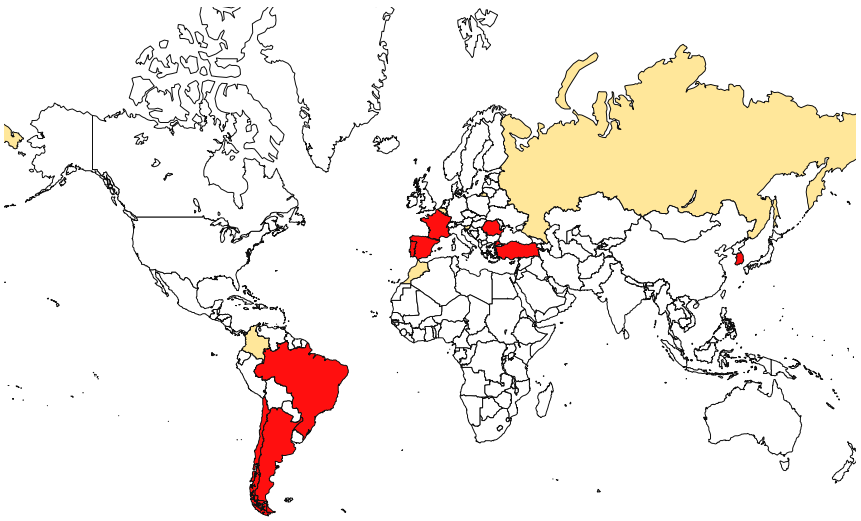

Figure 1: Renault's global production network (the darker and lighter areas represent upstream and downstream production locations, respectively)

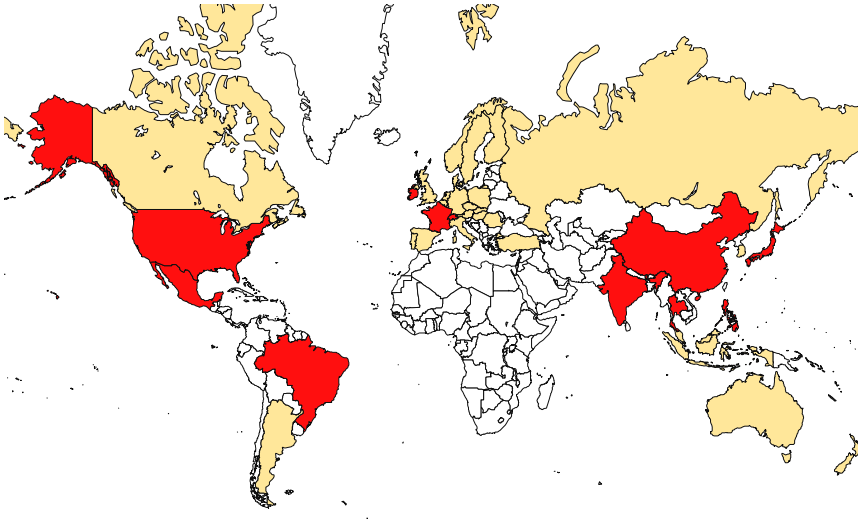

Figure 2: Essilor's global production network (the darker and lighter areas represent upstream and downstream production locations, respectively)

