Bi-Sourcing in the Global Economy*

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Abstract

In organizing production, many firms conduct *bi-sourcing*, i.e., acquiring the same set of inputs by both buying from external suppliers (outsourcing) and carrying out in-house production (insourcing). We show that, by adopting the bi-sourcing strategy, firms can use the payoff from one supplier as a backup option in negotiating with the other supplier (the *cross-threat effect*). When firms conduct bi-sourcing in the global economy consisting of the high-waged North and low-waged South, they need to make the location choice for both insourcing and outsourcing. We find that the low wage in the South can encourage investment by component suppliers (*the cost effect).* However, firms may achieve a better cross-threat effect by relocating overly strong component supplier from the cost-advantageous South to the cost-disadvantageous North (*the balancing effect*). The optimal bi-sourcing strategy is determined by the interplay of the cost effect and the balancing effect.

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1 Introduction

In organizing production, a firm needs to decide whether to produce intermediate inputs internally (insourcing) or purchase them from external suppliers (outsourcing). While much emphasis has been placed on the growth of outsourcing in business magazines and newspapers, an emerging interesting arrangement is worth investigating. Many firms are acquiring the same set of inputs by both purchasing from external suppliers and carrying out in-house production. We call it *bi-sourcing* as it contains both outsourcing and insourcing.

Mattel provides an example of bi-sourcing. "Mattel made most of its own die-casting molds at a facility in Malaysia, but also outsourced them to firms in Hong Kong" (Johnson, 2007). Another example is the long-term maintenance of U.S. airlines. It is reported that half of U.S. airlines' heavy-overhaul work is conducted by in-house mechanics, while the other half is now performed by outside vendors in the U.S. and overseas, which is a big surge from less than a third in 1990 (Carey and Frangos, 2005).

In recent years, with IT services gaining importance, business corporations have increasingly adopted a set of internal and external service providers in the global economy (Cohen and Young, 2006). For example, *DuPont* has created what it calls a global IT alliance that blends services from more than ten service providers and *DuPont*'s own internal resources to meet the demands of the business. Similarly, the accounts-payable process of *GMS*, a global manufacturing and service firm, has in fifteen years moved from being highly centralized and internal, to globally decentralized and internal, to globally decentralized with a mix of internal and external resources.

Why do companies conduct bi-sourcing in the global economy? To answer this question, we first look at how bi-sourcing may perform better than both insourcing and outsourcing in a closed-economy model.

By conducting the bi-sourcing strategy, the firm deals with both an internal supplier and an external supplier. In negotiating with one supplier, the firm can use its payoff from the other supplier as a backup option (called the *cross-threat*), thereby having a higher incentive to invest than in the case of either insourcing or outsourcing. Meanwhile, when negotiating sequentially with the two suppliers, it is optimal for the firm to bargain first with the internal supplier and then the external supplier. As the external supplier makes component investment later than the internal supplier, the incentive to invest under bi-sourcing is as strong as that under outsourcing, which in turn is stronger than that under insourcing according to the property rights theory of the firm (Grossman and Hart, 1986). Consequently, a bi-sourcing strategy induces higher levels of investment and thus production efficiency than does either insourcing or outsourcing.

The choice of organizational forms depends on the organizational fixed costs as well as production efficiency. Both insourcing and outsourcing involve significant fixed costs. As bi-sourcing contains both insourcing and outsourcing, it is expected to have the highest fixed costs among the three organizational forms. Our analysis thus predicts that only those firms with the highest productivity will adopt bi-sourcing because their revenues are large enough to cover the extra organizational fixed costs.

Our model is then extended to the global-economy setting that consists of the high-waged North and the low-waged South. In addition to deciding on the organizational form, the firm also chooses the location of component suppliers. A firm with its headquarters in the North can locate both the internal and external component suppliers in the North or in the South. Alternatively, the firm can choose to locate internal and external suppliers separately with one in the North and the other in the South.

What drives the location choice of the internal and external component suppliers? We identify two factors. One is the *cost effect*. With the lower wage in the South as compared with the North, the suppliers (both external and internal) have higher incentives to invest, which enhances production efficiency. The other factor is the *balancing effect*. The beauty of bi-sourcing lies in that the firm can use the *cross-threat* to increase its own incentive to invest. To maximize the effectiveness of the cross-threat, however, the firm does not want either component maker to be too strong relative to the other one. In particular, it could be optimal for the firm to locate the overly strong (or weak) supplier in the cost-disadvantageous North (or the cost-advantageous South) to achieve a better balancing effect between the two suppliers.

