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The link between organizational choice and global input sourcing under sequential production

Bilgehan Karabay

School of Economics, Finance and Marketing, RMIT University, Melbourne, Victoria, Australia

Correspondence
Bilgehan Karabay, School of Economics, Finance and Marketing, RMIT University, 445 Swanston Street, Bld. 80, Level 11, Melbourne, VIC 3000, Australia.
Email: bilgehan.karabay@gmail.com

Abstract

This article analyzes the ways heterogenous firms procure their inputs in the presence of relationship-specific investments and incomplete contracts. We first consider a closed economy in which firms decide how to structure their organization. Production is sequential and inputs (upstream and downstream) are sourced in the same order as production. While our closed-economy setup is analogous to Antràs and Chor (*Econometrica*, 2013), there are two distinct features: (1) The reward to each supplier is determined through bargaining over the full revenue of the firm (as opposed to marginal contribution of the supplier), and (2) The reward structure combined with our sequential bargaining protocol gives rise to linkages across suppliers. The analysis in Antràs and Chor (*Econometrica*, 2013) identifies a mechanism in which *upstream* organizational decisions have spillover effects on *downstream* suppliers' investment incentives. Thanks to our novel features, we identify another mechanism: the spillover effects of *downstream* organizational decisions on the investment incentive of *upstream* suppliers. Next, we consider an open economy in which firms not only make organizational decisions but also determine where to source their inputs. We show that these decisions are connected *between sequential production stages* such that the sourcing location of the upstream input may affect the organizational choice in the downstream stage. We then examine how within sectoral heterogeneity and variations in industry characteristics influence the relative prevalence of firms that choose to form different organizational structures.

KEYWORDS
global input sourcing, hold-up problem, incomplete contracts, multinationals, organizational choice, property rights, sequential production

JEL CLASSIFICATION
D23, F10, F23

1 | INTRODUCTION

Today, the production of goods involves various stages taking place across multiple countries. The data confirms this trend: while only 36% of world trade had occurred within global value chains in 1995, this number reached 49% in 2011 (WTO, 2015). This study aims to contribute the literature on this evident fragmentation of production. Our modeling of organizational choice follows Antràs (2003), whereas our modeling of global input sourcing is close in spirit to Antràs and Helpman (2004). Yet, our paper provides additional insights via sequential setting (sequential production and bargaining) similar to Antràs and Chor (2013). Moreover, unlike Antràs and Chor (2013), our framework distinguishes between domestic and offshore sourcing decisions of firms.

Our model has multiple sectors and each sector has multiple varieties produced under monopolistic competition. The essential elements of the production of each variety are as follows. First, it is sequential such that an upstream input is used to produce a downstream input, which is then used to produce a final output. We deviate from Antràs and Chor (2013) by assuming higher degree of complementarity between production stages: each stage input must be successfully completed for the final good to be produced and revenue to be realized.[1,2] Recent developments in the automotive industry provide a good example, where the shortage of semiconductors (chips) has forced several automakers to halt production.[3] Second, the production of the downstream input requires the physical presence of the upstream input. Automobiles, textiles, mobile phones and computers all fit well to this description (Harms et al., 2012 and Antràs & Chor, 2013).

Three types of agents engage in the production of each variety: upstream suppliers, downstream suppliers and final-good producers (firms). Final-good producers are heterogenous with respect to their productivity. Suppliers need to make relationship-specific investments to produce inputs and contracts are incomplete. In this environment, there is a standard hold-up problem of underinvestment and any credible terms of exchange can be defined ex post, once investments are made and contingencies are realized. Following Antràs and Chor (2013), we assume that inputs are sourced sequentially in the same order as production through bilateral negotiations between final-good producers and input suppliers. We differ from Antràs and Chor (2013) by assuming that bargaining is over the full revenue rather than the incremental revenue suppliers contribute. For this reason, we solve the bargaining game backwards using subgame perfect equilibrium. Consequently, the reward structure together with our bargaining protocol generates linkages across suppliers (upstream and downstream). Additionally, as in Antràs (2003), we allow final-good producers to ask for ex ante lump-sum transfers from suppliers before any input is produced. Since these transfers enable final-good producers to capture the entire surplus, there is no *rent-extraction motive* in making organizational decisions.

We initially focus on a closed-economy in which final-good producers decide how to structure their organization: outsourcing versus vertical integration. The firm's organizational choice at each stage determines asset ownership, which comes with the residual rights of control. These control rights affect ex ante investment incentive of suppliers by changing the distribution of surplus between parties, that is, revenue shares. In a vertically integrated firm, the supplier becomes part of the firm and has no control rights, implying that her investment incentive is lower compared to an independent supplier.[4] Since inputs are sequential complements (recall Endnote 2) and final-good producers have no rent-extraction motive (due to ex ante transfers), it is always optimal to choose outsourcing in the upstream stage. Thus, the key organizational decision is over the downstream supplier. The relative strength of two opposing forces determines this organizational choice. The first one is related to the nature of production and reward structure. The production technology implies that higher investment by the upstream supplier increases the marginal return of the downstream supplier's own investment. The reward to each type of supplier (upstream and downstream) depends on the project's total revenue. This reward structure allows the upstream supplier to internalize the positive effect of her own investment on the downstream supplier, and thus, it is the downstream supplier who must be given more control rights.[5] So, the first force pushes the final-good producer to choose outsourcing in the downstream stage. The second force emerges from the sequential nature of bargaining. When negotiations are taking place for the downstream input in the second stage, any payment made to the upstream supplier in the first stage is sunk. Subgame perfection dictates that when negotiating with the upstream supplier, the final-good producer is willing to bargain over only the residual revenue, that is, revenue that would be left over from the negotiations with the downstream supplier. This provides more bargaining power and thus more incentive to the downstream supplier vis-à-vis the upstream supplier.[6] Hence, to leave more for the bargaining with the upstream supplier, the second force pushes the final-good producer to choose vertical integration in the downstream stage.

Next, we extend our model to an open economy with two countries, North and South. All final-good producers are located in the North and now they decide not only how to structure their organization but also where to source inputs: domestically from the North or internationally from the South. A major benefit of geographical dispersion is to access to cheap factors (Navaretti & Venables, 2004). At the same time, cross-border transactions tend to exacerbate the hold-up problem (Antràs & Staiger, 2012). To capture these salient facts, we assume that in the South, although the wage rate is lower, there is higher efficiency loss from hold-up due to loose intellectual property rights (IPR).[7] Moreover, with the fragmentation of production, one pronounced finding in the literature is the trade off between lower input costs and higher trade costs. To account for this finding, we also consider two types of trade costs. First, we employ iceberg transport costs for shipping inputs between countries. Our iceberg formulation of transport costs combined with our sequential production process generates shipping costs that are proportional to the gross value of the input being transported. In other words, it is more costly to ship a downstream input relative to an upstream input. This is in line with Antràs and de Gortari (2020), who provide a suggestive empirical evidence.[8] Second, we consider fixed coordination costs, which are incurred when inputs are sourced from different countries. This assumption is in harmony with Harrigan and Venables (2006), who argue that a physical separation of the value chain stages can cause uncertainty about the delivery of inputs, which in turn makes production planning complicated.

Using this setting, we first show that firms' sourcing location and organizational mode decisions are linked *between sequential production stages*: the organizational choice in the downstream stage may change depending on where the upstream input is sourced due to the asymmetry in the hold-up friction between locations.[9] Those firms that choose to transact with an upstream supplier in the South are more likely to integrate their downstream suppliers, since this allows them to bring more to the table in negotiations for the upstream input and mitigates the more severe underinvestment problem in the South.

Our results regarding global input sourcing indicate that all firms choose to source both inputs domestically from the North when transport costs are substantial. In other words, with large transport costs, inputs are sourced where the final output is assembled. This result carries a closely-related intuition to Baldwin and Venables (2013), where due to transport costs, firms may choose to cluster production stages within the same country even when that country may not be the lowest cost site within a cluster. In contrast, if the wage gap between the North and South is substantial, all firms source both inputs internationally from the South, to wit, the lowest cost site due to cheaper labor. Otherwise, more productive firms procure the upstream input from the North and the downstream input from the South to avoid the more severe hold-up friction in the South while still enjoying the lower Southern wage rate in the downstream stage. This finding is in line with Antràs et al. (2017), which state that more productive firms would be able afford the higher fixed costs to search and source from a larger set of countries to lower their sourcing costs. On the flip side, depending on the scale of coordination costs, less productive firms may either follow more productive firms and procure the upstream input from the North and the downstream one from the South or procure both inputs from a single country, the North or South.

We then shift the focus from firms to industries and look at how within sectoral heterogeneity and variations in industry characteristics influence the relative prevalence of organizational forms. We find that when firms' organizational choice depends on their input-sourcing location, firms more likely engage in outsourcing in sectors where the wage gap and trade costs are lower, the asymmetry in the hold-up friction due to loose IPR protection in the South is significant and the productivity dispersion is higher.

Prior Work. Our framework combines firms' boundary model of Antràs (2003) with heterogeneous firms model of Melitz (2003) to analyze domestic and offshore sourcing decisions of firms as in Antràs and Helpman (2004). Our key difference from Antràs and Helpman (2004) is the introduction of sequential production and bargaining that spills over across production stages. There are other differences as well. In Antràs and Helpman (2004), higher (lower) transport costs simply imply a higher (lower) wage rate in the South. This is not so straightforward in our model as transport costs augment along the value chain. In addition, they assume asymmetry in fixed operating costs across organizational modes, which allows a firm's productivity to affect its organizational choice.[10] We do not assume any asymmetry in fixed operating costs; instead, there are fixed coordination costs when inputs are sourced from different countries. Hence, a firm's productivity does not affect its organizational choice directly, but indirectly through the sourcing location of inputs. Moreover, while the sourcing decision in Antràs and Helpman (2004) involves only one input (manufacturing component), it involves both inputs (upstream and downstream) in our paper, which in turn allows us to examine the effect of sourcing location in one stage on organizational choice in the other stage.

While our sequential setting is similar to the benchmark model of Antràs and Chor (2013), we diverge in two aspects: (1) Bargaining for each input is over the full revenue rather than suppliers' marginal contribution, and (2) There are linkages across suppliers in sequential bargaining. In our model, organizational decisions over the downstream supplier affect how much is left over for the upstream supplier and the firm to bargain over. Accordingly, vertical integration in the downstream stage can be appealing as it leaves more stake (bargaining share) for the upstream supplier. Put it differently, organizational decisions in the *downstream* stage spill over on *upstream* suppliers through this bargaining share linkage. This is different from Antràs and Chor (2013), where they show that organizational decisions in the *upstream* stage have spillovers on *downstream* suppliers. Thus, we identify another mechanism through which spillovers along the supply chain are transmitted that is quite different from their benchmark setting.[11] In addition, by assuming an asymmetry in the hold-up friction between countries, our model allows input-sourcing location choice to directly affect bargaining shares of agents, and this in turn influences the organizational choice. This finding is to be contrasted with Antràs and Chor (2013), in which the decision to integrate a particular stage input merely depends on its position in the value chain, independent of the sourcing location of the input (see Proposition 6 on p. 2156).[12]

We have a generic setup that allows for various extensions. One such extension is done in Karabay (2022), where the firm's organizational choice involves not only its ownership structure (outsourcing vs. vertical integration) but also its input procurement strategy (delegation vs. control). This latter strategy means the final-good producer decides whether to procure the upstream input itself (control) or delegate this procurement to the downstream supplier (delegation). This analysis generates a new organizational form titled 'Outsourcing with Delegation.' Since the main focus of that paper is on this new organizational mode, unlike the current paper, a full-fledged open-economy analysis is shut down by assuming: (1) all firms are identical, (2) it is always optimal to source both inputs from the South, that is, sourcing decision is imposed on firms rather than analyzed, and (3) there are no trade costs.

The sequential bargaining protocol in our paper is related to Du et al. (2009). They consider bi-sourcing strategy, in which a given input can be partly insourced within the firm and partly outsourced using an independent supplier. Their framework is different than ours in two respects. First, inputs that pertain to sequential bargaining are perfect substitutes and due to this substitutability, sequential bargaining helps to improve the threat point of the final-good producer. This is different than ours since upstream and downstream inputs are complementary in our case. Second, their model does not have sequential production.

Our setting permits the adoption of different organizational modes in sourcing each input, that is, hybrid sourcing. In this regard, our paper is related to Schwarz and Suedekum (2014) and Nowak et al. (2016). Using a model with a continuum of suppliers and symmetric inputs, Schwarz and Suedekum (2014) show that hybrid sourcing occurs as it enables the adjustment of investment incentives and revenue distribution within the firm. On the other hand, the model of Nowak et al. (2016) features two input suppliers like ours. By introducing asymmetries across inputs, they can determine the firm's sourcing mode for each input. These papers diverge from ours as inputs enter the production process simultaneously and thus, they cannot capture the additional insights provided by our sequential setting.

The rest of the paper is organized as follows. In Section 2, we lay out the model in a closed economy and focus solely on firms' organizational choice. Section 3 extends our model to an open economy to allow for international sourcing of inputs. Here, we also examine how within sectoral heterogeneity and variations in industry characteristics influence the relative prevalence of firms that choose to form different organizational structures. Section 4 discusses some variants and extensions of our model. The last section concludes. Most proofs in the main text are relegated to Appendix A, whereas the detailed analysis of cases discussed in the open-economy context is covered in Appendix B. Technical details of extensions to our benchmark model can be found in our Online Appendix C.

2 | THE CLOSED-ECONOMY MODEL

2.1 | Preferences

Consider an economy that is populated by consumers with identical preferences

$$U = y_0 + \frac{1}{\eta}\sum_{j=1}^{J} Y_j^{\eta},\ 0 < \eta < 1, \tag{1}$$

where y_0 is a consumption of a homogeneous good, Y_j is an index of aggregate consumption in sector j, and η is a parameter such that $\frac{1}{1-\eta}$ represents the elasticity of substitution between Y_i and Y_j. Aggregate consumption in sector j is given by

$$Y_j = \left(\int y_j(i)^{\alpha} di\right)^{1/\alpha}, 0 < \alpha < 1,$$

where $y_j(i)$ is the consumption of variety i in sector j and $\frac{1}{1-\alpha}$ represents the elasticity of substitution between any two varieties in a given sector. We assume that $\alpha > \eta$ so that varieties in a given sector are more substitutable for each other than for y_0 or for varieties from a different sector. Hence, the inverse demand curve for each variety in sector j is

$$p_j(i) = Y_j^{\eta-\alpha} y_j(i)^{\alpha-1}. \tag{2}$$

2.2 | Production

Production of each variety entails a well-defined sequence of stages, where a failure in any one of them destroys the whole project.[13] Three types of agents engage in this production: final-good producers, upstream suppliers and downstream suppliers. To start producing, an initial investment must be made, modeled as a fixed sunk cost of entry expressed in f_e units of labor. If we denote the wage rate by ω, this entry cost is equal to ωf_e . Upon paying this cost, the unique final-good producer of variety i in sector j draws a productivity parameter $\varphi(i)$ from a common distribution $g_j(\varphi)$, which has positive support over $(0, \infty)$ and has a continuous cumulative distribution $G_j(\varphi)$. Once this productivity level is realized, the final-good producer decides whether to continue production or exit the market. If the production continues, a fixed cost of operations in f_c units of labor must be paid, which amounts to ωf_c.

