

Egger, Peter H.; Erhardt, Katharina; Masllorens, Gerard

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Backward Versus Forward Integration of Firms in Global Value Chains

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Poschingerstr. 5, 81679 Munich, Germany

Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de

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Abstract

Production processes are increasingly organized in international value-chain networks. The involved firms can be operating at arm's length or be vertically integrated. Both the incidence and the direction of integration (backward or forward in the value chain) depend on specific characteristics of the firms and their economic environment. We propose a simple model of vertical integration in a supplier-producer relationship that is rooted in the property-rights theory to learn about the determinants of forward versus backward integrations. Generally, the profitability and direction of integration depend on the relative investment intensity of the producer and the supplier so as to align investment incentives and maximize joint surplus. Moreover, the organizational form depends on the fixed costs of firm integration and the market environment in the input market as well as the relative importance of the specific input for the final output. These results are strongly confirmed in a large panel of worldwide directed ownership linkages.

JEL-Codes: L140, L220, L230, L240.

Keywords: firm integration, global value chains, investment.

Peter H. Egger
KOF Swiss Economic Institute
ETH Zurich / Switzerland
egger@kof.ethz.ch

Katharina Erhardt
Düsseldorf Institute for Competition Economics
(DICE), Heinrich-Heine-University
Düsseldorf / Germany
erhardt@dice.hhu.de

Gerard Masllorens
KOF Swiss Economic Institute
ETH Zurich / Switzerland
masllorensfontes@kof.ethz.ch

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1 Introduction

Modern production entertains the mechanics of comparative advantage to an unprecedented degree. This becomes evident in the specialization of production facilities on ever-thinner slices of their products' value chains, in their sourcing of inputs from suppliers at home as well as abroad, and in their supply to customers there. Today, there is an unparalleled gap between the revenue earned and the value added generated for the average firm, and much of this is owed to imported inputs and global value chains as a major source of international trade (Johnson and Noguera, 2012; Bernard and Fort, 2015; Alfaro et al., 2019).

The increasing dependence of individual firms on production networks is also reflected in a greater complexity of organization structures and the mixed sourcing and supply of inputs within and outside the boundaries of the firm through arm's-length versus in-house (integrated) transactions. The literature on the organizational structure of global production networks is large. Theoretical work interested in the boundaries of the firm and vertical integration largely builds upon the seminal Grossman-Hart-Moore property-rights framework (Grossman and Hart, 1986; Hart and Moore, 1990). This work emphasizes the importance of ownership rights as a source of power when contracts are incomplete. Ownership of assets determines the distribution of surplus between parties. The core insight of this literature is that residual rights of control should be assigned to the party whose investment contributes most to the value of the final output (see also Whinston, 2001).

One interesting feature stands out in the earlier work on vertical integration: the focus is almost entirely on the integration of input suppliers by and up the stream of a final-goods producer (Grossman and Helpman, 2003, 2005; Antràs, 2003, 2005; Feenstra and Hanson, 2005; Nunn and Trefler, 2008; Alfaro et al., 2019). As has been noted by Del Prete and Rungi (2017) this focus is unwarranted from the perspective of the data which appear to feature both backward and forward integration. We will document this fact in the present paper in the largest-possible international dataset for this purpose we know of.

The models of Acemoglu et al. (2010) and Lileeva and van Biesebroeck (2013) are notable exceptions in this regard, as the direction of integration can be forward or backward there. However, the data neither of Acemoglu et al. (2010) nor of Lileeva and van Biesebroeck (2013) permit separating forward and backward integration. Acemoglu et al. (2010) assume that backward integration is the dominant form of integration, and under this assumption they obtain that the marginal effects of buyer and supplier investment intensities are unambiguous (and opposite) for the integration versus arm's-length transaction attractiveness to the producer. Provided

this assumption holds, they find support for their results in the data. In contrast, Lileeva and van Biesebroeck (2013) explicitly allow for forward integration to exist as well. They look for an effect of the difference in investments between producer and supplier. If this difference is large enough, the more investment-intensive party should be given control and integrate the other one. They find support for this hypothesis, but, as said, cannot explicitly check whether indeed forward and backward integration happen where the model predicts them to do. Both Acemoglu et al. (2010) and Lileeva and van Biesebroeck (2013) focus on shareholder firms in a single country, Britain with Acemoglu et al. (2010) and Canada with Lileeva and van Biesebroeck (2013). Liu (2020) proposes a model, where forward, backward, and no integration of heterogeneous firms are possible in a property-rights framework of the Grossman and Hart (1986) type. In her empirical analysis, Liu (2020) focuses on the role of relationship-specific investments for integration outcomes. Common to all of the aforementioned work is that the outcomes of interest are obtained from already established integration and value-chain-linkage choices. In that sense, the validation of theoretical forces behind firms' integration choices is based on data that entail some pre-selection of choices.¹

Relative to the aforementioned work, the present paper adopts a very different empirical strategy that allows for a more precise identification of the theoretical forces behind integration choices. In particular, the empirical model analyzes the extensive margin of firm integration choices over time, taking into account the universe of potential firm-to-firm links around the globe and across all sectors. To that end, we make use of a large panel dataset of worldwide shareholder-affiliate ownership links among 1,565,167 firms which we observe annually over the period 2007-2013. In these data, the potential network – in other words, the choice set – amounts to $(1,565,167 - 1)1,565,167$ potential links in the cross section. In order to work with the full choice set but at the same time being able to operationalize the analysis with modern computer hardware, we aggregate the individual choices into sector-country-to-sector-country cells in each year and obtain a distribution of frequencies of integration links across cross-sectional units and time periods.² With the relative positioning of potential links between sector-country pairs in value chains, this permits assigning to every potential link whether it is in the forward or the back-

¹Most of the literature including the mentioned work as well as the present paper focuses on the use of a single input. van Biesebroeck and Zhang (2014) consider several inputs and demonstrate that intricate interdependencies may emerge between them.

²Econometric work on individual choice problems suggests that if choices depend on variables and parameters that can be grouped (e.g., into country-sectors here) they can be aggregated and analyzed in terms of frequency of occurrence (see Schmidheiny and Brülhart, 2011).

ward direction. Moreover, the such-arranged dataset permits exploiting the variation in sector-country characteristics of the shareholder as well as the affiliate to assess theoretical hypotheses from this different choice angle relative to earlier work. Altogether, this enables the analysis of – the frequency but also the direction of – firms’ integration choices with a focus on a rich set of interactions of fundamental drivers of and obstacles to integration and also a rich set of fixed effects. Crucially, the latter permits a focus on *changes* in fundamentals and the associated responses in integration outcomes. Compared to earlier empirical work, identifying integration choices following changes in fundamentals is an important step towards an identification of the mechanisms at work.

In particular, we augment the theoretical underpinnings of integration choices to allow for fixed costs of integration and derive a rich set of novel predictions regarding the expected changes in integration outcomes following a change in these costs. Empirically, we use the variation in the implementation of bilateral investment treaties (BITs) – which are designed to reduce inter alia expected costs of integration across national borders – over time to understand how different sectors and countries react differently to these policies.³ In the model, changes in fixed costs interact with other, firm- and market-specific fundamentals in determining the profitability of forward and backward integration. The associated set of empirical results provides a strong test of the importance of the model’s mechanisms at work in the data.

Towards analyzing the data, it is key to assign each firm link a direction. We do so by using the sector delineation of the World Input Output Tables (WIOT) in most of the analysis.⁴ We keep the finest available sector classification of the WIOT for all manufacturing sectors, but use a more aggregated sector classification for various services industries. Ultimately, all firms in the data can be placed in one of 38 sectors and one of 199 countries. The WIOT provides information on the extent and ranking of input suppliers across countries and sectors for each country and sector. Using the aforementioned information suggests that 52% of the mentioned firm-to-firm links are ones, where the subsidiary operates in one of the five most-important supplying sectors of the shareholder’s sector and country. Accordingly, backward integration

³The United Nations Conference of Trade and Development (UNCTAD) provides a collection of all important international investment agreements (IIAs), including the signatory parties as well as the dates of signature and entry into force.

⁴The sector definition of WIOT is more coarse than the one actually available from the firm data. Moreover, as the firms in the data belong in 199 countries, we have to impute the associated information for countries not explicitly included in the WIOT. However, we document in a sensitivity analysis that neither the use of the WIOT sector delineation (as opposed to much finer-grained input-output tables from the United States) nor the imputations for countries outside of the WIOT drive the main insights.

is important in terms of frequency of occurrence, and we can support some of the findings of Acemoglu et al. (2010) in this much larger dataset. However, in 52% of the cases the subsidiary operates in a sector which is among the five most important buying ones of the shareholder's sector and country. Clearly, there is a certain overlap in the most important buying and supplying sectors for any country and sector, but in 13% of the cases the subsidiary is in one of the five most important buying sectors but not one of the most important supplying sectors, and the same is true vice versa to an identical extent. Hence, forward integration appears as prevalent as backward integration all over the world.⁵

The analysis conducted in this paper goes beyond the typical focus on investment intensity as determinant of integration. In particular, we consider three further channels of influence on the propensity and direction of integration and ownership of producers and suppliers: the relative density of the market in which the producer and the supplier operate; the relative reliance on and importance of the supplier's input in the producer's output; and the relative importance of fixed integration costs. These channels are important for two reasons. First, market thickness and fixed costs on the one hand parameterize important characteristics of sectors and countries which capture the economic environment there. Perhaps more importantly, countries devise policies to affect them without typically considering their relevance for value chains and firm integration. Second, input reliance is an important technological feature that can be measured relatively well by way of input-output data and it should be a deep parameter that affects the boundaries of the firm. In this theoretical setting, we obtain four results: first, the relative investment intensity of one party relative to the other increases the profitability of owning it and, with an association of the parties with being the producer or supplier, determines the direction of integration; second, greater thickness in the potential-shareholder-versus-affiliate market and higher fixed costs of integration reduce the propensity of backward and forward ownership; third, a greater input reliance of the supplier makes integration more likely; finally, market

⁵Clearly, the choice problem regarding ownership links of firms in all pairs of 38 sectors and 199 countries over 7 years is huge. At the same time, the sector granularity may be considered coarse for a definition of upstream and downstream sectors and associated backward and forward ownership links. To address this point, we construct an alternative dataset of all pairs of 234 sectors using the granularity of the input-output tables of the United States and 199 possible affiliate countries. Employing this sector granularity in conjunction with 199 shareholder countries establishes a choice set whose analysis is beyond the reach of modern workstation computing. Therefore, we select five large European shareholder countries to end up with a problem which, across 7 years, still entertains the variation of some 55 million ownership-choice cells. The key insight from this analysis is that the benchmark conclusions drawn from the coarser sector delineation but much bigger country-pair choice set are largely robust and not owed to sector-aggregation bias.

thickness and fixed costs interact with each other and the cross derivative is such that higher fixed integration costs raise the effect of greater market thickness on forward integration but reduce it on backward integration. What is key here is that, apart from the investment-intensity channel, the synopsis of the other aforementioned channels of influence had been outside of the scope of theoretical and empirical work on the direction of integration.

We find support for all of the four theoretical results. Hence, a firm's relative increase in investment intensity raises the propensity to own a firm with a lower intensity, a greater market thickness reduces and investment-agreement membership increases this propensity, and a higher input reliance also increases the propensity of shareholder-affiliate ownership. We also find support of the interaction effect between market thickness and fixed integration costs.

We deem the main findings to be important for several reasons. Both theory and empirical analysis consider a larger set of predictions and hypotheses relative to the literature. In particular, we address the relevance of parameters which are potentially affected by policy (regarding competition and foreign investment). Therefore, the results have important implications, for instance, for foreign-investment or competition policy and their intended as well as unintended effects on GVCs. Moreover, the focus on the direction of firm integration is relevant also for the literature on foreign investment and multinational firms in that it brings to the table GVC aspects and parameters which determine where headquarters (shareholders) and affiliates are located and, perhaps most importantly from a political-economy perspective, it informs us about the likely national and sectoral ownership of the assets in an economy. Regarding the econometric strategy, this paper improves on two drawbacks of earlier work. First, it takes into account the full set of ownership choices and input-output linkages consistent with the non-zero cells of global-value-chain tables and a notion of inputs that is broader than in most empirical work on GVCs. Second, the use of time variation in the data in conjunction with high-dimensional fixed effects helps reducing the bias from omitted drivers of firm ownership and improves on the identification of causal effects.

The rest of the paper is organized as follows. The next section introduces a model of vertical integration. Chapter 3 describes the construction of the novel dataset used for the empirical analysis in Chapter 4. Section 5 provides some extensions and evidence on the robustness of the main findings. The last section concludes.