The optimal bi-sourcing strategy is determined by the interplay of the cost effect and the balancing effect. In many cases we have considered, locating both internal and external suppliers in the South yields the highest production efficiency among all possible patterns of the bi-sourcing strategy. When one supplier is too strong relative to the other, the balancing effect dominates the cost effect, and it is then optimal to have the stronger supplier in the North and the weaker supplier in the South.

Our paper is related to a growing literature on the choice between insourcing and outsourcing in the global economy. These studies make use of recent advances in the economic theory of organizations such as transaction costs economics (TCE) and property-rights theory (PRT)[1] to explain the

[1]See Williamson (1975, 1985) for the TCE, and Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995) for the PRT.

growing vertical disintegration of production in the global economy.[2] Our paper is most closely related to Antràs and Helpman (2004). They integrate the property-rights theory of firm and the heterogeneity of firm productivity (Melitz (2003)) into a general equilibrium model of international trade to study the choice between insourcing and outsourcing in the global economy. However, in their paper as well as related papers in this strand of literature, outsourcing and insourcing are two distinct and separate modes of acquiring intermediate inputs. In contrast, we focus on the emerging pattern of bi-sourcing and its strategies in the global economy.

Our paper is also associated with the industrial organization literature on second sourcing or dual sourcing.[3] Some of these papers study the benefits for a buyer to use multiple outside or inside sellers when there is uncertainty about production costs. Others investigate the incentives for a seller to license its technology to its rivals as a credible commitment to high-quality/low-price supply in face of uncertain market demand. With a few exceptions,[4] however, the industrial organization literature does not look into the impacts of dual-sourcing on the incentives for R&D or investment, which is the focus of our paper. We use an incomplete-contracts framework to study how various sourcing strategies affect the incentives to invest.

The rest of the paper is organized as follows. Section 2 lays out the basic model. The benchmark case of a closed economy model is analyzed in Section 3, and it is then extended to the case of global economy in Section 4. Section 5 concludes the paper.

2 Basic Model

We extend the framework of Antràs and Helpman (2004) to study bi-sourcing. Consider an economy consisting of two sectors: a homogeneous good (X) produced with the constant returns to scale technology and a continuum of differentiated goods (Y) produced with the increasing returns to scale technology. There is a unit measure of consumers with the preference of the representative consumer given by

[2] The papers include McLaren (1999), Grossman and Helpman (2002, 2004, 2005), Puga and Trefler (2002), Antràs (2003), Marin and Verdier (2003), Antràs and Helpman (2004), Antràs et al. (2005), Grossman et al. (2005), etc. See Antràs (2005), Spencer (2005), and Helpman (2006) for literature review.

[3] See, for example, Anton and Yao (1987), Shepard (1987), Farrell and Gallini (1988), and Kerschbamer and Tournas (2003).

[4] See Riordan and Sappington (1989) and Dick (1992).

$$U = X^{1-\mu}Y^{\mu}, Y = \left[\int_{\omega\in\Omega} y(\omega)^{\alpha} d\omega\right]^{1/\alpha}, \tag{1}$$

where μ represents the weight that the consumers put on the differentiated goods, X is the consumption of the homogeneous good, $y(\omega)$ is the consumption of variety ω of the differentiated goods Y, Y is the index of aggregate consumption of differentiated goods and the set Ω represents the mass of those goods. The elasticity of substitution between any two differentiated goods is $\sigma \equiv 1/(1-\alpha) > 1$. The consumer preference of equation (1) leads to an inverse demand function for each variety ω of the differentiated goods:

$$p(\omega) = \frac{\mu I}{Y}\left(\frac{y(\omega)}{Y}\right)^{\alpha-1} \tag{2}$$

where $p(\omega)$ is the price of variety ω and I denotes the consumers' total expenditure.