Each variety requires the use of labor and two variety-specific inputs, both of which must be of high quality. A high-quality upstream input x_{1j} is produced using labor $L_{1j}(i)$ with a one-to-one linear technology: $x_{1j}(i) = L_{1j}(i)$. A high-quality downstream input x_{2j} is produced using a high-quality upstream input x_{1j} and labor $L_{2j}(i)$ with a Cobb-Douglas technology:

$x_{2j}(i) = \left(\frac{x_{1j}(i)}{\beta_j}\right)^{\beta_j}\left(\frac{L_{2j}(i)}{1-\beta_j}\right)^{1-\beta_j}$. Finally, a final-good variety can be produced using a high quality downstream input $x_{2j}(i)$ with a linear technology: $y_j(i) = \varphi(i)x_{2_j}(i)$, where $\varphi(i)$ is a firm-specific productivity parameter.[14] Here, $\beta_j \in (0, 1)$ represents the relative importance of the upstream input in the final-good production. As in Antràs (2003), the final-good producer asks for ex ante lump-sum transfers from suppliers before any input is produced, so competition among a large number of potential suppliers will drive each transfer to a level at which suppliers just break even.

Constant elasticity of substitution between sectors allows us to analyze each sector independently. From this point on, we will focus on a particular industry j and drop the index j from all variables. Likewise, we will omit index i on the productivity parameter.

2.3 | Input procurement

Contracts stipulating the purchase of a high-quality input for a certain price are not enforceable as no legal body can distinguish input quality. Along similar lines, we assume that the ex post revenue is not verifiable by outside parties. Therefore, the only contractibles are ex ante transfers and organizational structure.

Contract incompleteness and relationship-specific investments lead to a standard hold-up problem and any credible negotiation for an input can be done ex post once that input is produced. Following Antràs and Chor (2013), bargaining is sequential such that negotiations are done first for the upstream input and then for the downstream input. Yet, different from Antràs and Chor (2013), agents bargain over the full revenue rather than the incremental revenue that they help realize in the production sequence. This is sensible in our setting since all three agents, namely, the upstream supplier, the downstream supplier and the final-good producer, are required to generate any revenue. For example, upstream supplier alone cannot generate any revenue and it does not make sense to bargain over her incremental contribution. Given this structure, it is then natural to use subgame perfect equilibrium to solve the model.

The ex post bilateral negotiations are modeled as a generalized Nash bargaining. We denote by ϕ_i the bargaining power of the final-good producer with respect to the supplier of stage $i \in \{1, 2\}$. While bargaining takes place under each organizational mode, the distribution of the surplus between parties is affected by whether outsourcing (O) or vertical integration (V) is chosen. Let $\phi_{i,k}$ denote the fraction of the surplus the final-good producer captures with respect to the supplier of stage $i \in \{1, 2\}$ under organizational mode $k \in \{O, V\}$. Any failure in negotiations under outsourcing leads to both parties walking away with nothing, implying that $\phi_{i,O} = \phi_i$. On the other hand, if they fail to agree on a split under vertical integration, the final-good producer will still be able to sell a fraction of the final output. Through this outside option, vertical integration increases the final-good producer's share at the expense of the supplier, that is, $\phi_{i,V} > \phi_{i,O} = \phi_i$. Therefore, the supplier's incentive to invest under vertical integration is lower than it is under outsourcing.

Figure 1 summarizes the timing of events: (i) The final-good producer pays the cost of entry (ωf_e) and learns his productivity (φ). (ii) The decision is made whether to continue production or exit the market. (iii) If production continues, the fixed cost of operations (ωf_c) is paid and upstream and downstream suppliers are chosen together with the whole organizational structure. This is the stage where suppliers bid for the production of inputs and the final-good producer accepts a lump-sum transfer from one of each type of suppliers. (iv) The

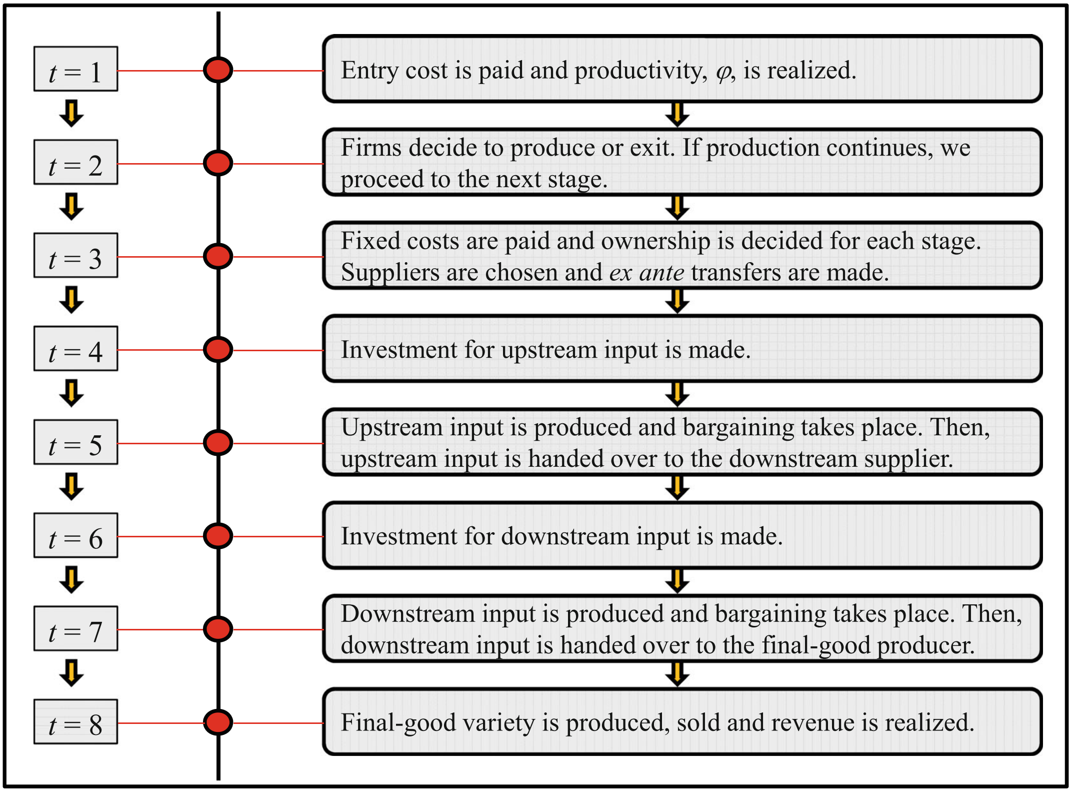

FIGURE 1 Timing of events. [Colour figure can be viewed at wileyonlinelibrary.com]

upstream supplier then chooses her investment in $L_1(i)$ and makes her production based on the specification provided by the final-good producer. (*v*) Provided that the input is of high quality, the two parties bargain over the allocation of the project's revenue. Once this bargaining is over, the upstream supplier is paid and the upstream input is delivered to the downstream supplier. (*vi*) The downstream supplier then chooses her investment in $L_2(i)$ and makes her production based on the specification provided by the final-good producer. (*vii*) If the input is of high quality, the two parties bargain over the allocation of the project's revenue. Once the bargaining is over, the downstream supplier is paid and the downstream input is delivered to the final-good producer. (*viii*) Finally, the final-good variety is produced, sold and the revenue is realized.

2.4 | Subgame perfect equilibrium

We first start with the second stage in which the final-good producer bargains with the downstream supplier. If the component is of high quality (taking for granted that the first component was of high quality), the potential surplus to be split is the total revenue from the sale of the final good, which, using Equation (2), can be written as

$$R(i) = p(i)y(i) = Y^{\eta-\alpha}y(i)^{\alpha}. \quad (3)$$

The downstream supplier takes the amount of $x_1(i)$ from the previous stage as given and chooses the amount of $L_2(i)$ to maximize $\left(1-\phi_{2,k}\right)R(i)-\omega L_2(i)$, for $k \in \{O, V\}$.

In the first stage, the final-good producer bargains with the upstream supplier. Since a fraction $1-\phi_{2,k}$ of the final revenue will be claimed by the downstream supplier, the final-good producer is willing to negotiate the remaining fraction with the upstream supplier. Thus, the upstream supplier chooses $L_1(i)$ to maximize $\left(1-\phi_{1,k}\right)\phi_{2,k}R(i)-\omega L_1(i)$ subject to $x_1(i)=L_1(i)$ and the best response of the downstream supplier.

At the beginning of the game, due to the competitive nature of both of the intermediate input markets, the final-good producer asks for ex ante transfers from the upstream and downstream suppliers in the amount of $\left(1-\phi_{1,k}\right)\phi_{2,k}R(i)-\omega L_{1,k}(i)$ and $\left(1-\phi_{2,k}\right)R(i)-\omega L_{2,k}(i)$, respectively, and leaves them no ex post surplus. Then using Equation (3), the ex post operating profits of the final-good producer are given by

$$\pi_{k\in\{O,V\}}(i)=Y^{\eta-\alpha}y_k(i)^{\alpha}-\omega(L_{1,k}(i)+L_{2,k}(i))-\omega f_c, \tag{4}$$

Lemma 1. It is always optimal to choose outsourcing in the upstream stage, that is, $\phi_{1,k}=\phi_{1,O}=\phi_1$.

Proof. In choosing the organizational mode, there is no rent-seeking motive since the final-good producer can capture the whole surplus via ex ante transfers. At the same time, the final-good producer does not make any input investment. Therefore, the only motive in choosing vertical integration is to reallocate revenue shares between suppliers to maximize profits. Due to the sequential order of bargaining, this reallocation is possible only from the downstream supplier to the upstream supplier. At the same time, input investments are complementary due to Cobb-Douglas structure. Therefore, integration in the upstream stage not only reduces the investment of the upstream supplier but also that of downstream supplier, both of which lower profits. Therefore, integrating the upstream supplier is never optimal.

Lemma 1 implies that if vertical integration ever takes place, it might only do so in the downstream stage. This finding is line with the empirical result of Alfaro and Charlton (2009), which states that multinationals tend to own later stages of production. This result is also confirmed in a recent empirical work by Del Prete and Rungi (2017). From this point forward, we will simplify the notation by replacing $\phi_{1,k}$ with ϕ_1. The next lemma gives us output, price and operating profits of any variety for a given organizational mode.

Lemma 2. For any variety i and organizational mode $k \in \{O, V\}$ we can state output $y_k(i)$, price $p_k(i)$ and operating profits $\pi_k(i)$ as

$$y_k(i)=\left[\left(\frac{(1-\phi_1)\phi_{2,k}}{1-\alpha(1-\beta)}\right)^{\beta}\left(1-\phi_{2,k}\right)^{1-\beta}\right]^{\frac{1}{1-\alpha}}\left(\frac{\alpha\varphi Y^{\eta-\alpha}}{\omega}\right)^{\frac{1}{1-\alpha}}, \tag{5}$$

$$p_k(i)=\left(\frac{1-\alpha(1-\beta)}{(1-\phi_1)\phi_{2,k}}\right)^{\beta}\left(\frac{1}{1-\phi_{2,k}}\right)^{1-\beta}\left(\frac{\omega}{\alpha\varphi}\right), \tag{6}$$

$$\pi_k(i)=Y^{\frac{\eta-\alpha}{1-\alpha}}\varphi^{\frac{\alpha}{1-\alpha}}\Psi_k(\beta)-\omega f_c, \tag{7}$$

where $\Psi_k(\beta) = \frac{1-\alpha\left[(1-\beta)(1-\phi_{2,k})+\frac{\beta}{1-\alpha(1-\beta)}(1-\phi_1)\phi_{2,k}\right]}{\left[\frac{1}{\alpha}\left(\frac{\omega[1-\alpha(1-\beta)]}{(1-\phi_1)\phi_{2,k}}\right)^{\beta}\left(\frac{\omega}{1-\phi_{2,k}}\right)^{1-\beta}\right]^{\frac{\alpha}{1-\alpha}}}$.

Proof. See Appendix A.

The final-good producer charges a constant mark-up over the marginal cost given the constant elasticity of demand. Due to contract incompleteness, this mark-up is $\frac{1}{[(1-\phi_1)\phi_{2,k}]^{\beta}(1-\phi_{2,k})^{1-\beta}}$ times larger than the mark-up that would result under complete contracts. While the mark-up is increasing in ϕ_1, it is decreasing (increasing) in $\phi_{2,k}$ for $\phi_{2,k} < \beta$ ($\phi_{2,k} > \beta$). Moreover, more productive firms produce more and charge less as can be seen from Equations (5) and (6).

After observing his productivity, the final-good producer decides whether to go on with the production or exit. There is a threshold productivity level, $\underline{\varphi}$, above which the production continues and the final-good producer chooses the ownership structure that maximizes his ex ante operating profits. This decision can be represented as follows.

$$\pi(\varphi, Y, \beta) = \begin{cases} \max\limits_{k\in\{O,V\}} \pi_k(\varphi, Y, \beta), & \text{for } \varphi \geqslant \underline{\varphi} \\ 0, & \text{for } \varphi < \underline{\varphi}. \end{cases}$$

The threshold productivity $\underline{\varphi}$ can be implicitly defined by $\pi(\underline{\varphi}, Y, \beta) = 0$ and it is a function of sector's aggregate consumption index Y, that is $\underline{\varphi}(Y)$. Moreover as in Melitz (2003), in equilibrium, expected operating profits of any firm is equal to the fixed cost of entry

$$\int_{\underline{\varphi}(Y)}^{\infty} \pi(\varphi, Y, \beta)dG(\varphi) = \omega f_e.$$

Proposition 1. The firm's operating profits $\pi_{k\in\{O,V\}}(i)$ in Equation (7) are decreasing in ϕ_1.

Proof. See Appendix A.

The final output and the optimal choice of the downstream input are both increasing in the amount of the upstream input, which in turn depends on the stake of the upstream supplier. This stake is decreasing in ϕ_1 (recall that the upstream supplier maximizes $(1-\phi_1)\phi_{2,k}R(i) - \omega L_1(i)$). Therefore, as ϕ_1 increases, the hold-up problem becomes more severe and profits go down.[15]

We are ready to analyze the organizational mode decision of the final-good producer. Let $\Gamma(\beta, \phi_1) = \frac{\pi_V+\omega f_c}{\pi_O+\omega f_c}$ denote the ratio of the variable profits under vertical integration to those under outsourcing. It shows the relative attractiveness of vertical integration vis-à-vis outsourcing.

Proposition 2. Consider the organizational mode decision of the final-good producer.