2 Model

2.1 Outline

We propose a model of vertical integration that is rooted in the property-rights theory advanced by Grossman and Hart (1986) and Hart and Moore (1990). In this model, two firms can decide to integrate backwards or forward but also to stay independent. The respective outcome depends on the relative investment intensity of the partners. We closely follow Acemoglu et al. (2010) but extend their model by introducing fixed costs of firm integration. The latter permits deriving further empirical predictions. In contrast to Acemoglu et al. (2010), when assessing these predictions, we will specifically address backward versus forward integrations explicitly.

The two parties, a supplier S and a producer P , are collaborating along the value chain. The output generated from this relationship depends on the investment undertaken by both parties. Assuming that contracts conditioning on investment or output levels are not available, investment incentives can be aligned through the allocation of property rights. In particular, the two parties can either decide to stay independent (I), or to integrate either backward (Bwd) or forward (Fwd). We assume the following timing:

1. The producer P offers an organizational form $o \in \{Fwd, I, Bwd\}$ and corresponding transfers, T_P^o and T_S^o , such that $T_P^o + T_S^o = 0$.⁶
2. The supplier S decides whether she accepts the offer to integrate or not.
3. The supplier S and producer P simultaneously decide on their investment levels $e_P^o \geq 0, e_S^o \geq 0$.
4. After investments are realized, the supplier and producer bargain over revenues according to Nash bargaining.

Producing the final output $Y(\cdot)$ involves, apart from the aforementioned investments e_P^o and e_S^o , a customized input provided by the supplier, $x_S \in (0, 1)$. Specifically, we will assume the production technology of the final output to be

$$Y(x_S, e_P^o, e_S^o) = \varphi x_S (p e_P^o + s e_S^o + 1) + (1 - \varphi)(p e_P^o + 1), \quad (1)$$

where $p > 0$ and $s > 0$ are two parameters governing the marginal product of investments by the producer and the supplier, respectively, and $\varphi \in (0, 1)$ indicates to which extent the final output relies on the provision of the customized input.

⁶We assume that there are no financial constraints such that transfers can be negative.

Following Acemoglu et al. (2010), we consider a simple quadratic form for the costs of investments:⁷

$$C_P(e_P^o) = \frac{1}{2}(e_P^o)^2 \text{ and } C_S(e_S^o) = \frac{1}{2}\varphi(e_S^o)^2. \quad (2)$$

Before determining the outcome of the Nash bargaining, we have to define the respective outside options V_i^o in case of disagreement for player i under each organizational form o . In the case of forward integration the supplier owns all assets and will keep the output generated. However, the producer can retain a fraction λ^P of her investment in case of disagreement. The respective outside options in the case of **forward integration** amount therefore to:

$$\begin{aligned} V_S^{Fwd} &= Y(x_S = 1, (1 - \lambda^P)e_P^{Fwd}, e_S^{Fwd}), \\ V_P^{Fwd} &= 0. \end{aligned} \quad (3)$$

If the two parties are not integrated but independent, every firm legally owns its assets. The supplier will, however, not supply the customized input to the producer in case of disagreement but sell it on the market. The marketability of the customized input is measured by θ which depends on both the specificity of the customized input and the competition in the market. Hence, outside options under **independence** are given by:

$$\begin{aligned} V_S^I &= \theta\varphi(se_S^I + 1), \\ V_P^I &= Y(x_S = 0, e_P^I, 0). \end{aligned} \quad (4)$$

Finally, under backward integration all assets belong to the producer and she will keep the entire output. As before, we assume that the supplier can retain a fraction λ^S of her investment. The respective outside options under **backward integration** are given by:

$$\begin{aligned} V_S^{Bwd} &= 0, \\ V_P^{Bwd} &= Y(x_S = 1, e_P^{Bwd}, (1 - \lambda^S)e_S^{Bwd}). \end{aligned} \quad (5)$$

The gross revenue accruing to each party under each organizational form, y_i^o , is determined by Nash bargaining:

$$\arg \max_{y_P^o} \{(y_P^o - V_P^o)(y_S^o - V_S^o)\} \text{ s.t. } y_S^o = Y(x_S = 1, e_P^o, e_S^o) - y_P^o \quad (6)$$

⁷Note that including φ avoids implicit economies of scale. See Acemoglu et al. (2010) for a discussion of that assumption.

The equilibrium gross revenue for any party i is therefore

$$y_i^o(e_P^o, e_S^o) = V_i^o + \frac{1}{2} (Y(x_S = 1, e_P^o, e_S^o) - V_S^o - V_P^o). \quad (7)$$

Profits are obtained by taking into account the cost of investment and integration as well as transfers:

$$\pi_i^o = y_i^o - C_i(e_i^o) - F_i^o + T_i^o, \quad (8)$$

where F_i^o denote fixed costs of integration paid by the owning party (the shareholder), with

$$\begin{aligned} F_S^{Fwd} &= F, & F_P^{Fwd} &= 0 \\ F_S^I &= F_P^I = 0 \\ F_S^{Bwd} &= 0, & F_P^{Bwd} &= F. \end{aligned}$$

Each party chooses its investment levels conditional on the chosen organizational form to maximize its profits (8):

$$e_S^{Fwd*} = s, \quad e_P^{Fwd*} = \frac{\lambda^P}{2} p \quad (9)$$

$$e_S^{I*} = \frac{1 + \theta}{2} s, \quad e_P^{I*} = (1 - \frac{\varphi}{2}) p \quad (10)$$

$$e_S^{Bwd*} = \frac{\lambda^S}{2} s, \quad e_P^{Bwd*} = p. \quad (11)$$

The equilibrium investment levels illustrate the main channel of the model mechanics: since, in equilibrium, any party invests most under that organizational form where the party is the owner of all assets, the optimal organizational form depends on the relative importance of the supplier's and the producer's investment for total output, which is governed by s and p . Given s and p , the attractiveness of the non-integration option is governed by θ and φ . The higher θ , the higher the incentives for the supplier to invest even under independence, because even in the event of disagreement, a large share of the benefits generated by the investment can then be collected. This decreases the need to use (forward) integration as a tool to align incentives between the parties. On the other hand, the incentive for the producers to invest into the joint output under non-integration is decreasing in φ , because φ governs the relative importance of the customized input which under the organizational form of independence would not be provided in the event of disagreement.

Therefore, the need to (backward) integrate increases in the relative importance of the customized input.

Since we assume that there are no credit constraints and we allow for transfers, the organizational form chosen in equilibrium will be the one that maximizes total surplus, $S^o = \pi_S^o + \pi_P^o$. The respective equilibrium organizational form chosen by any pair of supplier S and producer P can be expressed in terms of $\gamma = p/s$, the relative returns to investment for the producer and supplier. In particular, we can derive two loci as a function of γ , Δ^{Fwd} and Δ^{Bwd} , which represent the additional surplus generated by forward integration compared to independence and the additional surplus generated by backward integration compared to independence, respectively:

$$\Delta^{Fwd} = (1 - \theta)^2 \frac{s^2}{8} \varphi - \left((2 - \lambda^P)^2 - \varphi^2 \right) \frac{1}{8} (\gamma s)^2 - F, \quad (12)$$

$$\Delta^{Bwd} = \left(\frac{\varphi^2}{8} \right) (\gamma s)^2 - (1 + \theta - \lambda^S)(3 - \theta - \lambda^S) \frac{\varphi s^2}{8} - F. \quad (13)$$

Hence, the equilibrium organizational form is **forward integration** for any $\gamma < \gamma^{Fwd*}$, where

$$\gamma^{Fwd*} = \sqrt{\frac{\left((1 - \theta)^2 \frac{s^2}{8} \varphi - F \right)}{\left((2 - \lambda^P)^2 - \varphi^2 \right) \frac{1}{8} s^2}}. \quad (14)$$

The equilibrium organizational form is **backward integration** for any $\gamma > \gamma^{Bwd*}$, where

$$\gamma^{Bwd*} = \sqrt{\frac{\left((1 + \theta - \lambda^S)(3 - \theta - \lambda^S) \frac{\varphi s^2}{8} + F \right)}{\left(\left(\frac{\varphi^2}{8} \right) s^2 \right)}}. \quad (15)$$

For any $\gamma^{Fwd*} \leq \gamma \leq \gamma^{Bwd*}$, the two parties will choose to stay **independent**.⁸ Figure 1 depicts the net profitability and optimal choice of organizational form as a function of γ . In the support of γ – defined as a ratio of investment returns of the producer relative to the supplier –, Δ^{Fwd} is strictly decreasing, while Δ^{Bwd} is strictly increasing, establishing a well-defined ranking of the equilibrium organizational forms depending on γ . Forward integration is more desirable as the returns to

⁸Technically, there might arise situations where integration is always preferred to independence. In this case, backward integration is always preferred to forward integration when $\gamma > \gamma^{BF*}$, where $\gamma^{BF*} = \frac{(2 - \lambda^S)}{(2 - \lambda^P)} \sqrt{\varphi}$.

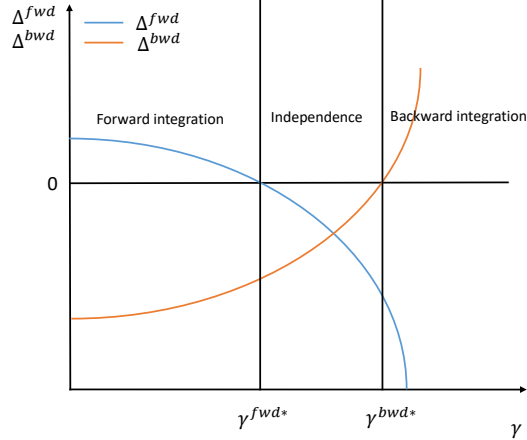


Figure 1: Graphical representation of the equilibrium organizational form as a function of $\gamma = p/s$.

investment for the supplier are relatively high, while the opposite holds for backward integration. Since fixed costs have to be incurred for both forms of integration but not for independence, the level of fixed costs acts as a shifter for both loci.

The intercepts of both loci, Δ^{Fwd} and Δ^{Bwd} , are governed by the differences in surplus across organizational forms stemming from supplier investment: These differences depend on θ – determining the level of supplier investment under independence – and λ^S – determining the level of supplier investment under backward integration. φ affects the intercept as it governs the importance of supplier investment for overall surplus.

The slopes of Δ^{Fwd} and Δ^{Bwd} with respect to γ depend on φ – determining the level of producer investment under independence – and λ^P – determining the level of producer investment under forward integration.⁹

2.2 Model Implications and Comparative Static Results

In our attempt to explain the various determinants of (international) firm integration along the value chain with the model at hand, we proceed as follows. The main mechanism of the model operates through the marginal returns to investment for the producer and the supplier, respectively. Hence, we expect forward integration

⁹For the design of Figure 1 and throughout the subsequent analysis we assume, consistent with the data, that a parameter configuration prevails, where any one of the three possible forms of integration are preferable for some values of γ .

to be more profitable – and, eventually, be the dominant mode of integration – as the supplier becomes relatively more investment intensive compared to the producer. Vice versa, we expect backward integration to be more profitable – and, eventually, be the dominant mode of integration – as the producer becomes relatively more investment intensive. These relationships become apparent from the slopes of the two differential-profit schedules for forward and backward integration in Figure 1. The figure clearly shows that the differential profitability of backward integration, Δ^{Bwd} , rises with $\gamma = p/s$, whereas the differential profitability of forward integration, Δ^{Fwd} , rises with $\gamma^{-1} = s/p$ (declines with γ).¹⁰ This is the core idea behind the Grossman-Hart-Moore property-rights framework: residual rights of control should be assigned to the party whose investment contributes most to the value of the final output.

Result 1: $\frac{\partial \Delta^{Fwd}}{\partial \gamma^{-1}} > 0$ and $\frac{\partial \Delta^{Bwd}}{\partial \gamma} > 0$.

In this framework, the organizational form chosen depends on θ and φ as these parameters determine the equilibrium investment levels under independence and, hence, the need to use integration to align incentives. Generally, integration becomes less likely, the higher the joint surplus is under independence. In particular, backward integration and taking control of the supplier is less likely the better the marketability of the customized input because the supplier’s incentives to invest are high even under independence. Similarly, the incentives of the producer to invest under independence are higher the lower φ , the relative importance of the customized input for the final product. Hence, forward integration becomes more likely for higher levels of φ since integration allows the supplier to incentivize appropriate investment of the producer.