To produce any variety of the differentiated goods, two variety-specific inputs, $h(\omega)$ and $m(\omega)$, are jointly required, which are referred to as headquarters service and manufactured component respectively. Correspondingly there are two kinds of producers: final good producers (denoted by H), who provide the variety-specific headquarters services ($h(\omega)$), and component makers (denoted by M), who supply the variety-specific manufactured components ($m(\omega)$). Each unit of $h(\omega)$ and $m(\omega)$ requires one unit of labor, the wage rate of which is assumed to be a constant w in the closed-economy setting (Section 3) and will be relaxed in the global-economy setting (Section 4). Every final good producer organizes the production process, combining the headquarters service and the manufactured component in the fashion of the Cobb-Douglas function to make the differentiated good

$$y(\omega) = \theta\left[\frac{h(\omega)}{\eta}\right]^{\eta}\left[\frac{m(\omega)}{1-\eta}\right]^{1-\eta}, \ 0 < \eta < 1, \tag{3}$$

where θ is a firm-specific productivity parameter, and η is a sector-specific parameter regarding the intensity of headquarters service in the production of differentiated good ω with a larger η indicating a higher intensity of headquarters service. Combined with (2), it yields the revenue

$$R = \mu I Y^{-\alpha}\theta^{\alpha}\left[\frac{h}{\eta}\right]^{\alpha\eta}\left[\frac{m}{1-\eta}\right]^{\alpha(1-\eta)} \tag{4}$$

where the variety parameter ω is left out hereon as all the cases are symmetric.

For simplicity, it is assumed that the final good producer owns the assets for the production of headquarters service (henceforth, the final good producer and the headquarters are used interchangeably).[5] But it needs to make an organizational choice for the supply of the manufactured component. The final good producer can set up a subsidiary making the component in-house (called insourcing and denoted by I), or contract with an external supplier for the manufactured component (called outsourcing and denoted by O), or both (called bi-sourcing and denoted by B). In the global-economy setting (Section 4), there is an additional location-choice decision between the high-waged North and the low-waged South for the component manufacturing.

The time line of the model is as follows. At time 0, the final good producer makes the organizational and location choices. *Ex ante* investments in input production, including manufactured component (m) and headquarters service (h), are made at date 1. At date 2, m is supplied and combined with h to make the final product.

As in Antràs and Helpman (2004), we consider a setting of incomplete contracts. It is assumed that the precise nature of the required inputs is difficult to specify *ex ante*, and that, once revealed *ex post*, the nature of the required inputs is still not verifiable by a third party. It is further assumed that the *ex ante* investments for input production are not contractible and neither is the sales revenue. As a result, the final good producer H and component supplier M bargain over the surplus value from trade at date 2 after they make their own investments at date 1. Following the property-rights theory of the firm (Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995)), we assume that the bargaining takes place in both outsourcing and insourcing and thus in all the three organizational forms we examine. Nevertheless, as ownership over the assets for component manufacturing confers the residual rights of control, the effective bargaining powers between H and M vary from outsourcing to insourcing and bi-sourcing, which will be elaborated further in Section 3.

[5] In a more general setting, it could be optimal for the component manufacturer to own the assets for the production of headquarters services, especially when component manufacturing is very important relative to headquarters service. We would like to thank an anonymous referee for pointing out this type of insourcing, which is alternative to the other type of insourcing – the final good producer owning the assets for component manufacturing. In this paper, as in Antras and Helpman (2004), we implicitly assume that the headquarters service is sufficiently important so that it is optimal (or not optimal) for the final good producers (or the component manufacturers) to own the assets for the production of headquarters services. What remains to be investigated is whether the final good producers should own the assets for component manufacturing or not.

3 Bi-sourcing in the Closed Economy

In this section, we analyze the equilibrium in a closed-economy setting where the production of both components and final goods is carried out in one country. The decision to be made concerns only with the organizational choice that the headquarters choose to have insourcing, or outsourcing, or bi-sourcing for the supply of components.

The three organizational forms differ in their fixed organizational costs. We assume that the fixed organizational costs of insourcing (denoted by f_I) are higher than those of outsourcing (denoted by f_O) (for rationales please read Antràs and Helpman (2004)), and that bi-sourcing has the highest fixed organizational costs (denoted by f_B) for the fixed costs associated with both insourcing and outsourcing are involved. That is:[6]

$$f_B > f_I > f_O. \tag{5}$$

The main difference among the three organizational forms, however, lies in their impacts on the incentives for investment in input production and consequently the size of the trading surplus, which we turn to in the following subsections.

3.1 Single Sourcing

In single sourcing, the final good producer H either signs a contract with M to purchase the variety-specific component (i.e., outsourcing) or integrates with M to produce the component in-house (i.e., insourcing).