(i) Ceteris paribus, there exists a unique $\widetilde{\beta} \in (0,1)$ such that $\Gamma(\beta, \phi_1) < 1$ for $\beta < \widetilde{\beta}$, $\Gamma(\beta, \phi_1) > 1$ for $\beta > \widetilde{\beta}$, and $\Gamma(\widetilde{\beta}, \phi_1) = 1$.

(ii) This unique threshold $\widetilde{\beta}$ decreases as ϕ_1 increases.

Proof. See Appendix A.

The first part establishes the existence of a unique upstream-input intensity, $\widetilde{\beta}$, that makes the final-good producer indifferent in choosing the optimal organizational form. It reminds us the importance of the residual rights of control as stated by Grossman and Hart (1986). Accordingly, if the investment by the upstream supplier is relatively more important in the production of the final output ($\beta > \widetilde{\beta}$), then the residual rights of control must stay with the final-good producer, that is, vertical integration in the downstream stage, so that more ownership can be allocated to the upstream supplier to mitigate the underinvestment in the upstream input. In contrast, when the downstream input is relatively more important ($\beta < \widetilde{\beta}$), more ownership must be given to the downstream supplier, that is, outsourcing. The second part indicates that as the degree of hold-up problem becomes more severe (as ϕ_1 increases), the range of β values for which vertical integration is optimal expands ($\widetilde{\beta}$ decreases). Intuitively, while ϕ_1 has a direct effect on the upstream input, it has an indirect effect on the downstream input through the feedback effect from the upstream input. Since the effect on the upstream input is first order, for a wider range of parameter space, it becomes relatively more important to alleviate underinvestment in the upstream stage via integrating the downstream supplier.

Next, we will consider a useful thought experiment where the final-good producer could freely choose optimal ϕ_2, say $\phi_2^{opt} \in [0,1]$, that maximizes operating profits. Higher ϕ_2 allows larger fraction of the revenue to be allocated to the upstream supplier but also induces the downstream supplier to produce less. The optimal ϕ_2 takes this trade-off into account.

Proposition 3. The optimal revenue share ϕ_2^{opt} is given by

$$\phi_2^{opt}(\beta) = \frac{\sqrt{[\beta(2-\phi_1-\alpha(1-\beta))]^2 + 4\beta[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]} - \beta(2-\phi_1-\alpha(1-\beta))}{\frac{2\left[(1-\beta)(1-\alpha(1-\beta))-\beta(1-\phi_1)\right]}{(1-\alpha(1-\beta))}}, \tag{8}$$

with $\phi_2^{opt}(0) = 0$ and $\phi_2^{opt}(1) = 1$. Moreover, it has the following properties:

(i) ϕ_2^{opt} is increasing in β.
(ii) For a given β, the operating profits in Equation (7) are increasing in ϕ_2 for $0 < \phi_2 < \phi_2^{opt}(\beta)$ and decreasing in ϕ_2 for $\phi_2^{opt}(\beta) < \phi_2 < 1$.
(iii) ϕ_2^{opt} is increasing in ϕ_1.

Proof. See Appendix A.

Figure 2 plots ϕ_2^{opt} as a function of β. It is increasing everywhere implying that as the importance of the upstream input in the final-good production increases, the optimal fraction of the revenue that is allocated to the downstream supplier, $1-\phi_2^{opt}(\beta)$, goes down. In reality, the final-good producer is allowed to choose only between $\phi_{2,O}$ and $\phi_{2,V}$. When β is low enough, such as point β_L in Figure 2, lower values of ϕ_2 yield higher profits, implying that outsourcing is the optimal organizational choice when dealing with the downstream supplier ($\phi_{2,O}$ is better). In contrast, when β is high enough, such as point β_H in Figure 2, higher values of ϕ_2 yield higher profits, implying that integration is the optimal organizational choice when dealing with the downstream supplier ($\phi_{2,V}$ is better). So far, this result is due to part (ii) of Proposition 3. *Given the existence*

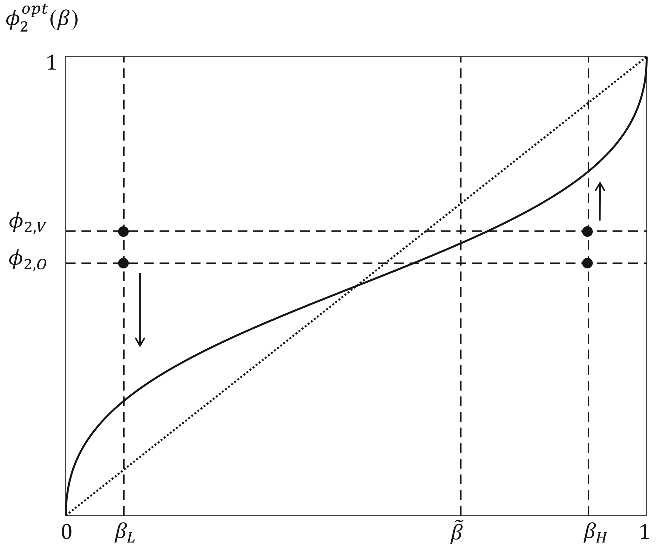

FIGURE 2 Optimal Revenue Share, $\phi_2^{opt}(\beta)$.

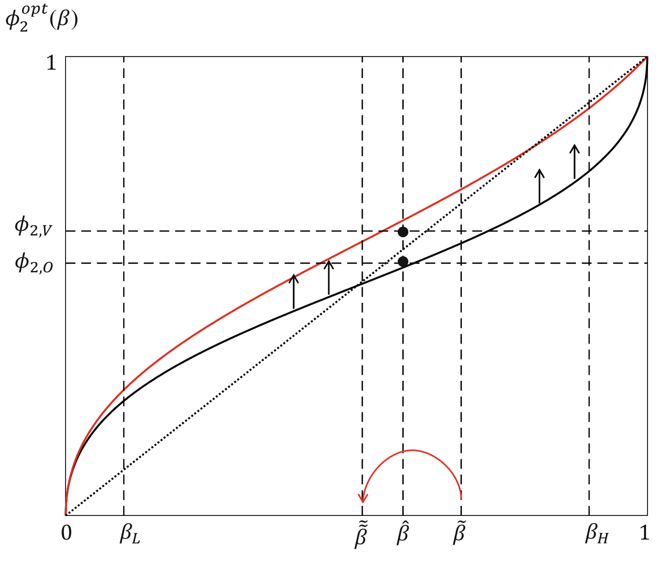

FIGURE 3 Change in $\phi_2^{opt}(\beta)$ as ϕ_1 increases. [Colour figure can be viewed at wileyonlinelibrary.com]

of a unique threshold $\widetilde{\beta}$ as stated in part (i) of Proposition 2, we can also state firms will choose outsourcing if $\beta < \widetilde{\beta}$, whereas they will choose integration if $\beta > \widetilde{\beta}$.

Figure 3 shows that for a given $\beta \in (0, 1)$, as ϕ_1 goes up, the optimal ϕ_2 increases to mitigate the intensified underinvestment problem in the upstream stage. At the same time, the unique threshold, stated in part (i) of Proposition 2 decreases from $\widetilde{\beta}$ to $\widetilde{\widetilde{\beta}}$. Consequently, the degree of hold-up friction might affect the organizational choice in the downstream stage. This possibility is shown in Figure 3 for a sector with an upstream-input intensity $\widehat{\beta}$. When the hold-up problem is not severe (lower ϕ_1), outsourcing is chosen in the downstream stage (since $\widehat{\beta} < \widetilde{\beta}$), whereas as it becomes worse (ϕ_1 goes up), then vertical integration is chosen in the downstream stage (since $\hat{\beta} > \tilde{\tilde{\beta}}$). A direct implication of this observation brings to light our novel contribution, that is, the asymmetry in the hold-up friction between sourcing locations of the upstream input might cause firms to choose different organizational modes when purchasing their downstream input.

3 | THE OPEN-ECONOMY MODEL

The production process is as described before but now there are two countries, North and South. Let ω^N and ω^S represent the fixed wage rate in the North and South, respectively, and $\omega^N > \omega^S$.[16] Final-good varieties are completed in the North, implying that all final-good producers are located in the North. The fixed entry and operating costs in each country are the same and expressed in units of northern wage, $\omega^N f_e$ and $\omega^N f_c$, respectively. We allow international fragmentation of production such that final-good producers can obtain their inputs (upstream and downstream) from either country. There are two types of trade costs associated with international sourcing. The first one is iceberg–type transport costs for components, whereby $\tau > 1$ units of an input must be shipped in order for 1 unit to arrive at destination. The second one is coordination costs, representing problems arising from coordinating the activities of suppliers in different countries and they are modeled as a fixed cost in units of Northern wage, $\omega^N f_s$.[17]

The ex post bilateral negotiations leave the final-good producer with a fraction $\phi_1^l \in (0, 1)$ of the surplus vis- à-vis the upstream supplier and a fraction $\phi_{2,k}^l \in (0, 1)$ of the surplus vis-à-vis the downstream supplier, for $l \in \{N, S\}$ and $k \in \{O, V\}$.[18] For the rest of the analysis, we will assume that $\phi_1^N < \phi_1^S$ and $\phi_{2,k}^N = \phi_{2,k}^S > 0$ for $k \in \{O, V\}$.[19] Having $\phi_1^N < \phi_1^S$ can be justified by slightly adjusting our model to an international context. Assume that when the upstream input is procured from the South, if negotiations fail, the final-good producer can obtain an inferior replica of this *Southern* upstream input from a neighboring country to continue with production. This is viable due to loose intellectual property rights (IPR) protection in the region. This outside option in turn increases the fraction of the surplus the final-good producer acquires in the South. In contrast, the North has a strong IPR protection and hence it is not likely to obtain a replica of the Northern upstream input. Since a higher value of ϕ_1 results in lower operating profits (recall Proposition 1) by reducing the investment incentive of both suppliers, the hold-up friction in the South is assumed to be larger.[20] This way of modeling the asymmetry in the degree of underinvestment problem will help us illuminate the role the sequential setup plays.[21]

In view of these additional assumptions above and using Equation (7), we have

$$\pi_k^{l_1,l_2}(\varphi, Y, \beta) = Y^{\frac{\eta-\alpha}{1-\alpha}} \varphi^{\frac{\alpha}{1-\alpha}} \Psi_k^{l_1,l_2}(\beta) - \omega^N (f_c + I(\varphi) f_s), \tag{9}$$

where

$$\Psi_k^{l_1,l_2}(\beta) = \frac{1 - \alpha\left[(1-\beta)(1-\phi_{2,k}) + \frac{\beta}{1-\alpha(1-\beta)}\left(1-\phi_1^{l_1}\right)\phi_{2,k}\right]}{\left[\frac{\tau^{l_1,l_2}}{\alpha}\left(\frac{\omega^{l_1}[1-\alpha(1-\beta)]}{\left(1-\phi_1^{l_1}\right)\phi_{2,k}}\right)^{\beta}\left(\frac{\omega^{l_2}}{1-\phi_{2,k}}\right)^{1-\beta}\right]^{\frac{\alpha}{1-\alpha}}}. \tag{10}$$

$\pi_k^{l_1,l_2}$ represents the operating profits of a firm with productivity φ that chooses the organization form $k \in \{O, V\}$ and procure the upstream input from country l_1 and the downstream input from country l_2, for $l_1, l_2 \in \{N, S\}$. In addition, we have

$$I(\varphi) = \begin{cases} 1, & \text{if } l_1 \neq l_2 \\ 0, & \text{if } l_1 = l_2 \end{cases} \text{ and } \tau^{l_1,l_2} = \begin{cases} 1, & \text{if } l_1 = N \text{ and } l_2 = N \\ \tau^{\beta}, & \text{if } l_1 = S \text{ and } l_2 = N \\ \tau, & \text{if } l_1 = S \text{ and } l_2 = S \\ \tau^{1+\beta}, & \text{if } l_1 = N \text{ and } l_2 = S \end{cases}.$$

Note that shipping the downstream input costs more than shipping the upstream input due to the production structure. Thus, the cost of transport when both inputs are procured from the South is higher than when the upstream input is procured from the South and the downstream input is procured from the North: $\tau^{S,S} = \tau > \tau^{\beta} = \tau^{S,N}$. Moreover, the highest transport costs occur when the upstream input is procured from the North and the downstream input is procured from the South: $\tau^{N,S} = \tau^{1+\beta}$. This is so since once completed, each input needs to be shipped to another country: the upstream input to the South and the downstream input to the North.

The firm's productivity determines whether the firm continues with the production or exit:

$$\pi(\varphi, Y, \beta) = \begin{cases} \max\limits_{\substack{k\in\{O,V\} \\ \text{and} \\ l_1,l_2\in\{N,S\}}} \pi_k^{l_1,l_2}(\varphi, Y, \beta), & \text{for } \varphi \geqslant \underline{\varphi} \\ 0, & \text{for } \varphi < \underline{\varphi} \end{cases},$$

where the threshold productivity $\underline{\varphi}$ can be implicitly defined by $\pi(\underline{\varphi}, Y, \beta) = 0$.

Now we can analyze the final-good producer's problem. Regarding the organizational choice, we know that it is always optimal to procure the upstream input via outsourcing and this is independent of the sourcing location. In contrast, the optimal organizational mode in the downstream stage might depend on the sourcing location of the upstream input due to the asymmetry in the hold-up friction between the North and South. To see this, notice that since $\phi_1^N < \phi_1^S$, based on part (ii) of Proposition 2, the critical value of β, $\widetilde{\beta}^l$ for $l \in \{N, S\}$, is larger in the North, that is, $\widetilde{\beta}^S < \widetilde{\beta}^N$. Recall that β represents the relative importance of the upstream input. Since the hold-up friction is more severe in the South, this has a first-order negative effect on the upstream-input investment and to mitigate this, more incentives need to be given to the Southern upstream supplier. This can be done by reallocating revenue shares from the downstream to the upstream supplier, which raises the relative appeal of vertical integration in the downstream stage. Thus, integrating the downstream supplier will be opted for a wider range of β values in the South. As a result, we can state the following.

Proposition 4. Given an upstream-input intensity β, we have:

(i) for $\beta < \widetilde{\beta}^S < \widetilde{\beta}^N$, all firms choose outsourcing,
(ii) for $\widetilde{\beta}^S < \widetilde{\beta}^N < \beta$, all firms choose vertical integration, and
(iii) for $\widetilde{\beta}^S < \beta < \widetilde{\beta}^N$, those firms that procure the upstream input from the South prefer vertical integration, whereas those that procure the upstream input from the North prefer outsourcing.

Proof. The proof follows from Proposition 2.

Regarding the sourcing location, there are 4 options: (i) both inputs from the North (the *N*-*N* option), (ii) both inputs from the South (the *S*-*S* option), (iii) the upstream input from the North and the downstream input from the South (the *N-S* option), (iv) the upstream input from the South and the downstream input from the North (the *S-N* option). Yet, the next proposition allows us to ignore the *S-N* option.