Result 2: $\frac{\partial \gamma^{Fwd*}}{\partial \theta} < 0$ and $\frac{\partial \gamma^{Fwd*}}{\partial \varphi} > 0$. Furthermore, $\frac{\partial \gamma^{Bwd*}}{\partial \theta} > 0$ and $\frac{\partial \gamma^{Bwd*}}{\partial \varphi} < 0$.

An increase in fixed costs will shift both Δ^{Bwd} and Δ^{Fwd} downwards. Clearly, since integration is costly, any reduction in these costs will foster integration.

Result 3: $\frac{\partial \gamma^{Fwd*}}{\partial F} < 0$ and $\frac{\partial \gamma^{Bwd*}}{\partial F} > 0$.

¹⁰Below, we will speak of one or the other integration choice to be more likely, if the associated profitability is higher. The latter builds on the idea that in the data there will be stochastic shocks which will lead to some gap between latent deterministic profitabilities and firms’ choices.

A more subtle prediction of the model relates to second-order derivatives regarding variables of interest which affect the intercepts of Δ^{Fwd} and Δ^{Bwd} . Note that Δ^{Fwd} is globally downward-sloping, whereas Δ^{Bwd} is upward-sloping in γ . Note also that Δ^{Fwd} is concave, while Δ^{Bwd} is convex. Hence, inevitably, anything that shifts Δ^{Fwd} downwards will cause γ^{Fwd*} to be situated, where Δ^{Fwd} is more elastic (flatter). Increasing F gradually by the same magnitude will, hence, reduce γ^{Fwd*} by an ever larger magnitude. Since increasing θ shifts Δ^{Fwd} downwards akin to increasing F , the marginal effect of F on γ^{Fwd*} will become ever larger, if θ is increased. Economically, the difference in surplus between forward integration and independence decreases more rapidly as we move to the right. This is because the investment level of the producer is strictly higher under independence. The more important the producer's contribution to overall surplus becomes as γ rises, the more rapidly decreases the overall advantage of forward integration over independence. In a supplier-producer relationship that processes an input with a high marketability, the investment level of the supplier is relatively high even under independence, thus making the differential surplus under forward integration generally quite small. At this point changing the fixed costs of integration by a given amount makes it profitable to integrate forward for a larger range of γ compared to a situation with low θ .

The opposite is true for Δ^{Bwd} . The latter is also shifted downwards by an increase in F . In response, γ^{Bwd*} will move rightwards and be situated at a point where Δ^{Bwd} is now less elastic (steeper). Hence, increasing F subsequently by the same amount will induce smaller and smaller effects γ^{Bwd*} . By the same token, an increase in θ , which entails a down-ward shift of Δ^{Bwd} like F , will reduce the marginal effect of an increased F on γ^{Bwd*} . Economically, as before, the change in slope as γ increases comes from the fact that – with producer investment under backward integration being strictly larger than under independence – the differential surplus of backward integration as we move along the x-axis increases disproportionately.

Hence, a better marketability of inputs will increase the policy impact of reduced fixed costs on forward integration, while it will reduce it on backward integration.¹¹

¹¹By contrast, the role of φ is less straightforward. φ affects the slope of Δ^{Bwd} and Δ^{Fwd} directly through its impact on the producer's investment level under independence. A higher level of φ induces a flatter slope of Δ^{Fwd} but a steeper slope for Δ^{Bwd} . Consequently, a given change in fixed costs is amplified for forward integration but diminished for backward integration when φ is higher. However, φ also affects the relative importance of the producer's investment for differences in surpluses across organizational form. Graphically, this affects the position of the intercept and determines the relative importance of slope versus intercept for the overall effect such that the overall effect of φ remains ambiguous. This is different for the other effects examined.

Table 1: Implications for the direction of integration based on Results 2–4

	Derivatives	Implications for integration forces
Backward	$\frac{\partial \gamma^{Bwd*}}{\partial \theta} > 0$	-
	$\frac{\partial \gamma^{Bwd*}}{\partial \varphi} < 0$	+
	$\frac{\partial \gamma^{Bwd*}}{\partial F} > 0$	-
	$\frac{\partial^2 \gamma^{Bwd*}}{\partial F \partial \theta} < 0$	-
	Forward	
	$\frac{\partial \gamma^{Fwd*}}{\partial \theta} < 0$	-
	$\frac{\partial \gamma^{Fwd*}}{\partial \varphi} > 0$	+
	$\frac{\partial \gamma^{Fwd*}}{\partial F} < 0$	-
	$\frac{\partial^2 \gamma^{Fwd*}}{\partial F \partial \theta} < 0$	+

Result 4: $\frac{\partial^2 \gamma^{Fwd*}}{\partial F \partial \theta} < 0$ and $\frac{\partial^2 \gamma^{Bwd*}}{\partial F \partial \theta} < 0$.

Table 1 summarizes the comparative static results regarding the direction of firm integration based on the model parameters $\{\theta, \varphi, F\}$.

2.3 From Theoretical Results to Testable Predictions

The theoretical model generates empirical predictions regarding the integration choice of a given supplier-producer pair. This setting is clearly stylized as modern production is substantially more complex, involving many intermediate steps along the value chain. Moreover, in the dataset of firm-level ownership relationships that we are going to employ, at any given time we observe only the already realized outcome of integration between a given producer and a given supplier but not the latent (discrete) choices.

As has been shown by, e.g., Schmidheiny and Brülhart (2011) such micro-level choice problems can instead be analyzed by counting the number of firms within cells – here, we will consider shareholder-country-sector-to-subsidiary-country-sector cells – and compare the counts across these cells using a Poisson regression analysis. The idea is simple: according to the model, firms that have ceteris paribus low returns to investment will be owned by firms that have ceteris paribus high returns to investment. Hence, if we count the number of firms that have low returns to investment and are owned by firms with high returns to investment, we expect a higher count than vice versa. Clearly, as we count the number of firms for all possible combinations of shareholder-country-sectors and subsidiary-country-sectors over time, the empirical

measurement of parameters of interest such as $\{\gamma, \theta, \varphi, F\}$ can at most vary at the (shareholder)-sector-country-(subsidiary)-sector-country-year level but not the firm level. In this context, the theoretical results can be restated as follows.

Result 1 states that backward integration becomes more profitable with rising $\gamma = p/s$, whereas forward integration becomes more profitable with falling γ or rising $\gamma^{-1} = s/p$.

PREDICTION 1: Any (shareholder)-sector-country-(subsidiary)-sector-country combination that features a high investment intensity of the shareholder relative to that of the affiliate should contain a high count of integrated firms. This result is independent of the form of integration.

Result 2 states that an increase in θ – the marketability of the customized input outside of the relationship – makes any form integration less profitable. Moreover, Result 2 states that an increase in φ – the importance of the customized input for production – makes any form integration more profitable.

PREDICTION 2: Any (shareholder)-sector-country-(subsidiary)-sector-country combination that features a high marketability of the respective input sector should contain a lower count of integrated firms. Furthermore, any (shareholder)-sector-country-(subsidiary)-sector-country combination that features a high importance of the respective input sector should contain a higher count of firms.

Result 3 states that any reduction in fixed costs of integration increases the profitability of any form of integration.

PREDICTION 3: Any (shareholder)-sector-country-(subsidiary)-sector-country combination that features low costs of integration should contain a higher count of integrated firms.

Result 4 states that there is an interaction effect between an increase in the input marketability outside of a producer-supplier relationship and fixed integration costs: the sign of this interaction effect is negative for backward integration but positive for forward integration.

PREDICTION 4: Any (shareholder)-sector-country-(subsidiary)-sector-country cell that experienced a change in fixed integration costs should see a larger effect on the frequency of forward integration with a better marketability of the input. In

contrast, any (shareholder)-sector-country-(subsidiary)-sector-country cell that experienced a change in fixed integration costs should see a smaller effect on the frequency of backward integration with a better marketability of the input.

3 Data

The empirical analysis of this paper relies on a combination of two datasets. First, we use annual data on the global ownership of all firms contained in Bureau van Dijk’s ORBIS Database between 2007 and 2013. Second, we rely on the World Input Output Tables (WIOT) for the years covered. The latter contain information on the country-sector-to-country-sector input-output links of 43 economies and 56 sectors in each year over the period 2000-2014.

3.1 Firm-ownership Data

ORBIS is a large compilation of firm data that allows us to identify ownership relations. For any shareholder (owner) firm, we know in any year t the country of residence (incorporation) which we index by j and its main sector of operation which we index by s . Moreover, we know for the latter firm all of its affiliates as well as their country of residence i and sector r in the same year. Note that i and j as well as r and s may be the same or not. In the raw data, the coverage of firm-to-firm relationships increases over time. In order to exclude the possibility of any changes in ownership stemming from changes in data coverage over time and countries, we use only those shareholders and subsidiaries in our analysis that are observed over the entire period from 2007-2013.

Imposing those restrictions, we observe 571,636 unique shareholders and 993,531 unique subsidiaries across all years in 2007-2013.¹² The number of shareholder-subsidiary links amounts to 12,229,737.

Since we are interested in the extensive margin of firm-ownership links across countries and sectors, we aggregate the firm-to-firm ownership data up to the country-and-sector-pair level. We construct an $\{ij, rs, t\}$ -indexed dataset where the dependent variable, $(CF_{ij,t}^{rs})$, measures the number of shareholder-affiliate links from country-sector js in country-sector ir and year t . With 199 countries $\{i, j\}$ and 38 (ISIC Rev. 4) one-digit (two-digit for manufacturing) sectors, we end up with a $199^2 \cdot 38^2 = 57,183,844$ country-sector-pair cells of potential ownership links which

¹²Clearly, we can only include those firms of which the country of location and the main sector of operation are known.

are non-negative integers (and, hence, may be zero in absence of any such links). With annual data in the period 2007-2013 this yields a panel dataset of 400,286,908 observations.

In order to guard against a host of possible factors of influence on firm-to-firm integration choices beyond the ones in our focus, we employ a high-dimensional set of fixed effects. Doing so entails that only a subset of the data where links vary sufficiently across country and sector pairs as well as over time will inform the identification of the parameters of interest.¹³

3.2 Global-value-chain Data

The second key database our analysis rests upon are international (global) input-output-data coefficients as published in the World Input-Output Tables (WIOT). In particular, we use data from the 2016 release of WIOT, which distinguishes between 56 (ISIC Rev. 4) two-digit sectors and 43 countries, and which contains annual data for all the years of interest (2007-2013). Since we are constrained in terms of dimensionality – the final dataset will consist of $199^2 \cdot (\text{Number of Sectors})^2 \cdot 7$ observations – but at the same time want to keep the richness of the WIOT data for the value chain relationships across manufacturing sector, we combine all non-manufacturing sectors at the one-digit level but keep the original two-digit level for all manufacturing sectors. Hence, we aggregate the 56 WIOT sectors up to 38 sectors. The sectors used in the analysis are presented in Table A1 in the Appendix. We will later describe a robustness exercise in which we reduce the number of bilateral country relationships but use a substantially finer-grained sector classification.¹⁴

For the construction of any variables that describe the value chain relationships of any (shareholder)-sector-country-(subsidiary)-sector-country combination let us

¹³The discarded units of observation will all lack variation in ownership links within the dimension of one or more of the included types of fixed effects.

¹⁴Moreover, we impute WIOT coefficients for the countries contained in ORBIS but not in WIOT as follows. First, we group the 43 WIOT countries into 22 major world regions according to the detailed geoscheme of the United Nations (Northern America, Central America, Caribbean, South America, Northern Africa, Western Africa, Middle Africa, Eastern Africa, Southern Africa, Southern Europe, Western Europe, Northern Europe, Eastern Europe, Western Asia, Central Asia, Southern Asia, Eastern Asia, Southeast Asia, Australia and New Zealand, Micronesia, Polynesia, and Melanesia) and substitute coefficients for those countries in ORBIS which are not specifically contained in the WIOT by the respective annual average of the group they belong in. We will present sensitivity checks, where we focus only on those countries for which data are explicitly reported in the WIOT. As the WIOT do not contain any country from Africa, we impute the subsequent input-output measures for every African country in ORBIS by assigning it the WIOT “Rest of the World” average.

closely follow the notation in (Antràs and Chor, 2018) and define a world economy with J countries (indexed by i or j) and S sectors (indexed by r or s). Let us refer to the total value of inputs used by country j 's sector s that stems from country i 's sector r in year t as $Z_{ij,t}^{rs}$.