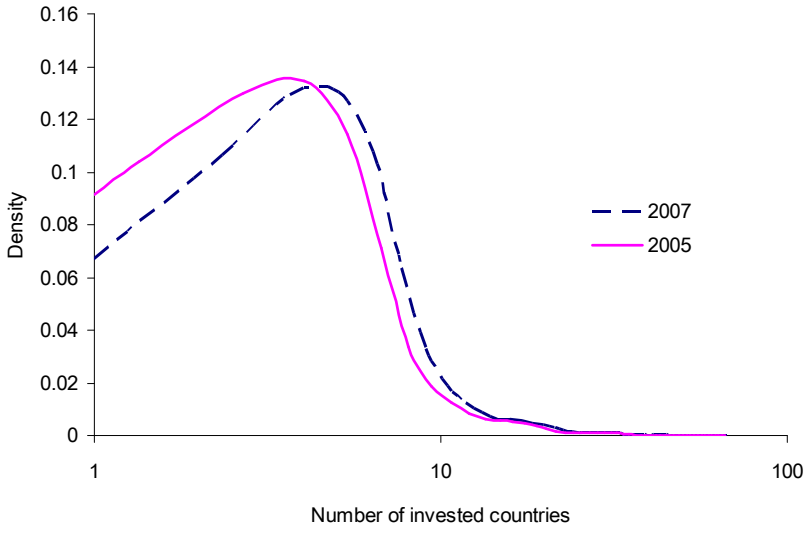


Figure 3: The distribution of French MNCs by the number of invested countries

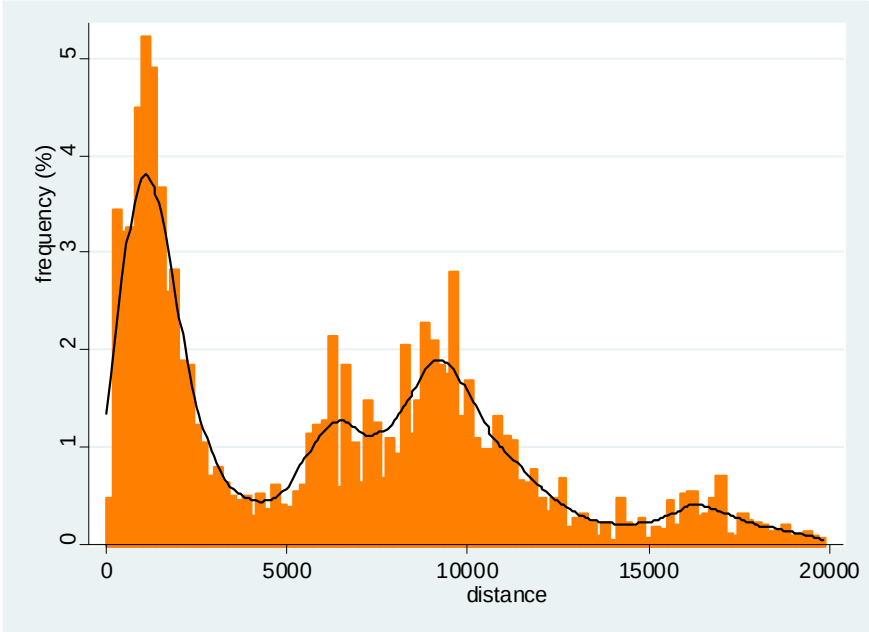


Figure 4: The distribution of French MNC subsidiaries by the distance between subsidiaries (kernel density estimates are represented by the curve)

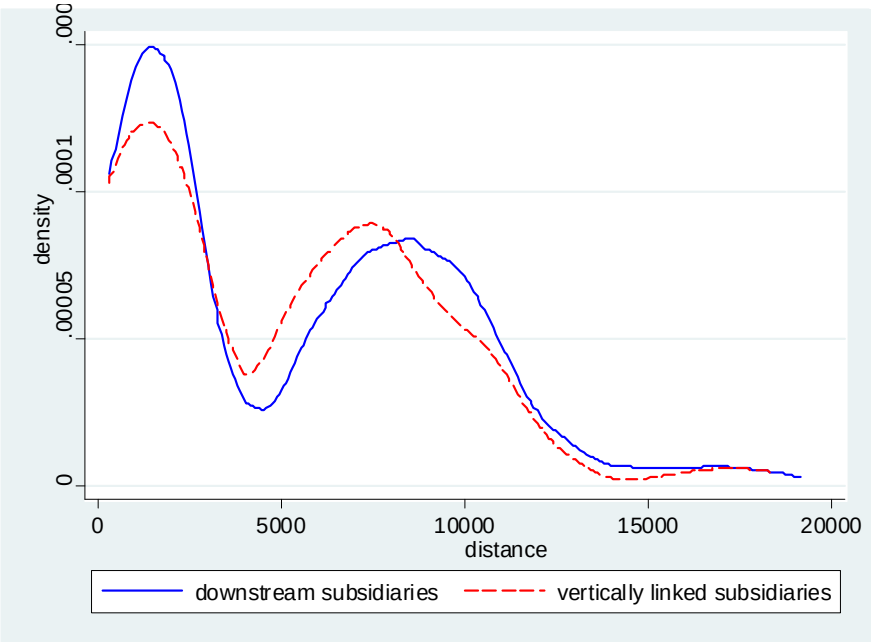


Figure 5: The kernel density of between-subsidiary distance: downstream subsidiaries v.s. vertically linked subsidiaries