Proposition 5. It is never optimal to procure the upstream input from the South and the downstream input from the North. Therefore, we can ignore the *S-N* option.

Proof. See Appendix A.

This proposition is not self-evident. After all, the *S-N* option has the second lowest transport costs since shipping costs are proportional to the gross value of the input being transported. Despite this advantage, a quick profit comparison reveals that the *S-N* option will always be dominated by either the *N-N* or *S-S* options. To be specific, the former dominates if the wage gap between the North and South is smaller than the iceberg transport cost parameter τ, that is, $\frac{\omega^N}{\omega^S} < \tau$, whereas the latter dominates if the reverse is true, that is, $\frac{\omega^N}{\omega^S} > \tau$.

For the rest of the analysis, we will focus on sectors with $\widetilde{\beta}^S < \beta < \widetilde{\beta}^N$ in which firms choose different organizational modes depending on the sourcing location of the upstream input. We do so to highlight our contribution and differentiate our work from the previous studies (such as Antràs, 2003 and Antràs & Helpman, 2004).

3.1 | Input procurement in sectors with $\widetilde{\beta}^S < \beta < \widetilde{\beta}^N$

In light of Proposition 5, there are in effect 3 options in choosing the procurement location of inputs: (1) both inputs from the North (the *N-N* option), (2) both inputs from the South (the *S-S* option), and (3) the upstream input from the North but the downstream input from the South (the *N-S* option). We also know from Lemma 1 and part (iii) of Proposition 4 that while outsourcing is always optimal in the upstream stage, we can have either organizational mode in the downstream stage. In particular, under the *N-N* and *N-S* options, since firms procure their upstream input from the North, they choose outsourcing in the downstream stage, whereas under the *S-S* option, the upstream input is sourced from the South and hence vertical integration is optimal in the downstream stage. The discussion below outlines the main results by comparing different options. A detailed technical version of this analysis can be found in Appendix B.

First, consider procuring both inputs from a single location: either the North (the *N-N* option) or the South (the *S-S* option). In the South, the wage rate is lower but the hold-up friction is more severe plus firms need to incur transport costs to ship the downstream input to the North. On the other hand, since input suppliers are from the same location in both options, there are no coordination costs, $\omega^N f_s$, implying that the comparison of variable profits is sufficient to select the better option, that is, $\frac{\pi_O^{N,N}(\varphi,Y,\beta)+\omega^N f_c}{\pi_V^{S,S}(\varphi,Y,\beta)+\omega^N f_c}$. Notice from Equation (9) that this ratio is independent of φ given that a firm's productivity does not change according to its sourcing location or organizational choice. Therefore, if one option is preferred over the other by a firm with productivity $\varphi \in [\underline{\varphi}, \infty)$, then the same option must be preferred by all active firms. Consequently, if the wage advantage in the South can overcome the more severe hold-up friction as well as the cost of transporting the downstream input, then all firms independent of their productivity choose the *S-S* option; otherwise, they all prefer the *N-N* option.

Next, consider procuring both inputs from the North (the *N-N* option) versus the upstream input from the North and the downstream input from the South (the *N-S* option). Since the upstream input is procured from the North under both options, there is no difference between the two regarding the hold-up friction. Under the N-S option, firms take advantage of lower Southern wage rate in the downstream stage at the expense of trade costs, that is, transport and coordination costs. While the wage rate and transport costs affect variable profits, coordination costs affect (raise) fixed costs. Given the additional fixed (coordination) costs under the N-S option, if transport costs are large enough to wipe out the wage advantage in the South, then all firms choose the N-N option. Instead, if the wage gap can compensate for transport costs so that variable profits are larger under the N-S option, then this gain must be weighed against fixed coordination costs. If coordination costs are not significant, then all firms choose the N-S option. On the other hand, if they are relatively large, then while more productive firms still prefer the N-S option (since they can produce more and therefore variable profits are more important to them), less productive firms prefer the N-N option as they cannot afford coordination costs.

Now consider the choice of procuring both inputs from the South (the S-S option) versus the upstream input from the North and the downstream input from the South (the N-S option). The N-S option allows firms to bypass the more severe hold-up friction in the South at the expense of higher wage rate in the upstream stage and additional trade costs. Trade costs are smaller under the S-S option since transport costs are lower ($\tau < \tau^{1+\beta}$) and there are no coordination costs. As a result, if the wage gap and lower transport costs can compensate the more severe hold-up friction in the South, then all firms choose the S-S option. Instead, if the hold-up friction is severe enough so that variable profits are larger under the N-S option, then this benefit must be balanced against fixed coordination costs. If coordination costs are not significant, then all firms choose the N-S option. On the other hand, if they are relatively large, then while more productive firms still prefer the N-S option (since they can produce more and therefore variable profits are more important to them), less productive firms fare better under the S-S option as they cannot afford coordination costs.

We can summarize these results as follows. (1) All else constant, all firms procure both inputs domestically from the North if transport costs are very large. (2) All else constant, all firms procure both inputs internationally from the South if the wage differential between the North and South is significant. (3) If neither transport costs nor the wage differential is substantial, then more productive firms source their upstream input from the North and downstream input from the South. By doing so, they can circumvent the more severe underinvestment problem in the South while still benefiting from the lower wage rate in the South in the downstream stage. Less productive firms do the same if they can cover the coordination costs. If they cannot, then they source both inputs from a single country.

From this discussion, the following conclusions can be made. More productive firms care more about factors affecting their variable profits: transport costs, the wage differential and the degree of hold-up friction. This is so since their productivity advantage allows them to produce more, which in turn makes them more sensitive to variable profits relative to fixed costs. Therefore, high-productivity firms choose the option with the highest variable profits. This is not always the case for low-productivity firms, since they do not produce enough output to ignore fixed-cost differentials, that is, additional coordination costs under the N-S option. To see this, consider a scenario in which variable profits are largest under the N-S option. When this advantage in variable profits is not large enough to cover additional fixed (coordination) costs, then less-productive firms are unable to choose this option. One such possibility is depicted in Figure 4. We have $\varphi^{\frac{\alpha}{1-\alpha}}$ on the horizontal axis and operating profits on the vertical axis. From Equation (9), we can see that the profit function is linear in $\varphi^{\frac{\alpha}{1-\alpha}}$, and its slope is proportional to $\Psi_k^{l_1,l_2}(\beta)$. By construction, the N-N option is the worst and consequently, the sourcing choice is between the N-S and S-S

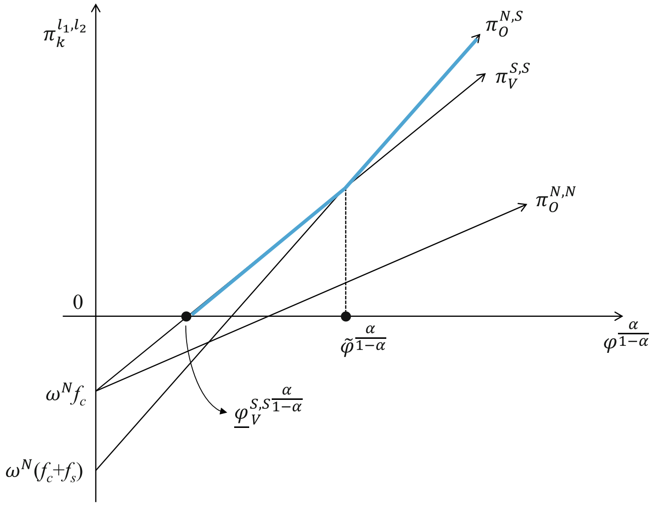

FIGURE 4 Equilibrium under Case 5. [Colour figure can be viewed at wileyonlinelibrary.com]

options. All firms below a productivity of $\underline{\varphi}_V^{S,S}$ expect negative operating profits independent of their organizational mode or input-procurement locations. The blue line shows the maximum operating profits attainable among all three profit functions. Firms with productivity between $\underline{\varphi}_V^{S,S}$ and $\tilde{\varphi}$ obtain their highest operating profits by procuring both inputs from the South (the *S-S* option) and choose vertical integration in the downstream stage as they cannot afford coordination costs. In contrast, firms with productivity above $\tilde{\varphi}$ can pay for coordination costs and thus find it optimal to procure the upstream input from the North and the downstream input from the South (the *N-S* option) and choose outsourcing in the downstream stage.

So far, the analysis has focused on firms. From now on, our focus will shift to industries. The next section looks at the factors that influence the relative prevalence of organizational forms.

3.2 | Prevalence of organizational forms in sectors with $\tilde{\beta}^S < \beta < \tilde{\beta}^N$

Assume that the distribution for firms' productivity, $G(\varphi)$ is a Pareto distribution with shape parameter κ

$$G(\varphi) = 1 - \left(\frac{\nu}{\varphi}\right)^{\kappa} \text{ for } 0 < \nu \leqslant \varphi, \tag{11}$$

where κ is large enough so that the size distribution of firms has a finite variance.[22] Consider the previous analysis and note that: (1) since outsourcing is always optimal in the upstream stage, we study the relative prevalence of organizational forms in the downstream stage, and (2) for the parameter space we focus on, those firms that source their upstream input from the North choose outsourcing in the downstream stage, whereas those that source their upstream input from the South choose vertical integration.

When all firms choose to source their upstream input from the same country, then the fraction of firms that choose outsourcing is either 0 (under the *S-S* option) or 1 (under the *N-N* and *N-S* options). Instead, the more interesting case is the one in which more productive firms choose the

N-S option and less productive firms choose the S-S option. In this case, there is a critical value of φ, $\widetilde{\varphi}$ as shown in Figure 4, that distinguishes more productive firms from less productive ones. Using Equation (9) and setting $\pi_O^{N,S}(\widetilde{\varphi}, Y, \beta) = \pi_V^{S,S}(\widetilde{\varphi}, Y, \beta)$, we obtain

$$\widetilde{\varphi} = Y^{\frac{\alpha-\eta}{\alpha}} \left[\frac{\omega^N f_s}{\Psi_O^{N,S}(\beta) - \Psi_V^{S,S}(\beta)} \right]^{\frac{1-\alpha}{\alpha}}. \tag{12}$$

Denoting λ the fraction of active firms that choose outsourcing in the downstream stage, we have

$$\lambda = \frac{1 - G(\widetilde{\varphi})}{1 - G(\underline{\varphi}_V^{S,S})} = \left(\frac{\underline{\varphi}_V^{S,S}}{\widetilde{\varphi}} \right)^{\kappa}, \tag{13}$$

where $\underline{\varphi}_V^{S,S}$ denotes the productivity of a break-even firm, which can be obtained by setting $\pi_V^{S,S}(\underline{\varphi}_V^{S,S}, Y, \beta) = 0$:

$$\underline{\varphi}_V^{S,S} = Y^{\frac{\alpha-\eta}{\alpha}} \left[\frac{\omega^N f_c}{\Psi_V^{S,S}(\beta)} \right]^{\frac{1-\alpha}{\alpha}}. \tag{14}$$

Next, using Equations (10), (12), and (14), we can rewrite Equation (13) as

$$\lambda = \left[\left(\frac{\Psi_O^{N,S}(\beta)}{\Psi_V^{S,S}(\beta)} - 1 \right) \frac{f_c}{f_s} \right]^{\frac{(1-\alpha)\kappa}{\alpha}} = \left[\left(\Theta_{O,V} \left(\frac{\omega^S}{\tau \omega^N} \right)^{\frac{\alpha\beta}{1-\alpha}} - 1 \right) \frac{f_c}{f_s} \right]^{\frac{(1-\alpha)\kappa}{\alpha}}, \tag{15}$$

where

$$\Theta_{O,V} = \frac{1-\alpha\left[(1-\beta)(1-\phi_{2,O}) + \frac{\beta}{1-\alpha(1-\beta)}(1-\phi_1^N)\phi_{2,O}\right]}{1-\alpha\left[(1-\beta)(1-\phi_{2,V}) + \frac{\beta}{1-\alpha(1-\beta)}(1-\phi_1^S)\phi_{2,V}\right]} \left[\left(\frac{1-\phi_1^N}{1-\phi_1^S} \frac{\phi_{2,O}}{\phi_{2,V}} \right)^{\beta} \left(\frac{1-\phi_{2,O}}{1-\phi_{2,V}} \right)^{1-\beta} \right]^{\frac{\alpha}{1-\alpha}} > 1.$$

We have $\Theta_{O,V} > 1$ since the severity of hold-up friction is lower in the North, that is, $\phi_1^N < \phi_1^S$. This follows from Proposition 1. The idea is that if there were no transport costs and no difference in the wage rate between countries, procuring the upstream input from the North would generate more value.

Holding α, β and ϕ_1^N constant, we look at how the fraction λ depends on the ratio of operating costs to coordination costs, $\frac{f_c}{f_s}$, the iceberg transport cost parameter, τ, the more severe hold-up friction in the South, ϕ_1^S, the wage gap between the North and South, $\frac{\omega^N}{\omega^S}$, and the dispersion of productivity, κ. Here, we consider small (marginal) changes in these parameters. We begin with a fall in trade costs. First, consider a decrease in coordination costs relative to operating costs, that is, an increase in $\frac{f_c}{f_s}$. As coordination costs decrease, more firms tend to obtain their upstream input from the North to benefit from the less severe hold-up friction and the downstream input from the South to benefit from the lower wage rate. Consequently, the fraction of active firms choosing outsourcing increases. Next, consider a decrease in the transport cost parameter, τ. While lower transport costs positively affect both sourcing patterns, it benefits the most to the N-S option where the transport costs are the largest. This again increases the fraction of firms choosing outsourcing. To sum up, any decrease in trade costs makes outsourcing more prevalent. On the other hand, a *marginal* improvement in IPR protection, that is, a decrease in the hold-up friction in the South, has the opposite effect.[23] As ϕ_1^S falls, the asymmetry in the hold-up friction diminishes and some firms switch sourcing their upstream input from the North to the South. This causes a decrease in the fraction of firms that chooses outsourcing, λ.[24] Similarly, an increase in the wage gap, $\frac{\omega^N}{\omega^S}$, makes sourcing both inputs from the South more attractive and thus makes vertical integration more prevalent. In contrast, an increase in the dispersion of productivity, that is, a decrease in κ, increases the fraction of firms choosing outsourcing. This can be seen from Equation (13) since $\underline{\varphi}_V^{S,S} < \tilde{\varphi}$. Intuitively, higher dispersion industries (low κ) have more high-productivity firms that are more likely to choose the *N*-*S* option to avoid the more severe hold-up friction in the South while still enjoying the lower Southern wage rate in the downstream stage.