Input coefficient. The intermediate input-output linkages, $Z_{ij,t}^{rs}$, are measured in U.S. dollars. We can define a measure-free input coefficient $a_{ij,t}^{rs} = Z_{ij,t}^{rs}/Y_{j,t}^s$, where $Y_{j,t}^s$ is the gross output of sector s in country j at year t .¹⁵ Based on $a_{ij,t}^{rs}$, we can aggregate across supplying countries to obtain

$$a_{j,t}^{rs} = \sum_{i=1}^J a_{ij,t}^{rs} = \frac{\sum_{i=1}^J Z_{ij,t}^{rs}}{Y_{j,t}^s} \quad (16)$$

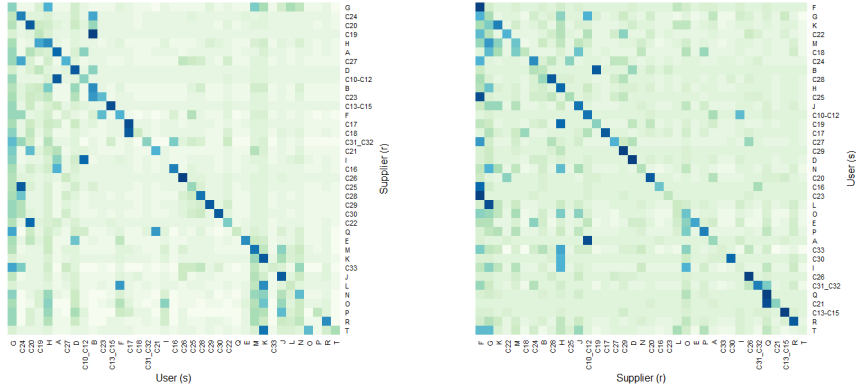
as a sector-pair-country-of-use input coefficient. The latter measures the normalized inputs of sector- r output (regardless of its geographic origin) as used by country j in its production of sector- s output in year t .

Output coefficient. Following the same logic, we can define $b_{ij,t}^{rs} = Z_{ij,t}^{rs}/Y_{i,t}^r$ as a measure-free (country- i -normalized) output of country i 's sector r used by country j 's sector s . This can be aggregated across using countries j to obtain

$$b_{i,t}^{rs} = \sum_{j=1}^J b_{ij,t}^{rs} = \frac{\sum_{j=1}^J Z_{ij,t}^{rs}}{Y_{i,t}^r} \quad (17)$$

as a sector-pair-country-of-supply output coefficient. The latter measures which sectors (regardless of the country) are the main users for country i 's sector- r output at year t .

¹⁵The WIOT distinguish three components of gross output – namely intermediate uses, final uses, and net inventories – instead of just two (intermediate and final uses). Therefore, we follow Antràs et al. (2012) in applying a “net inventory” correction.



(a) Average input coefficients (a^{rs}) (b) Average output coefficients (b^{rs})

Figure 2: Input and output coefficients (averages across countries and years).

Note: Sectors ordered by eigenvector centrality.

In Figure 2 we illustrate input and output coefficients averaged across countries and years by way of heat maps. There are some positive input-output relations for every sector pair. Nevertheless, there is a large overall degree of variation in the coefficients, and for many sector pairs the coefficients are close to zero. Hence, the variation is dominated by extreme values. For this reason, we will not use the information contained in input and output coefficients at face value but define binary indicators based on the average of ($\tilde{a}_j^{rs}, \tilde{b}_i^{rs}$) over years, which indicate if a given sector r is a major input or output sector for country j 's sector s . Specifically, we define one indicator stating whether sector r is among the top-5 input-supplying sectors to country j and sector s which proxies backward integration:

$$\text{Backward}_j^{rs} = \begin{cases} 1 & \text{if } \tilde{a}_j^{rs} \in \{\text{Top-5 } \tilde{a}_j^{rs} \text{ for } js\}, \\ 0 & \text{otherwise.} \end{cases}$$

Analogously, we define another indicator stating whether sector r is among the top-5 using sectors of output from country j and sector s which proxies forward integration:¹⁶

$$\text{Forward}_j^{rs} = \begin{cases} 1 & \text{if } \tilde{b}_j^{rs} \in \{\text{Top-5 } \tilde{b}_j^{rs} \text{ for } sj\}, \\ 0 & \text{otherwise.} \end{cases}$$

To proxy for backward and forward integration we are interested in the shareholder's suppliers of inputs as well as the shareholder's buyers of its output. Recall that, in a generic year, the dependent variable in the analysis is CF_{ij}^{rs} , where sj

¹⁶It will become clear immediately in the next paragraph, why we administer a slight change in the use of indices here.

pertains to (potential) shareholders whereas ri pertains to (potential) affiliates. In matching the information on input and output coefficients onto these data, we will use Backward_j^{rs} to indicate whether sector r of the affiliates is among the top-5 supplying sectors of shareholders in j and s . This variable will indicate that r is in the upstream direction of the value chain relative to s and j and associated shareholder-affiliate links would reflect a backward integration. Similarly, we will use Forward_j^{rs} to indicate a shareholder's top-5 using (or purchasing) industries r . This variable will indicate if s is in the downstream direction of the value chain and associated shareholder-affiliate links would reflect a forward integration.

3.3 Other Data

We will use firm-level accounting data contained in ORBIS to construct measurements for the explanatory variables discussed in the theoretical model.

R&D intensity as a measure of technology intensity (γ)

In the stylized model $\gamma = p/s$ reflects the relative productivity of investment of the input user (the producer firm, P) relative to the input supplier (the supplier firm, S). With sector-level data, the latter would be the relative productivity of the using and supplying country-sector pairs. This is not directly observed, but we conjecture the R&D intensity (i.e., the share of expenditures on research and development in total sales of a firm) to be closely associated with this productivity. In order to compute the average R&D intensity of the firms in a sector, we compute the average for all firms between the 2nd and the 99th percentile of the distribution to avoid outliers using the information contained in the ORBIS balance sheet dataset. We obtain the R&D intensity for the shareholder-sector s and the subsidiary sector r . Next we define a binary-indicator variable indicating a strong R&D intensity of the shareholder's sector s relative to the affiliate's sector r :

$$\tilde{\gamma}^{rs} = \begin{cases} 1 & \text{if R\&D intensity shareholder-sector } s \geq \text{R\&D intensity subsidiary-sector } r, \\ 0 & \text{otherwise.} \end{cases}$$

Shareholder and subsidiary relative densities in a market as a measure of competition (θ)

In the theoretical model, θ measures the marketability of inputs outside of a particular relationship between two firms. Hence, we interpret it as a measure of competition

or the availability of outside options. Again, this parameter cannot be directly observed. However, we follow Acemoglu et al. (2010) and measure it as the ratio of the total number of firms in (the shareholder) country j and sector s over the total number of firms in (the subsidiary) country i and sector r for backward integration and the inverse of that for forward integration:

$$\theta_{ij,t}^{rs} = \begin{cases} \theta_{ij,t}^{Bwd^{rs}} = \frac{\#firms_{j,t}^s}{\#firms_{i,t}^r} & \text{for backward integration,} \\ \theta_{ij,t}^{Fwd^{rs}} = \frac{\#firms_{i,t}^r}{\#firms_{j,t}^s} & \text{for forward integration.} \end{cases}$$

Total input consumption as a measure of reliance on customized inputs (φ)

The third important parameter in the model is the one reflecting the reliance on customized inputs, φ . A greater reliance on such inputs reduces the interval $[\gamma^{Fwd*}, \gamma^{Bwd*}]$ and, hence, makes any form of firm integration ceteris paribus more likely.

To measure φ we use the share of total input consumption over production for the producer. We employ the respective data from the WIOT and define two variables, $\varphi_{j,t}^{Bwd^s}$ and $\varphi_{i,t}^{Fwd^r}$. Specifically, we define the latter as:

$$\varphi_{j,t}^{Bwd^s} = \sum_{r=1}^R a_{j,t}^{rs}$$

$$\varphi_{i,t}^{Fwd^r} = \sum_{s=1}^S a_{i,t}^{sr}$$

where $\varphi_{j,t}^{Bwd^s}$ is the sum of input coefficients for a given shareholder country and sector across supplying (upstream) sectors at year t and proxies φ when the shareholder is the producer (backward integration). And $\varphi_{i,t}^{Fwd^r}$ is the sum of input coefficients for a given affiliate country and sector across all supplying sectors at year t and proxies φ when the affiliate is the producer (forward integration).

Bilateral-investment-treaty (BIT) membership as a measure of inverse fixed costs (F^{-1})

One particular concern with the ownership of firms in foreign countries is legal certainty and, hence, a ceteris paribus higher level of fixed integration costs than of

comparable domestic integration. An important instrument to reduce such risk and associated incremental fixed costs of integration are bilateral investment treaties (BITs), which are signed and put into force between many industrialized countries and the major potential host economies of their foreign affiliates.

The United Nations Conference of Trade and Development (UNCTAD) provides a collection of all important international investment agreements (IIAs), including the signatory parties as well as the dates of signature and entry into force. We use the incidence of such agreements as an inverse measure of fixed costs of integration between two countries:¹⁷

$$F_{ij,t}^{-1} \propto BIT_{ij,t} = \begin{cases} 1 & \text{if a BIT is in force between } i \text{ and } j \text{ at year } t, \\ 0 & \text{otherwise.} \end{cases}$$

BITs only pertain to cross-border investments. Unfortunately, we do not have comparable measures which reflect the costs of domestic integration across countries. In order to control for such costs – without being able to address them explicitly – we will include in the empirical models binary indicators which index domestic relationships. We will allow those indicators to carry year-specific coefficients in order for fixed integration costs and other drivers of domestic integration to be allowed to change over time.

$$F_{ii}^{-1} \propto Domestic_{ii} = \begin{cases} 1 & \text{if for } i = j, \\ 0 & \text{otherwise.} \end{cases}$$

3.4 Descriptive Statistics

We present summary statistics of the dependent variable and the explanatory variables in Table 2. The dependent variable of our analysis, the number of links between shareholders in sector r and country i with affiliates in sector s and country j in year t , $CF_{ij,t}^{rs}$, takes on a value of less than unity on average, and it displays a very large standard deviation. The reason for the small average value is that for a number of country-sector pairs there are no ownership links in the average year. This is one of the reasons for why we feel compelled to use count-data methods for the analysis. The cross-sectional binary variables $Backward_j^{rs}$ and $Forward_j^{rs}$ indicating whether r is a top-5 supplying or using sector, respectively take on values of about 0.15 each,

¹⁷The most important forms of IIAs are BITs and chapters on investment in preferential trade agreements (PTAs). We control for PTA membership separately. Moreover, we will control for all time-invariant country-pair-specific characteristics by way of respective fixed effects. To identify a reduction in fixed costs of integration we focus on BITs, here.

indicating that about 15 percent of the sector pairs imply some backward or forward vertical structure. The two are not completely identically frequent, because the data are not balanced. This is also reflected in the shareholder sector exhibiting at least as high an R&D intensity as the subsidiary sector in slightly more than 50% of the cases ($\tilde{\gamma}_t^{rs}$). About 38% of the observations represent potential links under a BIT regime. The relative importance of inputs (the input coefficient) is approximately the same for the shareholder as for the subsidiary sectors and countries in the data, about 54% each. The market thickness variable for the shareholder relative to the subsidiary sector and the inverse of it can reach large values, as they are measured as a ratio of firm numbers each. Finally, in about 42% of the country-sector-pair observations a PTA is in force.

Table 2: Summary Statistics of Regression Sample

Variable	Mean	Std. Dev.
Number of Firm-to-Firm Connections ($CF_{ij,t}^{rs}$)	0.430	69.523
Backward $_{ij}^{rs}$	0.153	0.360
Forward $_{ij}^{rs}$	0.146	0.353
Rel. high shareholder R&D intensity ($\tilde{\gamma}_t^{rs}$)	0.520	0.500
BIT ($F_{ij,t}^{-1}$)	0.377	0.485
Rel. importance of inputs for shareholder ($\varphi^{Bwd}_{j,t}^{rs}$)	0.538	0.181
Rel. importance of inputs for subsidiary ($\varphi^{Fwd}_{i,t}^{rs}$)	0.541	0.187
Market thickness of shareholder industry rel. to subsidiary industry ($\theta^{Bwd}_{ij,t}^{rs}$)	77.068	1382.147
Market thickness of subsidiary industry rel. to shareholder industry ($\theta^{Fwd}_{ij,t}^{rs}$)	351.908	3391.981
PTA $_{ij,t}$	0.416	0.493

Note: The regression sample refers to those observations that are not absorbed by fixed effects in the regression presented in Column (3) of Table 7 which contains all parameters. In particular any shareholder-sector-country to subsidiary-sector-country combinations that experience no changes over the period are absorbed by fixed effects. These are mainly shareholder-sector-country to subsidiary-sector-country combinations that entertain no firm-to-firm connections at all.