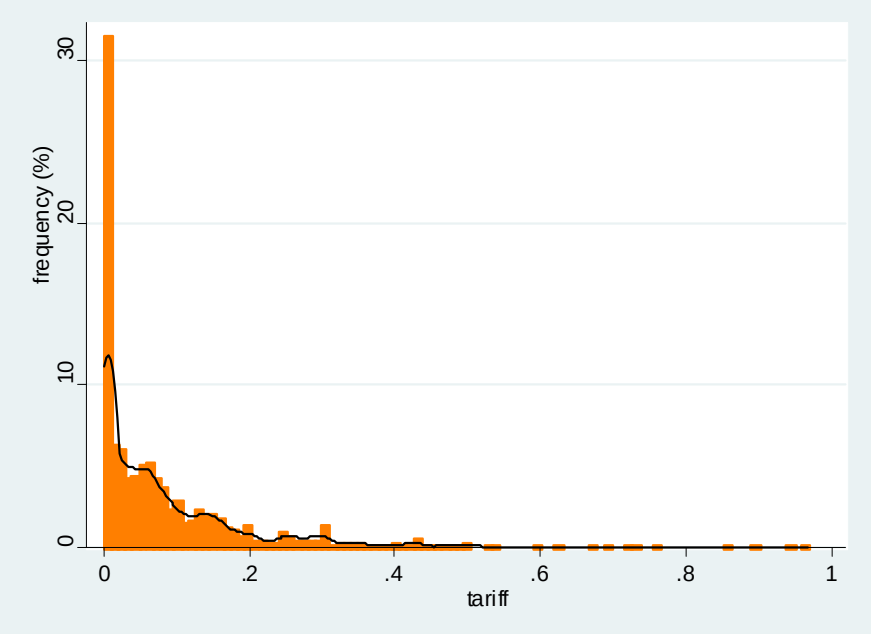


Figure 6: The distribution of French MNC subsidiaries by the tariff rate between subsidiaries (kernel density estimates are represented by the curve)

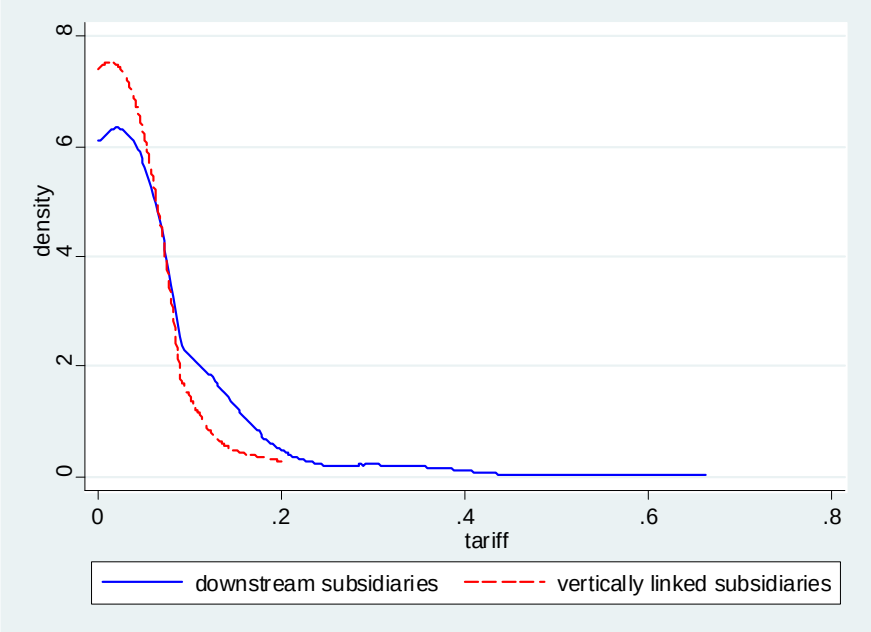


Figure 7: The kernel density of between-subsidiary tariff: downstream subsidiaries v.s. vertically linked subsidiaries