4 | DISCUSSION

This section explores, *one at a time*, some variants and extensions of our framework. We begin by considering changes to our closed-economy benchmark model. Here, the focus will be on the organizational mode. Next, we modify some assumptions regarding our open-economy setting to see how firms' sourcing decisions are affected.[25]

We start by admitting a richer production technology that enables not only sequential format but also modular features involving investment from the final-good producer ('snakes' and 'spiders' in the terminology of Baldwin & Venables, 2013). While doing so, we keep the contribution of each input to the final output intact to compare with our benchmark model. First, we allow the final-good producer to take part in the production of the downstream input. This analysis reveals that while outsourcing is still the only organizational mode in the upstream stage, vertical integration is more likely to occur in the downstream stage. Second, we let the final-good producer take part in the production of the upstream input. In this setting, we find that not only vertical integration is more likely to emerge, but also it can emerge in the upstream stage. Even so, provided that the final-good producer's contribution is below a certain threshold, vertical integration in the upstream stage does not occur and our results from the benchmark model carry over. We then analyze what happens in the absence of ex ante transfers. Now, the final-good producer has also a rent-extraction motive in choosing the organizational mode. In this case, vertical integration is more likely to occur and different than our benchmark, we can observe vertical integration in either stage.

We also look at some alternative assumptions in our open-economy setting. The first one is regarding the location of final-good assembly. Following the footsteps of Antràs and Helpman (2004), we have assumed that all final goods are completed in the North. Implicitly, this means the assembly of final output is either: (1) using a technology that is available only in the North, or (2) prohibitively expensive in the South. If we were to relax this assumption and let firms choose their assembly location, then all firms would choose to assemble the final output in the South. This is so since shipping costs compound along the value chain and the cost of producing the downstream input is cheaper in the South due to lower wage rate. We can then make the following conclusions: (1) Proposition 5 still holds and we can ignore the *S*-*N* option as before. (2) If either transport costs or the wage gap are substantial, all firms procure their inputs domestically from the South. (3) Otherwise, more productive firms procure the upstream input from the North and the downstream input from the South to avoid the more severe hold-up friction in the South while still enjoying the lower Southern wage in the downstream stage. On the other hand, depending on the scale of coordination costs, less productive firms may either follow more productive firms or procure both inputs from a single country. Compared to our current setting, it is now much more affordable to source inputs under the *N*-*S* and *S*-*S* options. Further, there is no equilibrium in which *all* firms independent of their productivity source both inputs from the North. The second assumption we relax is the hold-up asymmetry between the North and South. We have assumed that in the South, there is higher efficiency loss from hold-up due to loose intellectual property rights (IPR), that is, $\phi_1^N < \phi_1^S$. Here, we investigate what if the reverse were true, that is, $\phi_1^N > \phi_1^S$. In this scenario, the only reason to source inputs domestically from the North is to save on transport costs. As a result, the sourcing patterns of firms can be expressed on the basis of the magnitude of transport costs: (1) Proposition 5 is not valid anymore. Instead, no firm will procure the upstream input from the North and the downstream input from the South in equilibrium, so we can ignore the *N*-*S* option. (2) All firms procure both inputs from the North if transport costs are very large (larger than in our current setting), whereas they all source both inputs from the South if transports costs are very small. (3) For intermediate values of transport costs, more productive firms source the upstream input from the South and the downstream input from the North to avoid the hefty cost of transporting the downstream input from the South while still enjoying the lower Southern wage rate and less severe hold-up friction in the upstream stage. On the other hand, depending on the scale of coordination costs, less productive firms may either follow more productive firms or source both inputs from a single country. A quick comparison to our current setting shows that the *S*-*N* option can now occur in equilibrium whereas the *N*-*S* option cannot. Moreover, it is now more likely for firms to source the upstream input from the South due to less severe hold-up friction there compared to the North. Lastly, in the parameter space we consider, there is also a change regarding the organizational mode:[26] while those firms that source their upstream input from the South choose outsourcing in the downstream stage, those that source their inputs from the North choose vertical integration.

5 | CONCLUSION

This article develops a stylized model of North-South trade in intermediate goods in order to analyze heterogeneous firms' choice of (i) organizational form, and (ii) location for input procurement. Production consists of a well-defined sequence of highly complementary stages such that a failure in any stage demolishes the whole project. We consider an environment in which investments are relationship specific and complete contracts are unavailable. In such a setting, the allocation of ownership rights is crucial. When deciding on the optimal organizational form, firms take into account the relative importance of upstream and downstream components together with the variation in the hold-up friction in different locations. When deciding where to source inputs, firms take into account wage differentials and the degree of hold-up friction in different locations in addition to trade costs involving transporting inputs and coordinating suppliers stationed in different countries. In the last part, we also look at how different sector characteristics affect the relative pervasiveness of organizational forms. This analysis gives us a holistic picture of organizational structure of firms and their input-sourcing decisions.

Our model has a number of testable implications, some of which have already been tested and verified by other researchers (as stated in the introduction), while others are still open for empirical inspection. One such testable hypothesis is that firms that procure their early-stage inputs from loose IPR protection countries tend to choose vertical integration in later stages of production. Similarly, another testable finding is that as trade costs decrease, we expect an increase in the fraction of firms that choose outsourcing in later stages of production. This is to be contrasted to a *marginal* improvement in IPR protection in the South, where we expect a decrease in the share of firms that choose outsourcing in later stages of production.[27]

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CONFLICT OF INTEREST STATEMENT

The author declares no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

ORCID

Bilgehan Karabay https://orcid.org/0000-0001-8557-6073

ENDNOTES

1 This is reminiscent of the 'O-ring theory' of Kremer (1993). The classical example given in that paper is the space shuttle *Challenger*. It was made of many parts and failure in one part, O-rings, caused the explosion of it.

2 Antràs and Chor (2013) assume $\alpha > 0$ degree of substitutability between stage inputs so that output is still positive even if some stages are completed with an incompatible input. They then show that if elasticity of demand faced by the firm ($\rho > 0$) is lower than the elasticity of substitution across inputs, that is, $\rho < \alpha$, inputs are sequential substitutes, whereas if $\rho > \alpha$, inputs are sequential complements. When inputs are sequential substitutes (complements), more investment in upstream stages reduces (increases) the value of undertaking downstream investments. *Using their notation*, higher degree of complementarity between stage inputs in our paper means $\alpha = 0$, thus $\rho > \alpha = 0$ and inputs are sequential complements.

3 A General Motors plant in Kansas City shut down for lack of chips. Also, companies such as Mercedes-Benz and Renault have stopped the production of lower-priced models to reserve the limited supply of chips for more expensive models. See the article "A Tiny Part's Big Ripple: Global Chip Shortage Hobbles the Auto Industry," by Jack Ewing and Neal E. Boudette, New York Times, April 23, 2021 (updated on October 21, 2021).

4 The presence of ex ante transfers makes vertical integration less appealing, since integrated suppliers invest less. In this paper, we show that even with ex ante transfers, vertical integration can still be observed in equilibrium.

5 This first force is similar to Winter (2006). He considers a simple model with moral hazard, in which agents move sequentially in their tasks and all tasks must be successfully performed to complete the project. There is an implicit threat on early movers since an agent will exert effort as long as all agents in previous tasks exerted effort. This threat is less severe on late movers; thus, more reward is required to induce effort from them.

[6] In a different context, Feinberg and Kamien (2001) come up with the same result. They consider the problem of a merchant who must cross two successive jurisdictions to reach the market. The merchant cancels the whole journey if he must pay a tax in the first jurisdiction, since any payment would be sunk once he reaches the second jurisdiction (and thus the second jurisdiction can ask for a tax that is equivalent to the whole value of the merchandise). Miyagiwa (2009) extends this analysis by considering repeated interaction and finds that under stationary subgame perfect equilibrium, both jurisdictions can capture some part of the merchandise value.

[7] Compared to developed countries, developing countries have lower levels of IPR protection, see Maskus (2000).

[8] Antràs and de Gortari (2020) also justify this by pointing out that import duties and insurance costs are approximately proportional to the value of the goods being shipped. Our results do not hinge on the fact that shipping costs compound along the value chain. However, if we were to allow firms to choose their assembly location (instead of assuming all goods are assembled in the North), then increasing transport costs along the value chain incentivize firms to assemble the final output in the South. See Section 4 for further details.

[9] It is well-documented in the literature that the degree of hold-up friction affects firms' organizational choice. What we show is that this connection between the hold-up friction and organizational choice spills over across production stages under sequential setting.

[10] Antràs and Helpman (2004) assume that vertical integration entails larger fixed costs than outsourcing, which causes vertical integration to be chosen by more productive firm. In contrast, Grossman et al. (2005) and Defever and Toubal (2007) assume the reverse ranking of fixed costs, which causes vertical integration to be chosen by less productive firms. Thus, there is no consensus on the relative ranking of these fixed costs.

[11] Note that the mechanism described in Antràs and Chor (2013) is also present in our paper: organizational choice in the upstream stage affects the investment incentive of the upstream supplier, which in turn affects the investment incentive of the downstream supplier. Therefore, what we identify here is an additional mechanism.

[12] Antràs and Chor (2013) assume symmetry across productions stages. Recently, Alfaro et al. (2019), extend Antràs and Chor (2013) by allowing asymmetries across production stages. However, they do not focus on global sourcing location of inputs.

[13] The vertical sequencing in production is reminiscent of an assembly line in manufacturing, where a large number of a uniform good can be assembled. Although efficient, it is quite inflexible since operations must be done in a strictly-ordered sequence and a failure in any sequence results in the shutdown of the entire process.

[14] This production structure implies that unlike suppliers, the final-good producer does not make any investment. The consequence of relaxing this assumption is discussed in Section 4.

[15] As ϕ_1 increases, the production of not only the upstream input but also the downstream input goes down due to the feedback effect from the former to the latter. Therefore in this context, 'hold-up problem' refers to underinvestment in both inputs.

[16] This wage difference can be justified in a general equilibrium by assuming that ω^l for $l \in \{N, S\}$ is the productivity of labor in producing y_0, and that labor supply is large enough in both countries so that each produces y_0, which is defined in Equation (1).

[17] To minimize the taxonomy of cases, we do not assume any coordination costs when the supplier (upstream or downstream) and the final-good producer are from different countries. In other words, coordination costs occur only when the suppliers are from different countries.

[18] Recall that due to Lemma 1, it is always optimal to choose outsourcing in the upstream stage, that is, $\phi^l_{1,k} = \phi^l_{1,O} = \phi^l_1$ for $l \in \{N, S\}$ and $k \in \{O, V\}$.

[19] We introduce the asymmetry in the hold-up friction between sourcing locations through the parameter ϕ_1. Recall from Endnote 15 that as ϕ_1 increases, the production of both inputs go down together with the final output. In contrast, if we were to introduce asymmetry in ϕ_2 values, we couldn't call it a hold-up problem. The net effect on each input and the final good would be ambiguous and depends on the parameters of the model.

[20] The differences between firms and their suppliers, such as different local cultures, languages and practices, can complicate decisions and diminish the effectiveness of business operations. For example, Northern Ireland's official online channel for business provides specific guidelines highlighting these issues in working with international suppliers: https://www.nibusinessinfo.co.uk/content/challenges-sourcing-overseas. Similarly, for Canada: https://www.infoentrepreneurs.org/en/guides/manage-foreign-suppliers/. See also Assche and Schwartz (2010) for a similar assumption of a larger hold-up friction in the South.

[21] Bolatto et al. (2017) show that when inputs are sequential complements, greater IPR protection in suppliers' location makes vertical integration less likely. This is consistent with what we assume here: IPR protection is stronger in the North and vertical integration is less likely to occur compared to South since $\phi_1^N < \phi_1^S$ (recall part (ii) of Proposition 2 and the discussion about Figure 3).

[22] Pareto distribution is commonly used as it has nice properties, see Antràs and Helpman (2004).

[23] Here, we analyze a marginal improvement in IPR protection. Instead, if there is a large improvement in IPR protection (but still $\phi_1^N < \phi_1^S$), then it is possible to observe outsourcing in the South as well. In that case, there will be a non-monotonic increase in the value of λ to 1.

[24] We know from Proposition 1 that the firm's variable profits (and thus operating profits) decrease as the hold-up friction becomes more severe. Therefore, we have $\frac{\partial \Psi_V^{S,S}}{\partial \phi_1^S} < 0$.

[25] The details of the extensions of the closed-economy benchmark model are provided in our Online Appendix C, whereas the details of the alternative scenarios in the open-economy setting can be provided by the author upon request.

[26] When $\phi_1^N > \phi_1^S$, we have $\widetilde{\beta}^N < \widetilde{\beta}^S$ (see part (ii) of Proposition 2). The relevant parameter space of interest then is $\widetilde{\beta}^N < \beta < \widetilde{\beta}^S$.

[27] Notice that in contrast to a marginal improvement, a significant improvement in IPR protection may cause all firms to choose outsourcing (Recall Endnote 23).

[28] The other root is given by

$$\phi_{2,O}^{*other} = \frac{(1-\alpha(1-\beta))^2}{(1-\alpha(1-\beta))^2 - (1-\alpha(1-\beta\phi_1))},$$

which is either larger than 1 or negative (hence outside the allowed bounds of $\phi_{2,O}$), depending on whether the denominator is positive or negative, respectively.

[29] The other root is given by

$$\phi_2^{opt\_other}(\beta) = -\frac{(1-\alpha(1-\beta))\left[\sqrt{[\beta(2-\phi_1-\alpha(1-\beta))]^2+4\beta[(1-\beta)(1-\alpha(1-\beta))-\beta(1-\phi_1)]}+\beta(2-\phi_1-\alpha(1-\beta))\right]}{2[(1-\beta)(1-\alpha(1-\beta))-\beta(1-\phi_1)]},$$

which is either larger than 1 or negative (hence outside the allowed bounds of ϕ_2) depending on whether the denominator is negative or positive, respectively.

[30] We know that $\phi_2^{opt}(\overset{\dagger}{\beta}) \to \overset{\dagger}{\beta}$. Thus, ϕ_2^{opt} is increasing with respect to β at that point.

[31] We know that $\phi_2^{opt}(\overset{\dagger}{\beta}) \to \overset{\dagger}{\beta}$. From Equation (A6), it is easy to see that $\overset{\dagger}{\beta}$ is increasing in ϕ_1. Since ϕ_2^{opt} is increasing in β, this implies that $\frac{\partial \phi_2^{opt}}{\partial \phi_1}_{|\beta \to \overset{\dagger}{\beta}} > 0$.

[32] As can be seen from Equation (9), although $\max\{\pi_O^{N,N}(i, \underline{\varphi}_O^{N,S}), \pi_V^{S,S}(i, \underline{\varphi}_O^{N,S})\} < 0$, variable profits are still positive, that is, $\min\{\pi_O^{N,N}(i, \underline{\varphi}_O^{N,S}) + \omega^N f_c, \pi_V^{S,S}(i, \underline{\varphi}_O^{N,S}) + \omega^N f_c\} > 0$, since $\underline{\varphi}_O^{N,S} > 0$.