4 Empirical Analysis

In this section, we estimate parameters in order to see to which extent the data on shareholder-affiliate links and value-chain relations support or reject some the key predictions of the model on firm integration. As the dependent variable in our analysis, $CF_{ij,t}^{rs}$, is a country-sector-to-country-sector count of firm-to-firm links, we use a Poisson model to estimate the parameters on the observables which are motivated by the above model. Akin to the dependent variable, most explanatory variables introduced in the previous section vary across sectors or sector pairs and countries or country pairs as well as time.

In the empirical model, the parameters on variables measuring the backwardness (Backward_j^{rs}) versus the forwardness (Forward_j^{rs}) of the affiliates' country-sectors relative to the shareholders' and their interactions with variables capturing the essence of $\{\gamma, \theta, F\}$ are in the limelight. The latter will be represented by what we call

$$\text{Parameter}^{Bwd} = \begin{cases} \tilde{\gamma}^{rs} & \text{Technology Intensity Downstream/Upstream,} \\ \text{BIT}_{ij,t} & \text{Fixed Integration Cost,} \\ \theta^{Bwd rs}_{ij,t} & \text{Competition of Shareholders/Affiliates,} \\ \varphi^{Bwd s}_{j,t} & \text{Input Dependence of Shareholders,} \end{cases}$$

for backward or upstream and

$$\text{Parameter}^{Fwd} = \begin{cases} \tilde{\gamma}^{rs} & \text{for Technology Intensity Downstream/Upstream,} \\ \text{BIT}_{ij,t} & \text{Fixed Integration Cost,} \\ \theta^{Fwd rs}_{ij,t} & \text{Competition of Affiliates/Shareholders,} \\ \varphi^{Fwd r}_{i,t} & \text{Input Dependence of Affiliates,} \end{cases}$$

for forward or downstream integration directions. Hence, the proposed model reads

$$\begin{aligned} CF_{ij,t}^{rs} = & \exp(\beta_{\text{Parameter}^{Bwd}} \text{Parameter}^{Bwd} + \beta_{Bwd} \text{Backward}_j^{rs} + \beta_{Bwd \times Par.} (\text{Backward}_j^{rs} \times \text{Parameter}^{Bwd}) \\ & + \beta_{\text{Parameter}^{Fwd}} \text{Parameter}^{Fwd} + \beta_{Fwd} \text{Forward}_j^{rs} + \beta_{Fwd \times Par.} (\text{Forward}_j^{rs} \times \text{Parameter}^{Fwd}) \\ & + \beta_{PTA} PTA_{ij,t} + \sum_{t=2007}^{2013} \beta_{\text{Domestic},t} \text{Domestic}_{ij} + \eta_{ij} + \omega_{i,t}^r + \nu_{j,t}^s + \epsilon_{ij,t}^{rs}) \end{aligned} \quad (18)$$

where $\{\eta_{ij}, \omega_{i,t}^r, \nu_{j,t}^s\}$ are country-pair, owner-sector-country-time, and affiliate-country-sector-time fixed effects, respectively, and $\beta_{\text{Domestic},t}$ measure fixed-type effects for domestic links in every individual year covered. The parameter $\epsilon_{ij,t}^{rs}$ is a remainder error term.

The indicators Backward_j^{rs} and Forward_j^{rs} are the respective measures for the backwardness (indexed as Bwd) and the forwardness (indexed as Fwd), respectively, of the shareholders' country-sector sj relative to the affiliates' ri . Recall that these measures are based on top-5 sectors as defined above.

The parameters β_{Bwd} and β_{Fwd} measure the baseline effects of backwardness or upstreamness and forwardness or downstreamness, respectively. We include the main effects and estimate these parameters only to make sure that the interaction effects we are ultimately interested in do not pick up effects that should not be attributed to them. We will also abstain from interpreting the coefficients β_{PTA} and $\beta_{Domestic,t}$ as the corresponding variables on which they are estimated are only included to absorb otherwise omitted effects.

Clearly, in view of the model predictions from Section 2, the coefficients $\{\beta_{Parameter^{Bwd}}, \beta_{Parameter^{Fwd}}\}$ and $\{\beta_{Bwd \times Par}, \beta_{Fwd \times Par}\}$ are the ones of key interest here, and $Parameter^{Bwd}$ and $Parameter^{Fwd}$ have been defined above. The interpretation of these coefficients is one of average treatment effects.

We will present the results in a way, where we consider first the effect of one parameter of interest $(\gamma, \theta, \varphi, F)$ at a time. We will turn to a more comprehensive analysis later, where we condition on all relevant parameters simultaneously. The latter analysis will suggest that the degree of collinearity between the respective measures used to capture the parameters of interest is small enough so that leaving out some measures of interest at first does not invalidate the conclusions.

Changing the parameter γ given the other parameters will move us along the loci indicating the profitability of forward (Δ^{Fwd}) or backward integration (Δ^{Bwd}). In that sense, altering γ is telling about which **direction of integration** to expect. We will focus on this point, i.e., an assessment of Prediction 1, first. Then, we will consider effects of variables capturing parameters, which affect the intercept of the integration-profitability loci (γ, θ, F) or both the intercept and their slope (φ) . These parameters will determine the **strength of integration forces**.

Before turning to the empirical results, a word of caution is in order. In the theoretical model, there are only two players, one an input supplier and the other one an input user. Hence, the technological relationship is one-way. Empirically, this is not the case at the level of sector pairs nor is it true for country-sector pairs. To some extent, this is an outcome of aggregation. However, empirically it is not even true for firm-to-firm relations: a car manufacturer may purchase tires from a tire producer and the latter might transport the tires with the car producer's trucks (those would be classified as within-sector transactions with the chosen sector aggregation); the same car manufacturer may purchase LED bulbs for beamers from a bulb producer and the latter might transport the light bulbs with the car producer's trucks (those would be classified as between-sector transactions with the chosen sector aggregation). Hence, empirically, there may be a co-existence of shareholders in sj and their affiliates in ri and shareholders in ri and their affiliates in sj .

4.1 Investment Intensity (γ). Assessing Prediction 1

In this first subsection we discuss the empirical results of Prediction 1, which states that shareholders are expected to be relatively more investment intensive compared to subsidiaries. As said before, this prediction is crucial, as it addresses the possibility and profitability of not only backward but also of forward integration. In that sense, the remaining predictions are interesting mainly after documenting that an increase in the relative investment intensity on a potential shareholder's part (who could be a producer or a supplier) stimulates integration (backward or forward). Table 3 reports the estimates corresponding to an assessment of this prediction.

We present the results in three columns numbered (1)-(3). Whereas we focus on the prediction regarding backward integration in Column (1) and regarding forward integration in Column (2), we consider both of those integration directions together in Column (3). In general, note that the number of (country-sector-pair-time) observations utilized to estimate the parameters on the variables of interest in this table is some 28 million. The explanatory power of the model is quite large, but much of the variance is clearly explained by the fixed effects.

However, what is comforting to see is that the coefficient signs do not change between Columns (1) and (2) on the one hand and Column (3) on the other hand. The main effect of the investment-intensity variable $\tilde{\gamma}^{rs}$ is positive and so are the forward- and backward-relations interaction effects. The overall effect of the investment intensity is, hence, positive in any direction of integration, which is consistent with Prediction 1. The effect estimates suggest that, on average, slightly larger in the backward-integration than the forward-integration direction, according to Column (3). However, the effect difference is minor relative to the large size of either average treatment effect (which corresponds to the sum of the main effect and the respective interaction effect of $\tilde{\gamma}^{rs}$). Regarding the large treatment effect it should be borne in mind that, on average, the country-sector-pair counts measured by the dependent variable are relatively small. Hence, large effects in percent still mean small effects in terms of numbers.

4.2 Competition and Input-consumption Effects (θ, φ). Assessing Prediction 2

In this subsection, we assess Prediction 2 which suggests that a better marketability of the customized input which corresponds to a thicker market and increased competition (θ) increases the size of the non-integration subdomain $[\gamma^{Fwd*}, \gamma^{Bwd*}]$ in the model. Hence, as the outside option of at least one of the parties improves, any

Table 3: R&D Investment Intensity

Number of Firm-to-Firm Connections ($CF_{ij,t}^{rs}$)	(1)	(2)	(3)
Rel. high shareholder R&D intensity ($\tilde{\gamma}_t^{rs}$)	0.689*** (0.065)	0.745*** (0.069)	0.541*** (0.067)
Backward $_j^{rs}$	0.339*** (0.060)		0.360*** (0.063)
Backward $_j^{rs} \times \tilde{\gamma}_t^{rs}$	0.560*** (0.075)		0.324*** (0.079)
Forward $_j^{rs}$		0.327*** (0.051)	0.339*** (0.057)
Forward $_j^{rs} \times \tilde{\gamma}_t^{rs}$		0.531*** (0.056)	0.281*** (0.068)
PTA $_{ij,t}$	0.041*** (0.012)	0.041*** (0.013)	0.040*** (0.012)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Subsidiary-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	28,484,832	28,484,832	28,484,832
R ²	0.92838	0.92813	0.93018

Standard errors are clustered at country-industry pairs level and reported in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Prediction 1 suggests that the parameters on the main effects plus the ones on the two interaction terms with $\tilde{\gamma}$ should be positive.

form of integration becomes less likely. Moreover, the same prediction states that integration becomes more likely, the more crucial the input is (φ) and production of the downstream output depends on the customized input.

In Table 4 we present the results for the model when using $(\theta^{Bwd}, \theta^{Fwd})$ for market competition. Recall that for forward integration θ^{Fwd} is defined as the number of firms in affiliate-sector-country ri over the number of firms in shareholder-sector-country sj . Then ri is upstream and sj is downstream. For backward integration θ^{Bwd} is inversely defined and ri is downstream whereas js is upstream. In view of Prediction 2 we would expect a negative coefficient on both θ^{Bwd} and θ^{Fwd} . In the table, the prediction needs to be assessed not from the main effect of $(\theta^{Bwd}, \theta^{Fwd})$ but from the interaction effects (Backward $\times \theta^{Bwd}$, Forward $\times \theta^{Fwd}$) or at least from the sum of the coefficients on the main and interaction effects.

Again, we present results first separately for forward integration in Column (1) and backward integration in Column (2) and then jointly in Column (3). Indeed,

Table 4: Competition Effects

Number of Firm-to-Firm Connections ($CF_{i,t}^{rs}$)	(1)	(2)	(3)
Market thickness of shareholder industry rel. to subsidiary industry ($\theta^{Bwd^{rs}}_{i,t}$)	-0.023*** (0.004)		-0.011*** (0.003)
Backward $_j^{rs}$	0.916*** (0.054)		0.765*** (0.046)
Backward $_j^{rs} \times \theta^{Bwd^{rs}}_{i,t}$	-0.219*** (0.041)		-0.206*** (0.050)
Market thickness of subsidiary industry rel. to shareholder industry ($\theta^{Fwd^{rs}}_{i,t}$)		0.012*** (0.001)	0.015*** (0.002)
Forward $_j^{rs}$		0.802*** (0.057)	0.624*** (0.051)
Forward $_j^{rs} \times \theta^{Fwd^{rs}}_{i,t}$		-0.022*** (0.006)	-0.026*** (0.007)
PTA	0.038*** (0.009)	0.036*** (0.009)	0.037*** (0.009)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Subsidiary-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	28,600,089	28,600,089	28,600,089
R ²	0.92432	0.92314	0.92713

Standard errors are clustered at country-industry pairs level and reported in parentheses.

For better readability $\theta^{Bwd^{rs}}_{i,t}$ and $\theta^{Fwd^{rs}}_{i,t}$ have been scaled by 10^{-3} .

Column (3) also includes Output coef. $\times \theta^{Bwd}$ and Input coef. $\times \theta^{Fwd}$ as controls.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Prediction 2 suggests that the two interaction terms should be negative.

the reported coefficients suggest that the data support the hypothesis regarding competition and market thickness for the propensity of integration in either the backward or the forward direction in the value chain. Note that for better readability of the results the coefficients on θ as well as coefficients on interactions involving θ have been scaled by 10^{-3} .