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SUPPORTING INFORMATION

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Proof of Lemma 2. Starting from the second stage, the downstream supplier takes $x_1(i)$ as given and maximizes

$$\max_{L_2(i)} \left(1 - \phi_{2,k}\right) R(i) - \omega L_2(i), \text{ for } k \in \{O, V\},$$

where $R(i)$ is given by Equation (3) and $y(i) = \varphi x_2(i) = \varphi\left(\frac{x_1(i)}{\beta}\right)^{\beta}\left(\frac{L_2(i)}{1-\beta}\right)^{1-\beta}$. Thus, the first-order condition can be written as

$$\alpha\left(1-\phi_{2,k}\right)Y^{\eta-\alpha}y(i)^{\alpha-1}\frac{\partial y(i)}{\partial L_2(i)} - \omega = 0,$$

$$\Leftrightarrow \alpha\left(1-\phi_{2,k}\right)Y^{\eta-\alpha}y(i)^{\alpha}\left(\frac{1-\beta}{L_2(i)}\right) - \omega = 0. \quad \text{(A1)}$$

In the first stage, outsourcing will be the optimal organizational structure due to Lemma 1. In addition, given that a fraction $1-\phi_{2,k}$ of the revenue will be allocated to the downstream supplier, only the remaining fraction of the surplus will be negotiated. So, the maximization problem of the upstream supplier can be written as

$$\max_{L_1(i)}(1-\phi_1)\phi_{2,k}R(i) - \omega L_1(i), \text{ for } k \in \{O, V\},$$

subject to $x_1(i) = L_1(i)$ and the best response of the downstream supplier given by the first-order condition in Equation (A1). The first order condition is

$$\alpha(1-\phi_1)\phi_{2,k}Y^{\eta-\alpha}y(i)^{\alpha-1}\left(\frac{\partial y(i)}{\partial x_1(i)} + \frac{\partial y(i)}{\partial L_2(i)}\frac{\partial L_2(i)}{\partial x_1(i)}\right) - \omega = 0. \quad \text{(A2)}$$

Taking Equation (A1) and using the Implicit Function Theorem, we can write $\frac{\partial L_2(i)}{\partial x_1(i)}$ as

$$\frac{\partial L_2(i)}{\partial x_1(i)} = -\frac{\alpha y(i)^{\alpha-1}\frac{\partial y(i)}{\partial x_1(i)}L_2(i)^{-1}}{\alpha y(i)^{\alpha-1}\frac{\partial y(i)}{\partial L_2(i)}L_2(i)^{-1} - y(i)^{\alpha}L_2(i)^{-2}}.$$

Noting that $\frac{\partial y(i)}{\partial x_1(i)} = y(i)\left(\frac{\beta}{x_1(i)}\right)$ and $\frac{\partial y(i)}{\partial L_2(i)} = y(i)\left(\frac{1-\beta}{L_2(i)}\right)$, the above condition becomes

$$\frac{\partial L_2(i)}{\partial x_1(i)} = \frac{\alpha\beta\left(\frac{L_2(i)}{x_1(i)}\right)}{1-\alpha(1-\beta)}.$$

With this in hand, we obtain

$$\frac{\partial y(i)}{\partial x_1(i)} + \frac{\partial y(i)}{\partial L_2(i)}\frac{\partial L_2(i)}{\partial x_1(i)} = y(i)\left(\frac{\beta}{x_1(i)}\right)\left(\frac{1}{1-\alpha(1-\beta)}\right).$$

Plugging this back into Equation (A2), we can express the first-order condition for the upstream supplier as

$$\frac{\alpha(1-\phi_1)\phi_{2,k}}{1-\alpha(1-\beta)}Y^{\eta-\alpha}y(i)^{\alpha}\left(\frac{\beta}{x_1(i)}\right) - \omega = 0. \quad \text{(A3)}$$

With a little manipulation, we can rewrite Equations (A1) and (A3) as

$$\left(\frac{\alpha\left(1-\phi_{2,k}\right)}{\omega}\right)^{1-\beta}\left(Y^{\eta-\alpha}y(i)^{\alpha}\right)^{1-\beta}=\left(\frac{L_2(i)}{1-\beta}\right)^{1-\beta},$$

$$\left(\frac{\alpha(1-\phi_1)\phi_{2,k}}{(1-\alpha(1-\beta))\omega}\right)^{\beta}\left(Y^{\eta-\alpha}y(i)^{\alpha}\right)^{\beta}=\left(\frac{x_1(i)}{\beta}\right)^{\beta},$$

so pairwise multiplication of the two equations leads to

$$\left(\frac{(1-\phi_1)\phi_{2,k}}{1-\alpha(1-\beta)}\right)^{\beta}\left(1-\phi_{2,k}\right)^{1-\beta}\left(\frac{\alpha Y^{\eta-\alpha}y(i)^{\alpha}}{\omega}\right)=\frac{y(i)}{\varphi}.$$

Solving for $y(i)$ gives Equation (5). Moreover, using Equation (2), we can obtain $p(i)$ given in Equation (6).

Next, we derive the expression for the operating profit of variety i. Since $x_1(i) = L_1(i)$, from Equation (A3), we have

$$L_1(i)=\frac{\alpha\beta(1-\phi_1)\phi_{2,k}}{(1-\alpha(1-\beta))\omega}Y^{\eta-\alpha}y(i)^{\alpha}.$$

Similarly, from Equation (A1), we have

$$L_2(i)=\frac{\alpha(1-\beta)\left(1-\phi_{2,k}\right)}{\omega}Y^{\eta-\alpha}y(i)^{\alpha}.$$

Thus, Equation (4) becomes

$$\pi_{k\in\{O,V\}}(i)=\left(1-\alpha(1-\beta)\left(1-\phi_{2,k}\right)-\frac{\alpha\beta(1-\phi_1)\phi_{2,k}}{1-\alpha(1-\beta)}\right)Y^{\eta-\alpha}y(i)^{\alpha}-\omega f_c.$$

Plugging the value of $y(i)$ given in Equation (5) into the above equation gives us Equation (7).

Proof of Proposition 1. Taking the derivative of Equation (7) with respect to ϕ_1 and simplifying, we obtain

$$\frac{\partial\pi_{k\in\{O,V\}}}{\partial\phi_1}=-\alpha\beta\left[\frac{(1-\alpha(1-\beta))\left(1-\phi_{2,k}\right)+\phi_1\phi_{2,k}}{(1-\alpha)(1-\phi_1)}\right]\Omega<0,$$

where $\Omega=\dfrac{Y^{\frac{\eta-\alpha}{1-\alpha}}\varphi^{\frac{\alpha}{1-\alpha}}}{\left[\frac{\omega}{\alpha}\left(\frac{[1-\alpha(1-\beta)]}{(1-\phi_1)\phi_{2,k}}\right)^{\beta}\left(\frac{1}{1-\phi_{2,k}}\right)^{1-\beta}\right]^{\frac{\alpha}{1-\alpha}}}$. ■

Proof of Proposition 2. We start the proof by stating the following lemma.

Lemma 3. Let $\Gamma(\beta,\phi_1)=\frac{\pi_V+\omega f_c}{\pi_O+\omega f_c}$ denote the ratio of the variable profits under vertical integration to those under outsourcing. We have:

(i) $\Gamma(\beta,\phi_1)$ is increasing in β, that is, $\frac{\partial\Gamma(\beta,\phi_1)}{\partial\beta}>0$, where $\Gamma(0,\phi_1)<1$ and $\Gamma(1,\phi_1)>1$.

(ii) $\Gamma(\beta,\phi_1)$ is increasing in ϕ_1, that is, $\frac{\partial\Gamma(\beta,\phi_1)}{\partial\phi_1}>0$.

Proof of Lemma 3. Using Equation (7), $\Gamma(\beta,\phi_1)$ can be written explicitly as

$$\Gamma(\beta,\phi_1)=\left(\left(\frac{\phi_{2,V}}{\phi_{2,O}}\right)^{\beta}\left(\frac{1-\phi_{2,V}}{1-\phi_{2,O}}\right)^{1-\beta}\right)^{\frac{\alpha}{1-\alpha}}\frac{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))\left(1-\phi_{2,V}\right)+\beta\left(1-\phi_1\right)\phi_{2,V}\right]}{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))\left(1-\phi_{2,O}\right)+\beta\left(1-\phi_1\right)\phi_{2,O}\right]}. \tag{A4}$$

Note that $\Gamma(.)$ does not depend on factor prices due to the Cobb–Douglas technology.

(i) Taking logarithm of Equation (A4) and differentiating with respect to β yields

$$\frac{\partial\ln\Gamma(\beta,\phi_1)}{\partial\beta}=\alpha v\left(\phi_{2,O},\phi_{2,V}\right),$$

where

$$v\left(\phi_{2,O},\phi_{2,V}\right)=\begin{cases}\frac{1}{1-\alpha}\left[\ln\left(\frac{\phi_{2,V}}{\phi_{2,O}}\right)-\ln\left(\frac{1-\phi_{2,V}}{1-\phi_{2,O}}\right)\right]\\+\frac{2(1-\alpha(1-\beta))\left(1-\phi_{2,V}\right)+\phi_1\phi_{2,V}}{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))\left(1-\phi_{2,V}\right)+\beta\left(1-\phi_1\right)\phi_{2,V}\right]}\\-\frac{2(1-\alpha(1-\beta))\left(1-\phi_{2,O}\right)+\phi_1\phi_{2,O}}{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))\left(1-\phi_{2,O}\right)+\beta\left(1-\phi_1\right)\phi_{2,O}\right]}\end{cases}.$$

Notice that $v\left(\phi_{2,V},\phi_{2,V}\right)=0$. Hence, if $v_{\phi_{2,O}}\left(\phi_{2,O},\phi_{2,V}\right)<0$, then we can conclude that $v\left(\phi_{2,O},\phi_{2,V}\right)>0$ since $\phi_{2,O}<\phi_{2,V}$ by definition. This will then mean that $\frac{d\ln\Gamma(\beta)}{d\beta}>0$. By taking the derivative of $v\left(\phi_{2,O},\phi_{2,V}\right)$ with respect to $\phi_{2,O}$ and simplifying, we obtain

$$v_{\phi_{2,O}}\left(\phi_{2,O},\phi_{2,V}\right)=\begin{cases}-\frac{1}{1-\alpha}\left(\frac{1}{\phi_{2,O}\left(1-\phi_{2,O}\right)}\right)\\+\frac{(1-\alpha(1-\beta))\left[2(1-\alpha)\left(1-\phi_1\right)+(1-\alpha(1-\beta))\phi_1\right]}{\left\{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))\left(1-\phi_{2,O}\right)+\beta\left(1-\phi_1\right)\phi_{2,O}\right]\right\}^2}\end{cases}.$$

This implies that $v_{\phi_{2,O}}\left(\phi_{2,O},\phi_{2,V}\right)<0$ if and only if

$$g\left(\phi_{2,O}\right)>(1-\alpha)(1-\alpha(1-\beta))[2(1-\alpha)(1-\phi_1)+(1-\alpha(1-\beta))\phi_1], \tag{A5}$$

where

$$g\left(\phi_{2,O}\right)=\frac{\left\{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))\left(1-\phi_{2,O}\right)+\beta(1-\phi_1)\phi_{2,O}\right]\right\}^2}{\phi_{2,O}\left(1-\phi_{2,O}\right)}.$$

Notice that the right-hand side of the expression in inequality (A5) is independent of $\phi_{2,O}$. Hence, if the inequality is satisfied at the minimum value of $g\left(\phi_{2,O}\right)$, then it will be satisfied for all $\phi_{2,O}$. Taking logs and differentiating

$$\frac{\partial \ln g(\phi_{2,O})}{\partial \phi_{2,O}} = \frac{2\alpha[(1-\beta)(1-\alpha(1-\beta))-\beta(1-\phi_1)]}{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))(1-\phi_{2,O})+\beta(1-\phi_1)\phi_{2,O}\right]} - \frac{1}{\phi_{2,O}} + \frac{1}{1-\phi_{2,O}}.$$

Setting this equal to 0 yields a value of $\phi_{2,O}$:[28]

$$\phi_{2,O}^* = \frac{(1-\alpha(1-\beta))^2}{(1-\alpha(1-\beta))^2+(1-\alpha(1-\beta\phi_1))},$$

where $0 < \phi_{2,O}^* < 1$. Note that $g(\phi_{2,O}) \to \infty$ when $\phi_{2,O} \to 0$ as well as when $\phi_{2,O} \to 1$. In addition, we have $g''\left(\phi_{2,O}^*\right) > 0$. Thus, $g\left(\phi_{2,O}^*\right)$ is a local minimum. Since $0 < \phi_{2,O} < 1$ and $\phi_{2,O}^*$ is the only root within this range such that $g'\left(\phi_{2,O}^*\right) = 0$, it is also the global minimum for this range. By evaluating the function at this point and simplifying, we obtain

$$g\left(\phi_{2,O}^*\right) = 4(1-\alpha(1-\beta))^2(1-\alpha(1-\beta\phi_1)).$$

The final task is to establish that (A5) holds. This is satisfied if and only if

$$\begin{gathered} 4(1-\alpha(1-\beta))^2(1-\alpha(1-\beta\phi_1)) \\ > \\ (1-\alpha)(1-\alpha(1-\beta))[2(1-\alpha)(1-\phi_1)+(1-\alpha(1-\beta))\phi_1] \\ \Leftrightarrow \\ (1-\alpha(1-\beta))\left\{(1-\alpha)[(1-\alpha)(2+\phi_1)+\alpha\beta(4+3\phi_1)]+4\alpha^2\beta^2\phi_1\right\} > 0, \end{gathered}$$

which is true. Hence, $\frac{\partial \ln \Gamma(\beta,\phi_1)}{\partial \beta} > 0$.

In addition, evaluating Equation (A4) at $\beta = 0$ and $\beta = 1$, we obtain

$$\Gamma(0,\phi_1) = \left(\frac{1-\phi_{2,V}}{1-\phi_{2,O}}\right)^{\frac{\alpha}{1-\alpha}}\left(\frac{1-\alpha\left(1-\phi_{2,V}\right)}{1-\alpha\left(1-\phi_{2,O}\right)}\right) < 1, \text{ and}$$

$$\Gamma(1,\phi_1) = \left(\frac{(1-\phi_1)\phi_{2,V}}{(1-\phi_1)\phi_{2,O}}\right)^{\frac{\alpha}{1-\alpha}}\left(\frac{1-\alpha(1-\phi_1)\phi_{2,V}}{1-\alpha(1-\phi_1)\phi_{2,O}}\right) > 1,$$

where inequalities follow from $\phi_{2,V} > \phi_{2,O}$ and the fact that $(1-\alpha x)x^{\frac{\alpha}{1-\alpha}}$ is an increasing function of x for $\alpha \in (0,1)$ and $x \in (0,1)$. This completes part (i) of the proof.