We summarize the results regarding input dependence in Table 5 in an analogous way. As with market thickness θ , we define φ separately for when the affiliate-sector-country ri is up the stream (backward) or down the stream (forward) of the shareholder-sector-country sj as $(\varphi^{Bwd}, \varphi^{Fwd})$. Recall that our measures of $(\varphi^{Bwd}, \varphi^{Fwd})$ vary only at the country-sector-year level so that any main effects thereof are absorbed by the country-sector-year fixed effects in the model. In view of Prediction 2 we would expect the parameters on the country-sector-pair-year-variant (Backward $\times \varphi^{Bwd}$, Forward $\times \varphi^{Fwd}$) to be positive, as the propensity of integration should increase with greater input dependence. Again, we present results for the separate focus on backward and forward integration in Columns (1) and (2) and we consider them jointly in Column (3). The coefficients of interest in Table 5 are unequivocally aligned with our expectations from Prediction 2, irrespective of which

Table 5: Total Input-consumption Effects

Number of Firm-to-Firm Connections ($CF_{ij,t}^{rs}$)	(1)	(2)	(3)
Backward $_j^{rs}$	-0.031 (0.145)		-1.109*** (0.184)
Backward $_j^{rs} \times$ Rel. importance of inputs for shareholder ($\varphi^{Bwd^s}_{j,t}$)	1.985*** (0.266)		1.636*** (0.225)
Forward $_j^{rs}$		-0.102 (0.175)	-0.206 (0.195)
Forward $_j^{rs} \times$ Rel. importance of inputs for subsidiary ($\varphi^{Fwd^r}_{i,t}$)		1.933*** (0.346)	0.941*** (0.270)
PTA $_{ij,t}$	0.039*** (0.009)	0.036*** (0.009)	0.038*** (0.009)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Subsidiary-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	28,576,343	28,560,530	28,536,807
R ²	0.92498	0.92368	0.92921

Standard errors are clustered at country-industry pairs level and reported in parentheses.

Column (3) also includes Output coef. $\times \varphi^{Bwd}$ and Input coef. $\times \varphi^{Fwd}$ as controls.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Prediction 2 suggests that the parameters on the two interaction terms should be positive.

column of results we consider.

4.3 Fixed Integration Costs. Assessing Prediction 3

Prediction 3 states that a reduction in fixed integration costs should increase the inclination towards integration. Recall that we use two types of variables to account for the inverse of fixed integration costs: binary indicators for domestic integrations and BIT for foreign integrations. We do not present the time-specific parameters on the domestic indicators, but it should be noted that those are positive, and they reflect that the propensity of domestic ownership is particularly high in the data. Hence, we focus on BITs as a measure of inverse fixed foreign integration costs.

We understand that BITs help firms to invest abroad as they reduce fixed integration costs *ceteris paribus* through provisions pertaining to the "national treatment" or the "fair and equitable treatment" of foreign establishments. They also reduce the risk of expropriation through clauses against any kind of expropriation and the inclusion of reliable and efficient enforcement mechanisms such as arbitration courts.

In view of Prediction 3, we would expect a positive coefficient on BITs both for forward and backward integrations. Again we would expect this to be revealed from the interaction effects $\{\text{Backward} \times F_{ij,t}^{-1}, \text{Forward} \times F_{ij,t}^{-1}\}$ as well as from the sum of

Table 6: Fixed-cost Effects

Number of Firm-to-firm Connections ($CF_{ij,t}^{rs}$)	(1)	(2)	(3)
BIT ($F_{ij,t}^{-1}$)	-0.036 (0.030)	-0.005 (0.031)	-0.053 (0.034)
Backward $_j^{rs}$	0.901*** (0.056)		0.753*** (0.048)
Backward $_j^{rs} \times F_{ij,t}^{-1}$	0.267*** (0.047)		0.206*** (0.044)
Forward $_j^{rs}$		0.792*** (0.059)	0.615*** (0.053)
Forward $_j^{rs} \times F_{ij,t}^{-1}$		0.172*** (0.048)	0.095** (0.045)
PTA $_{ij,t}$	0.039*** (0.009)	0.037*** (0.009)	0.037*** (0.009)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Subsidiary-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	28,600,089	28,600,089	28,600,089
R ²	0.92433	0.92314	0.92711

Standard errors are clustered at country-industry pairs level and reported in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Prediction 3 suggests that the parameters on the two interaction terms should be positive.

the interaction-term coefficients and the main effect of BITs.

We summarize the results focused on (inverse) fixed integration costs in Table 6. As before, we consider the effects on backward and forward integrations separately in Columns (1) and (2) and pool them in Column (3). The results are unequivocally aligned with Prediction 3.

4.4 Conditioning on all parameters. Assessing Prediction 1-3

In the previous subsections, we provided evidence regarding Predictions 1 to 3, separately. Note, however, that in Figure 1 the intercept as well as γ^{Fwd*} depend on F , φ , and θ , for Δ^{Fwd} . The same is true for the intercept as well as γ^{Bwd*} for Δ^{Bwd} . In this subsection, therefore, we provide the results of estimating (18) conditioning on all the parameters simultaneously. These results are presented in Table 7, where the effects on backward and forward integration are presented in Columns (1) and

(2), respectively, and then jointly in Column (3). All of the corresponding results are clearly supportive of our model.

4.5 Cross Effects of Relevant Parameters. Assessing Prediction 4

In a final step, we integrate all results from before and add two further ones which entail the cross-derivative in Prediction 4, namely, $\frac{\partial^2 \gamma^{Bwd*}}{\partial F \partial \theta}$ and $\frac{\partial^2 \gamma^{Fwd*}}{\partial F \partial \theta}$. The latter terms ask how the impact of input marketability and fixed integration costs interact with each other and, in terms of the empirical model, require the inclusion of triple-interaction terms in the specification.

We present the corresponding results in Table 8, which has a similar organization as the previous tables. Prediction 4 states that the effect size of any change in fixed costs should be increasing in θ for forward integration but should be decreasing in θ for backward integration.

Again, Columns (1) and (2) focus on backward and forward integrations separately, while we pool the estimates in Column (3). The corresponding estimates in the third column are supportive of Prediction 4: the point estimate on the backward-integration term $\text{Backward}_j^{rs} \times F^{-1} \times \theta$ is negative as expected, and the estimate on the forward-integration term $\text{Forward}_j^{rs} \times F^{-1} \times \theta$ is positive as expected though not statistically significant. Most of the coefficients can be estimated at what is deemed to be a sufficient degree of precision by conventional standards. This is remarkable as the simultaneous identification of main, interaction and triple-interaction tends to be difficult even with large data.

5 Robustness

In this section we perform several robustness checks. First, we change the originally-adopted definition of how to classify forward and backward relations by creating Top-H Input $_j^{rs}$ and Top-H Output $_j^{rs}$ with H measuring whether a sector is among the H most-important ones with $H \in \{1, \dots, 10\}$. Second, we use a different measure of investment intensity. Third, we run a number of robustness checks on different subsamples of the data. Finally, we consider the same hypotheses as above in a dataset with finer sector granularity but fewer country pairs.

Table 7: All parameters

Number of Firm-to-Firm Connections ($CF_{ij,t}^{rs}$)	(1)	(2)	(3)
Rel. high shareholder R&D intensity ($\tilde{\gamma}_t^{rs}$)	0.699*** (0.065)	0.714*** (0.072)	0.515*** (0.068)
BIT ($F_{ij,t}^{-1}$)	-0.050 (0.031)	-0.024 (0.032)	-0.079** (0.034)
Market thickness of shareholder-to-affiliate industry ($\theta^{Bwd}_{ij,t}^{rs}$)	-0.019*** (0.004)		-0.012*** (0.003)
Backward $_j^{rs}$	-0.485*** (0.133)		-0.517*** (0.128)
Backward $_j^{rs} \times \tilde{\gamma}_t^{rs}$	0.524*** (0.074)		0.300*** (0.076)
Backward $_j^{rs} \times$ Rel. importance of inputs for shareholder ($\varphi^{Bwd}_{j,t}$)	1.753*** (0.249)		1.833*** (0.238)
Backward $_j^{rs} \times F_{ij,t}^{-1}$	0.294*** (0.045)		0.236*** (0.042)
Backward $_j^{rs} \times \theta^{Bwd}_{ij,t}^{rs}$	-0.207*** (0.041)		-0.225*** (0.044)
Market thickness of affiliate-to-shareholder industry ($\theta^{Fwd}_{ij,t}^{rs}$)		0.013*** (0.001)	0.013*** (0.001)
Forward $_j^{rs}$		-0.824*** (0.171)	-0.683*** (0.156)
Forward $_j^{rs} \times \tilde{\gamma}_t^{rs}$		0.599*** (0.058)	0.332*** (0.065)
Forward $_j^{rs} \times$ Rel. importance of inputs for affiliate ($\varphi^{Fwd}_{i,t}$)		2.373*** (0.342)	2.162*** (0.303)
Forward $_j^{rs} \times F_{ij,t}^{-1}$		0.205*** (0.046)	0.105** (0.044)
Forward $_j^{rs} \times \theta^{Fwd}_{ij,t}^{rs}$		-0.021*** (0.006)	-0.022*** (0.006)
PTA	0.041*** (0.012)	0.042*** (0.013)	0.041*** (0.012)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Affiliate-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	28,461,136	28,445,367	28,421,694
R ²	0.92897	0.92897	0.93164

Standard errors are clustered at country-industry-pair level and reported in parentheses.

For better readability $\theta^{Bwd}_{ij,t}^{rs}$ and $\theta^{Fwd}_{ij,t}^{rs}$ have been scaled by 10^{-3} .

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Competition and Fixed-cost Effects

Number of Firm-to-Firm Connections ($CF_{ij,t}^{rs}$)	(1)	(2)	(3)
BIT ($F_{ij,t}^{-1}$)	-0.050 (0.031)	-0.022 (0.032)	-0.074** (0.034)
Rel. high shareholder R&D intensity ($\tilde{\gamma}_t^{rs}$)	0.688*** (0.064)	0.743*** (0.069)	0.539*** (0.067)
Market thickness of shareholder industry rel. to subsidiary industry ($\theta^{Bwd^{rs}}_{ij,t}$)	-0.013** (0.005)		-0.005 (0.004)
Backward $_j^{rs}$	0.324*** (0.061)		0.351*** (0.064)
Backward $_j^{rs} \times \tilde{\gamma}_t^{rs}$	0.560*** (0.075)		0.323*** (0.079)
Backward $_j^{rs} \times \theta^{Bwd^{rs}}_{ij,t}$	-0.144*** (0.046)		-0.179*** (0.054)
Backward $_j^{rs} \times F_{ij,t}^{-1}$	0.315*** (0.048)		0.246*** (0.046)
$F_{ij,t}^{-1} \times \theta^{Bwd^{rs}}_{ij,t}$	-0.012** (0.005)		-0.012*** (0.004)
Backward $_j^{rs} \times F_{ij,t}^{-1} \times \theta^{Bwd^{rs}}_{ij,t}$	-0.195*** (0.070)		-0.202*** (0.078)
Market thickness of subsidiary industry rel. to shareholder industry ($\theta^{Fwd^{rs}}_{ij,t}$)		0.012*** (0.002)	0.012*** (0.002)
Forward $_j^{rs}$		0.320*** (0.053)	0.334*** (0.058)
Forward $_j^{rs} \times \tilde{\gamma}_t^{rs}$		0.533*** (0.056)	0.284*** (0.068)
Forward $_j^{rs} \times \theta^{Fwd^{rs}}_{ij,t}$		-0.035** (0.015)	-0.035** (0.016)
Forward $_j^{rs} \times F_{ij,t}^{-1}$		0.212*** (0.046)	0.121*** (0.046)
$F_{ij,t}^{-1} \times \theta^{Fwd^{rs}}_{ij,t}$		0.002 (0.002)	0.002 (0.002)
Forward $_j^{rs} \times F_{ij,t}^{-1} \times \theta^{Fwd^{rs}}_{ij,t}$		0.022 (0.015)	0.022 (0.016)
PTA $_{ij,t}$	0.041*** (0.012)	0.041*** (0.013)	0.040*** (0.013)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Subsidiary-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	28,484,832	28,484,832	28,484,832
R ²	0.92844	0.92818	0.93028

Standard errors are clustered at country-industry pairs level and reported in parentheses.

For better readability $\theta^{Bwd^{rs}}_{ij,t}$ and $\theta^{Fwd^{rs}}_{ij,t}$ have been scaled by 10^{-3} .

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: Prediction 4 suggests that the parameter on the triple interaction should be negative.

5.1 Different Definitions of Forward/Backward

In our first robustness check we change the definition for forward and backward integration. In Section 3.2 we defined $\text{Backward}_j^{r,s}$ as an indicator variable consisting on whether sector r of the affiliates is among the top-5 supplying sectors of shareholders in j and s . Respectively we defined $\text{Forward}_j^{r,s}$ to indicate a shareholder's top-5 using (or purchasing) industries r . The election of the top-5 supplying and top-5 using industries was somehow arbitrary. In this section we consider the top- H supplying and top- H using, where $H \in \{1, \dots, 10\}$

In Figure 3, we present the estimates of the interaction-term parameters as in Column (3) of Tables 3, 4, 5, and 6 for the alternative definitions of forward and backward, respectively. This figure documents the robustness to using a different number of sectors in determining importance as input suppliers or customers.

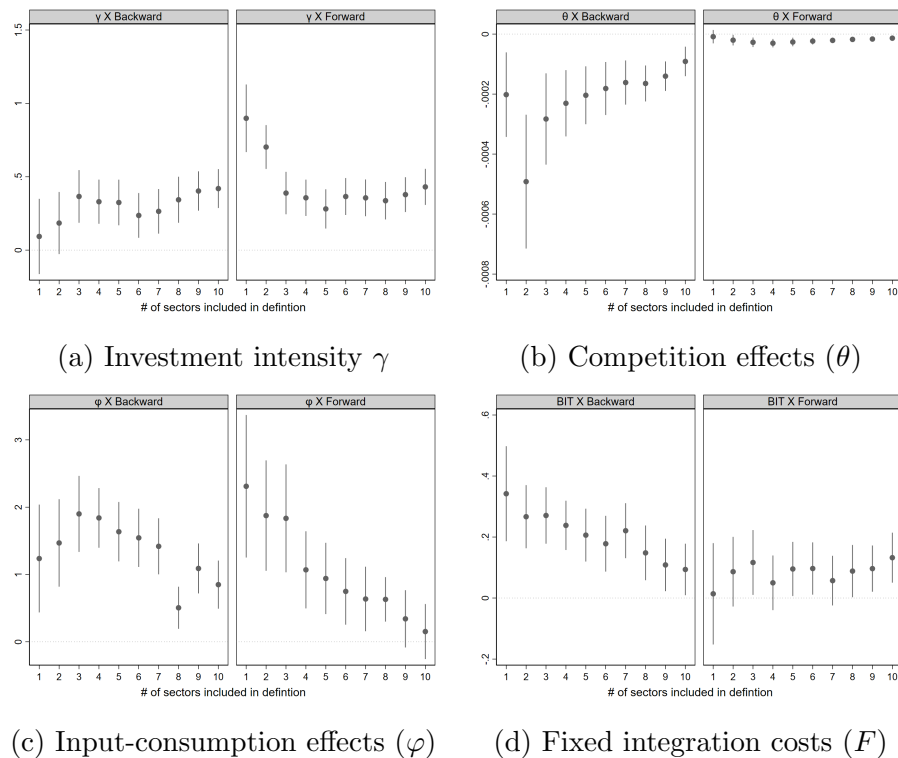


Figure 3: Robustness check using different definitions of Forward/Backward. Note: We present the estimates of the interaction-term parameters as in Column (3) of Tables 3, 4, 5, and 6 for the alternative definitions of forward and backward. The positioning along the x-axis indicates the number of sectors used to define top input and top output sectors, respectively.

5.2 Different Measures of Investment Intensity (γ)

Our next robustness check employs an alternative measure of investment intensity at the sector level. While R&D intensity is our preferred measure for investment intensity, it is possible that R&D expenditures are not homogeneously reported for all types of firms. For this reason, we provide estimates for an alternative measure of γ , namely the physical-capital investment intensity.

To construct this measure we divide physical-capital investment expenditures¹⁸ by total sales and create $\tilde{\gamma}'$ as the physical-capital-investment equivalent of $\tilde{\gamma}$.

Table 9: Physical-capital Investment Intensity

Number of Firm-to-Firm Connections ($CF_{ij,t}^{rs}$)	(1)	(2)	(3)
Rel.-high shareholder phys.-cap. investment intensity (γ_t^{rs})	0.814*** (0.077)	0.966*** (0.069)	0.675*** (0.082)
Backward $_j^{rs}$	0.550*** (0.062)		0.484*** (0.065)
Backward $_j^{rs} \times \tilde{\gamma}'^{rs}$	0.245*** (0.074)		0.143* (0.078)
Forward $_j^{rs}$		0.512*** (0.064)	0.378*** (0.067)
Forward $_j^{rs} \times \tilde{\gamma}'^{rs}$		0.301*** (0.081)	0.303*** (0.085)
PTA $_{ij,t}$	0.038*** (0.010)	0.035*** (0.010)	0.037*** (0.010)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Subsidiary-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	28,600,089	28,600,089	28,600,089
R ²	0.92764	0.92811	0.93020

Standard errors are clustered at country-industry pairs level and reported in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: The model in Section 2 suggests that the two interaction terms should be positive.

The results associated with using the alternative measure $\tilde{\gamma}'$ lead to similar qualitative conclusions as the ones using the original $\tilde{\gamma}$.

¹⁸We define this as the difference between fixed tangible assets in year t minus those in $t - 1$ plus the recorded depreciation in year t .

5.3 Using Only Countries Covered in the WIOT

Our third robustness check bases the original analysis on the subsample of countries that are explicitly included in the WIOT, so that we use direct and not any imputed measures of their input and output coefficients. It turns out that the imputation for countries outside the WIOT does not have any qualitative impact on our findings.

5.4 A Case Study Using the Fine-grained U.S. Input-output Table and Five Shareholder Countries

A benefit of the analysis in the main text was the broad coverage of firms across shareholders and affiliates over a large spectrum of sector and country pairs. As outlined above, this coverage required a coarser treatment of the sectoral delineation in comparison to some earlier work (see, e.g., Acemoglu et al., 2010).

In this subsection, we assess the relevance of the sector-level granularity by following Alfaro et al. (2019) in using a single country's, the United States', input-output table in order to provide for a much finer aggregation of sectors.¹⁹

Specifically, in this subsection we make use of the input-output tables of the United States of the year 2007, which is the first year of the sample period. We convert the sector classification used in the U.S. tables into the NACE Revision 2 classification at the four-digit level using correspondence tables from the Bureau of Economic Analysis and Eurostat's Reference And Management Of Nomenclatures. Moreover, we aggregate the non-manufacturing sectors to the one-digit NACE level while distinguishing manufacturing activities at the four-digit level. This leaves us with 8 non-manufacturing and 226 manufacturing sectors. As we focus on shareholder and affiliate sector pairs, using this fine granularity of sectors means that only for a single shareholder and affiliate country pair there are 54,756 possible sector-to-sector links which can be traced throughout the seven-year sample period in 2007-2013. For reasons mentioned above, it would be infeasible for computational reasons to apply this sector-pair structure with all the country pairs based on 199 countries to consider potential shareholder-affiliate links. Therefore, to reduce the size of the choice problem we select five large European shareholder countries (France, Germany, Italy, Spain, and the United Kingdom) and consider possible forward versus

¹⁹To some, an additional advantage of this exercise is that it can avoid a certain degree of endogeneity of technology choices at the country-sector level. However, to others the use of a foreign country's input-output technology matrix might introduce some measurement error and, hence, add a source of endogeneity in estimation. In any case, we deem this strategy a useful robustness exercise, as the associated analysis will be able to reveal to which extent the sector granularity might matter for the conclusions drawn.

backward ownership links in 54,756 sector pairs and 199 potential affiliate countries. This obtains a potential number of 54,482,220 ownership cells per year or 381,375,540 cells across the seven years which we use to run the same regressions as in Table 7.

For this exercise we define Backward_j^{rs} (Forward_j^{rs}) using again the top-5 supplying (using) sectors for every shareholder sector. And also market thickness ($\theta^{Bwd}, \theta^{Fwd}$), input reliance ($\varphi^{Bwd}, \varphi^{Fwd}$), and inverse fixed costs (BIT) are defined in the same way as before. Due to the more fine-grained sector structure, the data do not exhibit enough variation to compute the R&D investment intensity ($\tilde{\gamma}$) at the 4-digit level for the manufacturing sectors. Therefore, we define this measure at the 2-digit sector level and we assume the same value for all sub-sectors as in the earlier analysis.

Table 10 presents the results for this robustness test. For the sake of brevity, let us focus on the results in Column (3). These suggest that the parameters for market thickness ($\theta^{Bwd}, \theta^{Fwd}$) and input reliance ($\varphi^{Bwd}, \varphi^{Fwd}$) all have the expected signs and are estimated at a comparably high statistical precision. Regarding inverse fixed costs (BITs), the parameters have the expected positive sign, but they are not statistically significant at conventional levels. This lack of statistical significance is owed to the fact that BITs do only vary across country pairs and time but not sectors. Hence, the dimension from which the associated parameters are defined is substantially reduced relative to the earlier analysis. Overall, only 30 BITs (compared with 242 in the full sample of $0.5 \cdot 199(199 - 1)$ foreign country pairs) came into force during the sample period in the data used in this subsection. Finally, the investment intensity parameter ($\tilde{\gamma}$) shows a positive and significant coefficient for forward integration, while it is not statistically significant for backward integration.

However, overall the results in Table 10 support the earlier findings and suggest that none of the conclusions drawn before is the result of a possible sector aggregation bias.

6 Conclusions

Production processes are increasingly organized in international value chains. Firms involved in such chains can be operating at arm's length or be vertically integrated. Incidence of integration as well as its direction (upward or downward) depend on specific characteristics of the participating firms. We propose a simple model of vertical integration in a supplier-producer relationship that is rooted in property-rights theory. Generally, the direction of integration – backward versus forward – depends on the relative investment intensity of the producer and the supplier so as to align investment incentives and maximize joint surplus. Moreover, the organizational form – arm's length production versus vertical integration – depends on the market

Table 10: Case Study

Number of Firm-to-Firm Connections ($CF_{ij,t}^{rs}$)	(1)	(2)	(3)
Rel. high shareholder R&D intensity ($\tilde{\gamma}_t^{rs}$)	0.538*** (0.186)	0.460*** (0.138)	0.461*** (0.142)
BIT ($F_{ij,t}^{-1}$)	0.084* (0.044)	0.093* (0.052)	0.092* (0.050)
Market thickness of shareholder-to-affiliate industry ($\theta^{Bwd}_{ij,t}^{rs}$)	-0.024*** (0.005)		-0.024*** (0.006)
Backward $_j^{rs}$	-0.917** (0.396)		-1.482*** (0.433)
Backward $_j^{rs} \times \tilde{\gamma}_t^{rs}$	0.547*** (0.210)		-0.179 (0.303)
Backward $_j^{rs} \times$ Rel. importance of inputs for shareholder ($\varphi_{j,t}^{sB}$)	3.098*** (1.136)		4.861*** (1.194)
Backward $_j^{rs} \times F_{ij,t}^{-1}$	0.155 (0.112)		0.002 (0.159)
Backward $_j^{rs} \times \theta^{Bwd}_{ij,t}^{rs}$	-0.842*** (0.181)		-0.858*** (0.190)
Market thickness of affiliate-to-shareholder industry ($\theta^{Fwd}_{ij,t}^{rs}$)		-0.003 (0.006)	-0.001 (0.005)
Forward $_j^{rs}$		-0.879 (0.642)	-1.166* (0.657)
Forward $_j^{rs} \times \tilde{\gamma}_t^{rs}$		0.450** (0.202)	0.461* (0.278)
Forward $_j^{rs} \times$ Rel. importance of inputs for affiliate ($\varphi_{i,t}^{rF}$)		2.172** (1.051)	2.745** (1.081)
Forward $_j^{rs} \times F_{ij,t}^{-1}$		0.121 (0.134)	0.119 (0.174)
Forward $_j^{rs} \times \theta^{Fwd}_{ij,t}^{rs}$		-0.074*** (0.020)	-0.075*** (0.028)
PTA	-0.048 (0.031)	-0.046 (0.030)	-0.046 (0.030)
Country-pair FE	✓	✓	✓
Shareholder-country-industry-year FE	✓	✓	✓
Affiliate-country-industry-year FE	✓	✓	✓
Domestic-year FE	✓	✓	✓
Obs.	42,650,338	42,650,338	42,650,338
R ²	0.94079	0.94246	0.94330

Standard errors are clustered at country-industry-pair level and reported in parentheses.

We only keep shareholders from UK, ES, FR, DE and IT.

For better readability $\theta^{Bwd}_{ij,t}^{rs}$ and $\theta^{Fwd}_{ij,t}^{rs}$ have been scaled by 10^{-3} .

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

environment in the input market as well as the relative importance of the specific input for the final output.