(ii) Differentiating Equation (A4) with respect to ϕ_1, we obtain

$$\frac{\partial \Gamma(\beta,\phi_1)}{\partial \phi_1} = \frac{\alpha\beta[1-\alpha(1-\beta)]^2(\phi_{2,V}-\phi_{2,O})}{\left\{1-\alpha(1-\beta)-\alpha\left[(1-\beta)(1-\alpha(1-\beta))(1-\phi_{2,O})+\beta(1-\phi_1)\phi_{2,O}\right]\right\}^2}\Lambda > 0,$$

where $\Lambda = \left(\left(\frac{\phi_{2,V}}{\phi_{2,O}}\right)^{\beta}\left(\frac{1-\phi_{2,V}}{1-\phi_{2,O}}\right)^{1-\beta}\right)^{\frac{\alpha}{1-\alpha}}$.

Now, we have all the results to prove the proposition. The first part follows from part (i) of Lemma 3. Further, given that $\frac{\partial \Gamma(\beta,\phi_1)}{\partial \beta} > 0$ and $\Gamma(\widetilde{\beta}, \phi_1) = 1$, the second part follows part (ii) of Lemma 3. ■

Proof of Proposition 3. Taking the derivative of Equation (7) for $\phi_{2,k} = \phi_2$ and equating to zero gives us an expression that is proportional to the polynomial

$$\left.\begin{aligned} -[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]\phi_2^2 \\ -[\beta(1-\alpha(1-\beta))(2-\phi_1-\alpha(1-\beta))]\phi_2 \\ +\beta(1-\alpha(1-\beta))^2 \end{aligned}\right\} = 0.$$

Solving this expression for ϕ_2 gives us Equation (8). It is easy to see that, $\phi_2^{opt}(\beta) \in [0,1]$ with $\phi_2^{opt}(0) = 0$ and $\phi_2^{opt}(1) = 1$. It is also the only root in the relevant range of $\phi_2 \in (0,1)$.[29]

Notice from Equation (8) that whenever $(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1) = 0$, we have $\phi_2^{opt}(\beta) = \frac{0}{0}$. The value of $\beta \in (0,1)$ that makes $(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1) = 0$ is

$$\overset{\dagger}{\beta} = \frac{\sqrt{[2(1-\alpha)-\phi_1]^2 + 4\alpha(1-\alpha)} - [2(1-\alpha)-\phi_1]}{2\alpha}. \tag{A6}$$

It is easy to check that $\overset{\dagger}{\beta}$ is an inflection point and using L'Hôspital's rule, we can find $\phi_2^{opt}(\overset{\dagger}{\beta}) \to \overset{\dagger}{\beta}$.

(i) Define the term inside the square root in Equation (8) as

$$D = [\beta(2-\phi_1-\alpha(1-\beta))]^2 + 4\beta[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)].$$

D is positive since

$$\begin{aligned}&[\beta(2-\phi_1-\alpha(1-\beta))]^2 + 4\beta[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)] \\ &= \beta\left\{(1-\beta)\left[\beta(1-\beta)\alpha^2 + 4(1-\alpha) + 2\alpha\beta\phi_1\right] + \beta\phi_1^2\right\} > 0.\end{aligned}$$

Taking the derivative of Equation (8) with respect to β and simplifying, we obtain

$$\frac{\partial \phi_2^{opt}(\beta)}{\partial \beta} = \frac{E}{2\sqrt{D}[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]^2} > 0 \Leftrightarrow E > 0,$$

where E is given by

$$= \left\{\begin{matrix} \alpha\beta\begin{bmatrix}(1-\beta)(1-\alpha(1-\beta)) \\ -\beta(1-\phi_1)\end{bmatrix}\begin{bmatrix} 2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)] \\ -(1-\alpha(1-\beta))\left[\sqrt{D} - \beta(2-\phi_1-\alpha(1-\beta))\right]\end{bmatrix} \\ + \\ \begin{bmatrix}(1-\alpha)\left[1-\alpha(1-\beta)^2\right] \\ +\alpha\beta^2\phi_1\end{bmatrix}\begin{bmatrix} 2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)] \\ -(2-\phi_1-\alpha(1-\beta))\left[\sqrt{D} - \beta(2-\phi_1-\alpha(1-\beta))\right]\end{bmatrix}\end{matrix}\right\}$$

We will show that both lines of the above equation are non-negative and for a given β, at least one of them is positive except at $\beta = \overset{\dagger}{\beta}$, where $\overset{\dagger}{\beta}$ is given in Equation (A6).[30] Using the equation for $\phi_2^{opt}(\beta)$ given in Equation (8), we can rewrite the above equation as

$$= \left\{ \begin{array}{c} 2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]^2 \alpha\beta \left[1 - \phi_2^{opt}(\beta)\right] \\ + \\ 2\left[\begin{array}{c}(1-\beta)(1-\alpha(1-\beta)) \\ -\beta(1-\phi_1)\end{array}\right]\left[1 - \phi_2^{opt}(\beta) - \frac{(1-\phi_1)\phi_2^{opt}(\beta)}{1-\alpha(1-\beta)}\right]\left[\begin{array}{c}(1-\alpha)\left[1-\alpha(1-\beta)^2\right] \\ +\alpha\beta^2\phi_1\end{array}\right] \end{array} \right\}$$

Clearly, the first line of the above equation is positive except when $\beta = 0$ or $\beta = 1$, in which case it is zero. Now consider the second line. The last term is definitely positive. Therefore, it is sufficient to show the following.

Claim. $2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]\left[1 - \phi_2^{opt}(\beta) - \frac{(1-\phi_1)\phi_2^{opt}(\beta)}{1-\alpha(1-\beta)}\right] > 0.$

To show that this is indeed true, we rewrite this expression using Equation (8) as

$$\left\{ \begin{array}{c} 2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)] \\ -(1-\alpha(1-\beta))\left[\sqrt{D} - \beta(2-\phi_1-\alpha(1-\beta))\right] \\ -(1-\phi_1)\left[\sqrt{D} - \beta(2-\phi_1-\alpha(1-\beta))\right] \end{array} \right\} > 0,$$

$$\Leftrightarrow$$

$$\left[\begin{array}{c} 2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)] \\ +\beta(2-\phi_1-\alpha(1-\beta))^2 \end{array}\right] > (2-\phi_1-\alpha(1-\beta))\sqrt{D}.$$

Both sides are positive. If we take square of both sides and simplify, we obtain

$$\{2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]\}^2 > 0.$$

(ii) Taking the second derivative of Equation (7) with respect to ϕ_2 and evaluating at $\phi_2 = \phi_2^{opt}(\beta)$ given in Equation (8), we obtain a negative value, implying that $\phi_2^{opt}(\beta)$ is a local maximum. However, since ϕ_2 is restricted to be between 0 and 1, $\phi_2^{opt}(\beta)$ is also the global maximum within this range. It follows that for a given β, the revenue is increasing in ϕ_2 for $0 < \phi_2 < \phi_2^{opt}(\beta)$ and decreasing in ϕ_2 for $\phi_2^{opt}(\beta) < \phi_2 < 1$.

(iii) Taking the derivative of Equation (8) with respect to ϕ_1 and simplifying, we obtain

$$\frac{\partial \phi_2^{opt}(\beta)}{\partial \phi_1} = \frac{\beta[1-\alpha(1-\beta)]H}{2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]^2\sqrt{D}},$$

where H is given by

$$H = \left\{ \begin{array}{l} (1-\alpha(1-\beta))\left[\sqrt{D} - \beta(2-\phi_1-\alpha(1-\beta))\right] \\ \quad -2\beta[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]. \end{array} \right\}$$

In what follows, we will show that $H > 0$ for any $\beta \in (0,1)$ except at $\beta = \overset{\dagger}{\beta}$, where $\overset{\dagger}{\beta}$ is given in Equation (A6).[31] If this is the case, then it must be true that

$$(1-\alpha(1-\beta))\sqrt{D} > \beta \left\{ \begin{array}{l} 2[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)] \\ +(1-\alpha(1-\beta))[2-\phi_1-\alpha(1-\beta)] \end{array} . \right\}$$

Taking square of both sides of the above inequality and simplifying, we obtain

$$4\beta(1-\alpha)(1-\beta)[(1-\beta)(1-\alpha(1-\beta)) - \beta(1-\phi_1)]^2 > 0.$$

■

Proof of Proposition 5. Consider first the choice between the *S-S* and *S-N* options. Given that the upstream input is procured from the same country (South) under each option, the hold-up friction is identical and the same organizational mode will be chosen in the downstream stage. The comparison of any firm's variable profits between these two reveals that

$$\frac{\max_{k\in\{O,V\}} \pi_k^{S,S}(\varphi, Y, \beta) + \omega^N f_c}{\max_{k\in\{O,V\}} \pi_k^{S,N}(\varphi, Y, \beta) + \omega^N (f_c + f_s)} = \frac{\max_{k\in\{O,V\}} \Psi_k^{S,S}(\beta)}{\max_{k\in\{O,V\}} \Psi_k^{S,N}(\beta)} = \left(\frac{\omega^N}{\tau\omega^S}\right)^{\frac{\alpha(1-\beta)}{1-\alpha}}, \text{ for } k \in \{O, V\},$$

where π_k^{S,l_2} and Ψ_k^{S,l_2} for $k \in \{O,V\}$, $l_2 \in \{N,S\}$ are defined in Equations (9) and (10), respectively. Since total fixed costs are smaller under the *S-S* option (no coordination costs), for the *S-N* option to be at least as preferable as the *S-S* option, we must have

$$\max_{k\in\{O,V\}} \pi_k^{S,S}(\varphi, Y, \beta) \leqslant \max_{k\in\{O,V\}} \pi_k^{S,N}(\varphi, Y, \beta) \Rightarrow \frac{\omega^N}{\omega^S} < \tau. \tag{A7}$$

Next, consider the choice between the *N-N* and *S-N* options. Since the upstream input is procured from different countries under each option, the hold-up friction is also different and depending on the value of β (recall Proposition 4), the organizational mode chosen in the downstream stage *might* vary. The comparison of any firm's variable profits between the two reveals that

$$\frac{\max_{k_1\in\{O,V\}} \pi_{k_1}^{N,N}(\varphi, Y, \beta) + \omega^N f_c}{\max_{k_2\in\{O,V\}} \pi_{k_2}^{S,N}(\varphi, Y, \beta) + \omega^N (f_c + f_s)} = \frac{\max_{k_1\in\{O,V\}} \Psi_{k_1}^{N,N}(\beta)}{\max_{k_2\in\{O,V\}} \Psi_{k_2}^{S,N}(\beta)} = \Theta_{k_1^*,k_2^*}\left(\frac{\tau\omega^S}{\omega^N}\right)^{\frac{\alpha\beta}{1-\alpha}},$$

where $k_1^* = \arg\max_{k_1\in\{O,V\}} \pi_{k_1}^{N,N}(\varphi, Y, \beta)$, $k_2^* = \arg\max_{k_2\in\{O,V\}} \pi_{k_2}^{S,N}(\varphi, Y, \beta)$, and

$$\Theta_{k_1^*,k_2^*} = \frac{1-\alpha\left[(1-\beta)\left(1-\phi_{2,k_1^*}\right)+\frac{\beta}{1-\alpha(1-\beta)}(1-\phi_1^N)\phi_{2,k_1^*}\right]}{1-\alpha\left[(1-\beta)\left(1-\phi_{2,k_2^*}\right)+\frac{\beta}{1-\alpha(1-\beta)}(1-\phi_1^S)\phi_{2,k_2^*}\right]}\left[\left(\frac{1-\phi_1^N}{1-\phi_1^S}\frac{\phi_{2,k_1^*}}{\phi_{2,k_2^*}}\right)^{\beta}\left(\frac{1-\phi_{2,k_1^*}}{1-\phi_{2,k_2^*}}\right)^{1-\beta}\right]^{\frac{\alpha}{1-\alpha}} > 1. \quad \text{(A8)}$$

The inequality $\Theta_{k_1^*,k_2^*} > 1$ holds since the severity of hold-up friction is lower in the North, that is, $\phi_1^N < \phi_1^S$. This follows from Proposition 1. Also, total fixed costs are smaller under the *N*-*N* option (no coordination costs). These observations imply that if there were no wage difference and no transport costs, the *N*-*N* option would be better. Thus, for the *S*-*N* option to be at least as preferable as the *N* -*N* option, it is necessary to have

$$\max_{k_1\in\{O,V\}} \pi_{k_1}^{N,N}(\varphi, Y, \beta) \leqslant \max_{k_2\in\{O,V\}} \pi_{k_2}^{S,N}(\varphi, Y, \beta) \Rightarrow \frac{\omega^N}{\omega^S} > \tau. \quad \text{(A9)}$$

Obviously, inequalities in (A7) and (A9) cannot hold at the same time. Therefore, the *S*-*N* option cannot be optimal for any firm in equilibrium. ∎

APPENDIX B. THE ANALYSIS OF SECTION 3.1

Utilizing Equations (9) and (10), we can express the ratio of variable profits under each option as follows.

$$\frac{\pi_O^{N,N}(i,\varphi)+\omega^N f_c}{\pi_V^{S,S}(i,\varphi)+\omega^N f_c} = \frac{\Psi_O^{N,N}(\beta)}{\Psi_V^{S,S}(\beta)} = \Theta_{O,V}\left(\frac{\tau\omega^S}{\omega^N}\right)^{\frac{\alpha}{1-\alpha}}, \quad \text{(B.1)}$$

$$\frac{\pi_O^{N,S}(i,\varphi)+\omega^N (f_c+f_s)}{\pi_O^{N,N}(i,\varphi)+\omega^N f_c} = \frac{\Psi_O^{N,S}(\beta)}{\Psi_O^{N,N}(\beta)} = \left[\frac{1}{\tau^{1+\beta}}\left(\frac{\omega^N}{\omega^S}\right)^{1-\beta}\right]^{\frac{\alpha}{1-\alpha}}, \quad \text{(B.2)}$$

$$\frac{\pi_O^{N,S}(i,\varphi)+\omega^N (f_c+f_s)}{\pi_V^{S,S}(i,\varphi)+\omega^N f_c} = \frac{\Psi_O^{N,S}(\beta)}{\Psi_V^{S,S}(\beta)} = \Theta_{O,V}\left(\frac{\omega^S}{\tau\omega^N}\right)^{\frac{\alpha\beta}{1-\alpha}}, \quad \text{(B.3)}$$

where $\Theta_{O,V} > 1$ is defined in Equation (A8) for $k_1^* = O$ and $k_2^* = V$. Now we are ready to consider different scenarios that can occur in equilibrium. In each scenario, we first assume a particular ranking of operating profits and then derive the condition required for this profit ranking to hold.

Case 1. $\max\left\{\pi_V^{S,S}(i,\varphi), \pi_O^{N,S}(i,\varphi)\right\} < \pi_O^{N,N}(i,\varphi), \forall\varphi.$

The ranking of profits in this case also implies the following ranking of *variable* profits:

$$\max\{\pi_V^{S,S}(i,\varphi)+\omega^N f_c, \pi_O^{N,S}(i,\varphi)+\omega^N(f_c+f_s)\} < \pi_O^{N,N}(i,\varphi)+\omega^N f_c, \forall\varphi. \quad \text{(B.4)}$$

The inequality, $\pi_O^{N,S}(i,\varphi)+\omega^N(f_c+f_s) < \pi_O^{N,N}(i,\varphi)+\omega^N f_c$, must hold for any φ since the ratio of variable profits under the *N*-*S* option to those under the *N* -*N* option is independent of φ. Hence, if this ratio given in Equation (B.2) is larger than 1 for any φ, then it must be true for all φ, that is, $\pi_O^{N,N}(i,\varphi)+\omega^N f_c < \pi_O^{N,S}(i,\varphi)+\omega^N(f_c+f_s), \forall\varphi$. Yet, this violates the assumed profit ranking for *high-productivity firms* by implying $\pi_O^{N,S}(i,\varphi) > \pi_O^{N,N}(i,\varphi)$, for large enough φ. This is so since for high-productivity firms, higher variable profits translate into higher profits: they can produce more and higher variable profits would be more than enough to compensate higher fixed costs.

Next, dividing both sides of inequality (B.4) by $\pi_O^{N,N}(i,\varphi) + \omega^N f_c$, we obtain

$$\max\left\{\frac{\pi_V^{S,S}(i,\varphi) + \omega^N f_c}{\pi_O^{N,N}(i,\varphi) + \omega^N f_c}, \frac{\pi_O^{N,S}(i,\varphi) + \omega^N (f_c + f_s)}{\pi_O^{N,N}(i,\varphi) + \omega^N f_c}\right\} < 1, \forall\varphi.$$

Using Equations (B.1) and (B.2), the required condition for the ranking of profits is given by

$$\frac{\omega^N}{\omega^S} < \min\left\{\tau^{\frac{1+\beta}{1-\beta}}, \Theta_{O,V}^{\frac{1-\alpha}{\alpha}}\tau\right\}.$$

A sufficient condition for the above inequality to hold is $\frac{\omega^N}{\omega^S} < \tau$. Therefore, when transport costs are high, all firms prefer to procure both inputs from the North (the *N*-*N* option).

Case 2. $\max\left\{\pi_O^{N,N}(i,\varphi), \pi_O^{N,S}(i,\varphi)\right\} < \pi_V^{S,S}(i,\varphi), \forall\varphi$.

The profit ranking in this case also implies the following ranking of *variable* profits:

$$\max\{\pi_O^{N,N}(i,\varphi) + \omega^N f_c, \pi_O^{N,S}(i,\varphi) + \omega^N (f_c + f_s)\} < \pi_V^{S,S}(i,\varphi) + \omega^N f_c, \forall\varphi. \quad \text{(B.5)}$$

The inequality, $\pi_O^{N,S}(i,\varphi) + \omega^N(f_c + f_s) < \pi_V^{S,S}(i,\varphi) + \omega^N f_c$, must hold for any φ since the ratio of variable profits under the *N*-*S* option to those under the *S* -*S* option is independent of φ. Hence, if this ratio given in Equation (B.3) is larger than 1 for any φ, then it must be true for all φ, that is, $\pi_V^{S,S}(i,\varphi) + \omega^N f_c < \pi_O^{N,S}(i,\varphi) + \omega^N(f_c + f_s)$, $\forall\varphi$. However, as in Case 1, this violates the assumed profit ranking for *high-productivity firms* by implying $\pi_O^{N,S}(i,\varphi) > \pi_V^{S,S}(i,\varphi)$, for large enough φ.

Next, dividing both sides of inequality (B.5) by $\pi_V^{S,S}(i,\varphi) + \omega^N f_c$, we obtain

$$\max\left\{\frac{\pi_O^{N,N}(i,\varphi) + \omega^N f_c}{\pi_V^{S,S}(i,\varphi) + \omega^N f_c}, \frac{\pi_O^{N,S}(i,\varphi) + \omega^N (f_c + f_s)}{\pi_V^{S,S}(i,\varphi) + \omega^N f_c}\right\} < 1, \forall\varphi.$$

Using Equations (B.1) and (B.3), the required condition for the ranking of profits is given by

$$\max\left\{\frac{\Theta_{O,V}^{\frac{1-\alpha}{\alpha\beta}}}{\tau}, \Theta_{O,V}^{\frac{1-\alpha}{\alpha}}\tau\right\} < \frac{\omega^N}{\omega^S}.$$

Therefore, when the wage gap is large, all firms prefer to procure both inputs from the South (the *S*-*S* option).

Case 3. $\max\left\{\pi_O^{N,N}(i,\varphi), \pi_V^{S,S}(i,\varphi)\right\} < \pi_O^{N,S}(i,\varphi)$, for $\varphi \in [\underline{\varphi}_O^{N,S}, \infty)$.

The profit ranking in this case also implies the following ranking of *variable* profits:

$$\max\{\pi_O^{N,N}(i,\varphi) + \omega^N f_c, \pi_V^{S,S}(i,\varphi) + \omega^N f_c\} < \pi_O^{N,S}(i,\varphi) + \omega^N (f_c + f_s), \forall\varphi. \quad \text{(B.6)}$$

Setting $\varphi = \underline{\varphi}_O^{N,S}$ in inequality (B.6) and dividing both sides by $\pi_O^{N,S}(i, \underline{\varphi}_O^{N,S}) + \omega^N(f_c + f_s)$, we obtain

$$\max\left\{\frac{\pi_O^{N,N}(i,\underline{\varphi}_O^{N,S}) + \omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_O^{N,S}) + \omega^N(f_c+f_s)}, \frac{\pi_V^{S,S}(i,\underline{\varphi}_O^{N,S}) + \omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_O^{N,S}) + \omega^N(f_c+f_s)}\right\} < \frac{f_c}{f_c+f_s} < 1, \tag{B.7}$$

where the left-hand-side represents the ratio of variable profits for the lowest-productivity firm that is active and the right-hand-side represents the ratio of fixed costs. The above condition uses the fact that the lowest-productivity firm that survives makes zero profit (since $\max\{\pi_O^{N,N}(i, \underline{\varphi}_O^{N,S}), \pi_V^{S,S}(i, \underline{\varphi}_O^{N,S})\} < \pi_O^{N,S}(i, \underline{\varphi}_O^{N,S}) = 0$).[32] Moreover, since the ratio of variable profits is independent of φ, the inequality in (B.7) must hold for all φ. Then, using Equations (B.2) and (B.3), the required condition for the ranking of profits is given by

$$\left(\frac{f_c+f_s}{f_c}\right)^{\frac{1-\alpha}{\alpha(1-\beta)}} \tau^{\frac{1+\beta}{1-\beta}} < \frac{\omega^N}{\omega^S} < \left(\frac{\Theta_{O,V}}{\frac{f_c+f_s}{f_c}}\right)^{\frac{1-\alpha}{\alpha\beta}} \frac{1}{\tau}.$$

Therefore, when the wage gap is large enough to incur the trade costs but not that large to outweigh the more severe hold-up friction in the South, all firms procure the upstream input from the North and the downstream input from the South (the *N*-*S* option).

Case 4. $\pi_V^{S,S}(i,\varphi) < \pi_O^{N,N}(i,\varphi), \forall\varphi$ and $\pi_O^{N,S}(i,\varphi)\begin{cases} < \pi_O^{N,N}(i,\varphi) \text{ for } \varphi \in [\underline{\varphi}_O^{N,N}, \hat{\varphi}), \\ = \pi_O^{N,N}(i,\varphi) \text{ for } \varphi = \hat{\varphi}, \\ > \pi_O^{N,N}(i,\varphi) \text{ for } \varphi \in (\hat{\varphi}, \infty). \end{cases}$

The profit ranking in this case also implies the following ranking of variable profits:

$$\pi_V^{S,S}(i,\varphi) + \omega^N f_c < \pi_O^{N,N}(i,\varphi) + \omega^N f_c < \pi_O^{N,S}(i,\varphi) + \omega^N(f_c+f_s)\ , \forall\varphi. \tag{B.8}$$

The inequality, $\pi_O^{N,N}(i,\varphi) + \omega^N f_c < \pi_O^{N,S}(i,\varphi) + \omega^N(f_c+f_s)$, must hold for any φ since the ratio of variable profits under the *N*-*S* option to those under the *N*-*N* option is independent of φ. Hence, if this ratio given in Equation (B.2) is smaller than 1 for any φ, then it must be true for all φ, that is, $\pi_O^{N,S}(i,\varphi) + \omega^N(f_c+f_s) < \pi_O^{N,N}(i,\varphi) + \omega^N f_c, \forall\varphi$. Yet, this violates the assumed profit ranking for $\varphi \in (\hat{\varphi}, \infty)$ by implying $\pi_O^{N,S}(i,\varphi) < \pi_O^{N,N}(i,\varphi), \forall\varphi$.

Next, setting $\varphi = \underline{\varphi}_O^{N,N}$ in inequality (B.8) and dividing each side by $\pi_O^{N,S}(i, \underline{\varphi}_O^{N,N}) + \omega^N(f_c + f_s)$, we obtain

$$\max\left\{\frac{\pi_V^{S,S}(i,\underline{\varphi}_O^{N,N}) + \omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_O^{N,N}) + \omega^N(f_c+f_s)}, \frac{f_c}{f_c+f_s}\right\} < \frac{\pi_O^{N,N}(i,\underline{\varphi}_O^{N,N}) + \omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_O^{N,N}) + \omega^N(f_c+f_s)} < 1, \tag{B.9}$$

where we have the ratio of variable profits for the lowest-productivity firm that is active as well as the ratio of fixed costs. The inequality $\frac{f_c}{f_c+f_s} < \frac{\pi_O^{N,N}(i,\underline{\varphi}_O^{N,N})+\omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_O^{N,N})+\omega^N(f_c+f_s)}$ follows from the fact that the lowest-productivity firm that survives makes zero profit (since $\pi_O^{N,S}(i, \underline{\varphi}_O^{N,N}) < \pi_O^{N,N}(i, \underline{\varphi}_O^{N,N}) = 0$).

Moreover, since the ratio of variable profits is independent of φ, the inequality in (B.9) must hold for all φ. Then, using Equations (B.2) and (B.3), the required condition for the ranking of profits is given by

$$\tau^{\frac{1+\beta}{1-\beta}} < \frac{\omega^N}{\omega^S} < \min\left\{\Theta_{O,V}^{\frac{1-\alpha}{\alpha}}\tau, \left(\frac{f_c+f_s}{f_c}\right)^{\frac{1-\alpha}{\alpha(1-\beta)}}\tau^{\frac{1+\beta}{1-\beta}}\right\}.$$

In this case, the wage difference is large enough to cover transport costs but not large enough to overbalance the more severe hold-up friction in the South. At the same time, not all firms can cover coordination costs. Since high-productivity firms can afford coordination costs, they procure the upstream input from the North and the downstream input from the South. In contrast, low-productivity firms cannot afford coordination costs and thus procure both inputs from the North.

Case 5. $\pi_O^{N,N}(i,\varphi) < \pi_V^{S,S}(i,\varphi), \forall\varphi$ and $\pi_O^{N,S}(i,\varphi)\begin{cases} < \pi_V^{S,S}(i,\varphi) \text{ for } \varphi \in [\underline{\varphi}_V^{S,S}, \widetilde{\varphi}), \\ = \pi_V^{S,S}(i,\varphi) \text{ for } \varphi = \widetilde{\varphi}, \\ > \pi_V^{S,S}(i,\varphi) \text{ for } \varphi \in (\widetilde{\varphi}, \infty). \end{cases}$

The profit ranking in this case also implies the following ranking of variable profits:

$$\pi_O^{N,N}(i,\varphi) + \omega^N f_c < \pi_V^{S,S}(i,\varphi) + \omega^N f_c < \pi_O^{N,S}(i,\varphi) + \omega^N(f_c+f_s)\ , \forall\varphi. \tag{B.10}$$

The inequality, $\pi_V^{S,S}(i,\varphi) + \omega^N f_c < \pi_O^{N,S}(i,\varphi) + \omega^N(f_c+f_s)$, must hold for any φ since the ratio of variable profits under the *N*-*S* option to those under the *S*-*S* option is independent of φ. Hence, if this ratio given in Equation (B.3) is smaller than 1 for any φ, then it must be true for all φ, that is, $\pi_O^{N,S}(i,\varphi) + \omega^N(f_c+f_s) < \pi_V^{S,S}(i,\varphi) + \omega^N f_c, \forall\varphi$. Yet, this violates the assumed profit ranking for $\varphi \in (\widetilde{\varphi}, \infty)$ by implying $\pi_O^{N,S}(i,\varphi) < \pi_V^{S,S}(i,\varphi), \forall\varphi$.

Next, setting $\varphi = \underline{\varphi}_V^{S,S}$ in inequality (B.10) and dividing each side by $\pi_O^{N,S}(i,\underline{\varphi}_V^{S,S}) + \omega^N(f_c+f_s)$, we obtain

$$\max\left\{\frac{\pi_O^{N,N}(i,\underline{\varphi}_V^{S,S}) + \omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_V^{S,S}) + \omega^N(f_c+f_s)}, \frac{f_c}{f_c+f_s}\right\} < \frac{\pi_V^{S,S}(i,\underline{\varphi}_V^{S,S}) + \omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_V^{S,S}) + \omega^N(f_c+f_s)} < 1, \tag{B.11}$$

where we have the ratio of variable profits for the lowest-productivity firm that is active as well as the ratio of fixed costs. The inequality $\frac{f_c}{f_c+f_s} < \frac{\pi_V^{S,S}(i,\underline{\varphi}_V^{S,S})+\omega^N f_c}{\pi_O^{N,S}(i,\underline{\varphi}_V^{S,S})+\omega^N(f_c+f_s)}$ follows from the fact that the lowest-productivity firm that survives makes zero profit (since $\pi_O^{N,S}(i,\underline{\varphi}_V^{S,S}) < \pi_V^{S,S}(i,\underline{\varphi}_V^{S,S}) = 0$). Moreover, since the ratio of variable profits is independent of φ, the inequality in (B.11) must hold for all φ. Then, using equations (B.2) and (B.3), we can write the required condition for the ranking of profits under Case 5 as

$$\max\left\{\Theta_{O,V}^{\frac{1-\alpha}{\alpha}}\tau, \left(\frac{\Theta_{O,V}}{\frac{f_c+f_s}{f_c}}\right)^{\frac{1-\alpha}{\alpha\beta}}\frac{1}{\tau}\right\} < \frac{\omega^N}{\omega^S} < \frac{\Theta_{O,V}^{\frac{1-\alpha}{\alpha\beta}}}{\tau}.$$

In this case, while the wage difference is large enough to overcome transport costs and the more severe hold-up friction in the South, it is not that large to cover coordination costs for all firms. Therefore, low-productivity firms procure both inputs from the South. In contrast, high-productivity firms can afford coordination costs and thus procure the upstream input from the North and the downstream input from the South.