We take a set of hypotheses derived from this model to a large dataset on firms, where two crucial ingredients are known for firms and years: (i) the sectoral affiliation of firms and, in conjunction with global input-output tables, the upstream versus downstream positioning of two firms, and (ii) firm-to-firm ownership. The combination of these two ingredients together permit identifying responses in the backward (upstream) versus forward (downstream) ownership characteristics between linked pairs of firms on the relative frequency of firm-to-firm ownership linkages between pairs of both sectors and countries over a time span of seven years between 2007 and 2013.

The data support a number of predictions of the model, in particular, ones related to the impact of competition, the relative technological intensity of the upstream and downstream sectors the firms in a pair of sectors and countries, and the fixed costs which we parameterize by the countries' membership in a bilateral investment treaty, BIT, which we argue is inversely related to fixed costs.

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Appendix

A Mathematical derivations

A.1 Optimal investment levels

Equilibrium investment levels depend on the particular organizational form and are chosen while taking the other party's investment as given:

$$e_S^{o*} = \arg \max_{e_S} \{y_S^o(e_P^{o*}, e_S^o) - C_S(e_S^o) - F_S^o + T_S^o\} \quad (19)$$

$$e_P^{o*} = \arg \max_{e_P} \{y_P^o(e_P^o, e_S^{o*}) - C_P(e_P^o) - F_P^o + T_P^o\} \quad (20)$$

Forward integration

$$\begin{aligned} & \max_{e_S} \{y_S^{Fwd}(e_P^{Fwd*}, e_S^{Fwd}) - C_S(e_S^{Fwd}) - F_S^{Fwd} + T_S^{Fwd}\} \\ & \varphi s + \frac{1}{2}(\varphi s - \varphi s) - \varphi e_S^{Fwd} = 0 \\ & e_S^{Fwd*} = s \\ & \max_{e_P} \{y_P^{Fwd}(e_P^{Fwd}, e_S^{Fwd*}) - C_P(e_P^{Fwd}) - F_P^{Fwd} + T_P^{Fwd}\} \\ & \frac{1}{2}(\varphi p + (1 - \varphi)p - \varphi p(1 - \lambda^P) - (1 - \varphi)p(1 - \lambda^P)) - e_P^{Fwd} = 0 \\ & e_P^{Fwd*} = \frac{\lambda^P}{2}p \end{aligned}$$

Independence

$$\begin{aligned}
& \max_{e_S} \{y_S^I(e_P^I, e_S^I) - C_S(e_S^I) - F_S^I + T_S^I\} \\
& \theta\varphi s + \frac{1}{2}\varphi s - \frac{1}{2}\theta\varphi s - \varphi e_S^I = 0 \\
& e_S^{I*} = \frac{1+\theta}{2}s \\
& \max_{e_P} \{y_P^I(e_P^I, e_S^{I*}) - C_P(e_P^I) - F_P^I + T_P^I\} \\
& (1-\varphi)p + \frac{1}{2}(\varphi p + (1-\varphi)p - (1-\varphi)p) - e_P^I = 0 \\
& e_P^{I*} = (1 - \frac{\varphi}{2})p
\end{aligned}$$

Backward integration

$$\begin{aligned}
& \max_{e_S} \{y_S^{Bwd}(e_P^{Bwd*}, e_S^{Bwd}) - C_S(e_S^{Bwd}) - F_S^{Bwd} + T_S^{Bwd}\} \\
& \frac{1}{2}(\varphi s - \varphi s(1 - \lambda^S)) - \varphi e_S^{Bwd} = 0 \\
& e_S^{Bwd*} = \frac{\lambda^S}{2}s \\
& \max_{e_P} \{y_P^{Bwd}(e_P^{Bwd}, e_S^{Bwd*}) - C_P(e_P^{Bwd}) - F_P^{Bwd} + T_P^{Bwd}\} \\
& \varphi p + (1-\varphi)p + \frac{1}{2}(\varphi p + (1-\varphi)p - \varphi p - (1-\varphi)p) - e_P^{Bwd} = 0 \\
& e_P^{Bwd*} = p
\end{aligned}$$

A.2 Equilibrium organizational form

Before deriving the equilibrium organizational form, we have to characterize the joint surplus under each organization form, $S^o = \pi_S^o + \pi_P^o$.

Forward integration

$$S^{Fwd} = \frac{1}{2}\varphi s^2 + \frac{\lambda^P}{2} \left(1 - \frac{\lambda^P}{4}\right) p^2 + 1 - F$$

Independence

$$S^I = 1 + \frac{1+\theta}{2}\varphi \left(1 - \left(\frac{1+\theta}{4}\right)\right) s^2 + \left(1 - \frac{\varphi}{2}\right) \left(\frac{1}{2} + \frac{\varphi}{4}\right) p^2$$

Backward integration

$$S^{Bwd} = \frac{1}{2}p^2 + 1 + \varphi \frac{\lambda^S}{2} \left(1 - \frac{\lambda^S}{4}\right) s^2 - F$$

Now, we can conduct a pairwise comparison of the surplus under each organizational form.

Forward integration versus no integration

$$\Delta^{Fwd} = S^{Fwd} - S^I$$

$$\Delta^{Fwd} = \frac{1}{2}\varphi s^2 + \frac{\lambda^P}{2} \left(1 - \frac{\lambda^P}{4}\right) p^2 + 1 - F - \left(1 + \frac{1+\theta}{2}\varphi \left(1 - \left(\frac{1+\theta}{4}\right)\right) s^2 + \left(1 - \frac{\varphi}{2}\right) \left(\frac{1}{2} + \frac{\varphi}{4}\right) p^2\right)$$

$$\Delta^{Fwd} = (1-\theta)^2 \frac{s^2}{8} \varphi - \left((2-\lambda^P)^2 - \varphi^2\right) \frac{1}{8} p^2 - F,$$

where $\left((2-\lambda^P)^2 - \varphi^2\right) > 0$. Using $p = \gamma s$, we can show that $\Delta^{Fwd} > 0$ as long as $\gamma < \gamma^{Fwd*}$, where:

$$\gamma^{Fwd*} = \sqrt{\frac{\left((1-\theta)^2 \frac{s^2}{8} \varphi - F\right)}{\left((2-\lambda^P)^2 - \varphi^2\right) \frac{1}{8} s^2}}.$$

Backward integration versus no integration

$$\Delta^{Bwd} = S^{Bwd} - S^I$$

$$\Delta^{Bwd} = \frac{1}{2}p^2 + 1 + \varphi \frac{\lambda^S}{2} \left(1 - \frac{\lambda^S}{4}\right) s^2 - F - \left(1 + \frac{1+\theta}{2}\varphi \left(1 - \left(\frac{1+\theta}{4}\right)\right) s^2 + \left(1 - \frac{\varphi}{2}\right) \left(\frac{1}{2} + \frac{\varphi}{4}\right) p^2\right)$$

$$\Delta^{Bwd} = \left(\frac{\varphi^2}{8}\right) p^2 - (1+\theta - \lambda^S)(3-\theta - \lambda^S) \frac{\varphi s^2}{8} - F,$$

where $(1 + \theta - \lambda^S)(3 - \theta - \lambda^S) > 0$. Using $p = \gamma s$, we can show that $\Delta^{Bwd} > 0$ as long as $\gamma > \gamma^{Bwd*}$, where:

$$\gamma^{Bwd*} = \sqrt{\frac{\left((1 + \theta - \lambda^S)(3 - \theta - \lambda^S) \frac{\varphi s^2}{8} + F \right)}{\left(\left(\frac{\varphi^2}{8} \right) s^2 \right)}}. \quad (21)$$

Backward integration versus forward integration

$$\begin{aligned} \Delta^{BF} &= S^{Bwd} - S^{Fwd} \\ \Delta^{BF} &= \frac{1}{2}p^2 + \varphi \frac{\lambda^S}{2} \left(1 - \frac{\lambda^S}{4} \right) s^2 - \frac{1}{2}\varphi s^2 - \frac{\lambda^P}{2} \left(1 - \frac{\lambda^P}{4} \right) p^2 \\ \Delta^{BF} &= (\lambda^P - 2)^2 \frac{1}{8}p^2 + (\lambda^S - 2)^2 \frac{1}{8}\varphi s^2 \end{aligned}$$

Using $p = \gamma s$, we can show that $\Delta^{BF} > 0$ as long as $\gamma > \gamma^{BF*}$, where:

$$\gamma^{BF*} = \frac{(2 - \lambda^S)}{(2 - \lambda^P)} \sqrt{\varphi}. \quad (22)$$

A.3 Comparative statics

$$\frac{\partial \gamma^{Fwd*}}{\partial \theta} = \frac{1}{\sqrt{\frac{((1-\theta)^2 \frac{s^2}{8} \varphi - F)}{((2-\lambda^P)^2 - \varphi^2) \frac{1}{8} s^2}}} \frac{\frac{s^2}{8} \varphi}{((2 - \lambda^P)^2 - \varphi^2) \frac{1}{8} s^2} (1 - \theta) (-1) < 0.$$

$$\frac{\partial \gamma^{Fwd*}}{\partial \varphi} = \frac{1}{2} \frac{1}{\sqrt{\frac{((1-\theta)^2 \frac{s^2}{8} \varphi - F)}{((2-\lambda^P)^2 - \varphi^2) \frac{1}{8} s^2}}} \frac{(1 - \theta)^2 \frac{s^2}{8} \left((2 - \lambda^P)^2 - \varphi^2 \right) \frac{1}{8} s^2 + \frac{1}{4} \varphi s^2 \left((1 - \theta)^2 \frac{s^2}{8} \varphi - F \right)}{\left(((2 - \lambda^P)^2 - \varphi^2) \frac{1}{8} s^2 \right)^2}.$$

Since $\left((2 - \lambda^P)^2 - \varphi^2 \right) > 0$, it must be true that $\left((1 - \theta)^2 \frac{s^2}{8} \varphi - F \right) > 0$ for forward integration being an equilibrium outcome ($\Delta^{Fwd} > 0$). Hence,

$$\frac{\partial \gamma^{Fwd*}}{\partial \varphi} > 0.$$

$$\frac{\partial \gamma^{Bwd*}}{\partial \theta} = \frac{1}{2} \frac{1}{\sqrt{\frac{((1+\theta-\lambda^S)(3-\theta-\lambda^S)\frac{\varphi s^2}{8} + F)}{((\frac{\varphi^2}{8})s^2)}}} \frac{\frac{\varphi s^2}{8}}{((\frac{\varphi^2}{8})s^2)} (1-\theta) 2 > 0$$

$$\frac{\partial \gamma^{Bwd*}}{\partial \varphi} = \left(\frac{\varphi s^2}{8}\right) (1+\theta-\lambda^S)(3-\theta-\lambda^S) \frac{1}{2} - \left((1+\theta-\lambda^S)(3-\theta-\lambda^S) \frac{\varphi s^2}{8} + F\right)$$

Since, $F > 0$

$$\frac{\partial \gamma^{Bwd*}}{\partial \varphi} < 0.$$

B Sector description

Table A1: Sector Description

Section	Division	Description
A	01-03	Agriculture, forestry and fishing
B	05-09	Mining and quarrying
C	10-12	Manufacture of food products, beverages and tobacco products
C	13-15	Manufacture of textiles, wearing apparel and leather products
C	16	Manufacture of wood and of products of wood and cork, except furniture; etc.
C	17	Manufacture of paper and paper products
C	18	Printing and reproduction of recorded media
C	19	Manufacture of coke and refined petroleum products
C	20	Manufacture of chemicals and chemical products
C	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C	22	Manufacture of rubber and plastic products
C	23	Manufacture of other non-metallic mineral products
C	24	Manufacture of basic metals
C	25	Manufacture of fabricated metal products, except machinery and equipment
C	26	Manufacture of computer, electronic and optical products
C	27	Manufacture of electrical equipment
C	28	Manufacture of machinery and equipment n.e.c.
C	29	Manufacture of motor vehicles, trailers and semi-trailers
C	30	Manufacture of other transport equipment
C	31-32	Manufacture of furniture; other manufacturing
C	33	Repair and installation of machinery and equipment
D	35	Electricity, gas, steam and air conditioning supply
E	36-39	Water supply; sewerage, waste management and remediation activities
F	41-43	Construction
G	45-47	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	49-53	Transportation and storage
I	55-56	Accommodation and food service activities
J	58-63	Information and communication
K	64-66	Financial and insurance activities
L	68	Real estate activities
M	69-75	Professional, scientific and technical activities
N	77-82	Administrative and support service activities
O	84	Public administration and defense; compulsory social security
P	85	Education
Q	86-88	Human health and social work activities
R-S	90-96	Arts, entertainment and recreation
T	97-98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	99	Activities of extraterritorial organizations and bodies