As shown by Grossman and Hart (1986) and Antràs and Helpman (2004), even if the final good producer H has the same bargaining power with the internal and external suppliers, it can obtain greater *effective* bargaining power vis-a-vis the internal supplier as compared with the external supplier. This is because under insourcing the final good producer owns the assets for component manufacturing and has better outside options. For simplicity, we assume that the *ex post* bargaining process follows a generalized Nash bargaining game where H has higher effective bargaining power in insourcing (denoted by $\beta_I \in (0,1)$) than in outsourcing (denoted by $\beta_O \in (0,1)$), i.e., $\beta_I > \beta_O$.[7]

Assume further that the *ex post* bargaining is efficient. Then H and M will reach an agreement on the division of surplus R at date 2. H gets $\beta_k R$

[6]For convenience, the fixed costs (f_I, f_O and f_B) are expressed in terms of units of labor. We can obtain the monetary value of fixed costs by multiplying them by wage rate w.

[7]Henceforth, effective bargaining power is simply referred to as bargaining power.

and M gets $(1-\beta_k)R$, where $\beta_k = \beta_O$ in the case of outsourcing (i.e., $k = O$) and $\beta_k = \beta_I$ in the case of insourcing (i.e., $k = I$). At date 1, M and H choose m and h to maximize $(1-\beta_k)R - wm$ and $\beta_k R - wh$ respectively. The total payoff of the two parties under single sourcing can be shown as follows:

$$\pi_k = \phi_k(\mu I)^{\frac{1}{1-\alpha}} Y^{-\frac{\alpha}{1-\alpha}} \theta^{\frac{\alpha}{1-\alpha}} - wf_k \tag{6}$$

where

$$\phi_k = \alpha^{\frac{\alpha}{1-\alpha}} w^{-\frac{\alpha}{1-\alpha}} (\beta_k)^{\frac{\alpha}{1-\alpha}\eta} (1-\beta_k)^{\frac{\alpha}{1-\alpha}(1-\eta)} [1-\alpha(\beta_k\eta + (1-\beta_k)(1-\eta))].$$

To save space, derivation of key equations and proof of all Lemmas and Propositions are contained in the Appendix (available upon request).

3.2 Bi-sourcing

The scenario of bi-sourcing is more complicated as the final good producer H obtains the manufactured component from two suppliers — one internal (denoted by M_1) and one external (denoted by M_2). The investments made by the internal and external suppliers are denoted by m_1 and m_2, respectively.

We define some notation as follows:

$$\begin{aligned} R &= \mu I Y^{-\alpha}\theta^{\alpha}[\tfrac{h}{\eta}]^{\alpha\eta}[\tfrac{m_1+m_2}{1-\eta}]^{\alpha(1-\eta)}, \\ R_1 &= \mu I Y^{-\alpha}\theta^{\alpha}[\tfrac{h}{\eta}]^{\alpha\eta}[\tfrac{m_1}{1-\eta}]^{\alpha(1-\eta)}, \\ R_2 &= \mu I Y^{-\alpha}\theta^{\alpha}[\tfrac{h}{\eta}]^{\alpha\eta}[\tfrac{m_2}{1-\eta}]^{\alpha(1-\eta)}. \end{aligned} \tag{7}$$

Expressions (7) denote the respective total revenues when both M_1 and M_2 supply the component (R), only M_1 supplies the component (R_1) and only M_2 provides the component (R_2). In negotiations, the total revenue available to the three parties amounts to R, from which H needs to pay P_1 to M_1 and P_2 to M_2 respectively.

We consider a sequential bargaining process among the three parties. After deciding to adopt bi-sourcing but before all three parties make any investment, the final good producer H may announce whether to negotiate with the internal supplier M_1 first and then the external supplier M_2 or the other way around.[8]

[8] There is a large literature on multi-party bargaining problems, focusing on the Nash bargaining solution and the strategic bargaining approaches that have unique equilibrium and implement the Nash bargaining solution (Jun, 1987; Chae and Yang, 1988, 1994; Krishna and Serrano, 1996). The three-party bargaining problem studied by Marx and Shaffer (2004) is probably the closest to the bargaining problem of bi-sourcing. They use strategic bargaining approach to analyze how a buyer bargains sequentially with two sell-

Consider the case where the headquarters H first bargains with the internal supplier M_1 and then with the external supplier M_2. Using the backward induction approach, we first analyze the second stage — the negotiation between H and M_2 — given that H has successfully concluded its negotiation with M_1, in which H pays P_1 to M_1 and retains $R_1 - P_1$ for itself.

In negotiating with M_2, H expects to get $R - P_1 - P_2$ if the transaction is carried out but obtains the disagreement option value $R_1 - P_1$ if negotiation breaks down, whereas M_2 obtains a transfer payment P_2 from H if the transaction is conducted and zero otherwise. Given that bargaining is efficient, H and M_2 reach an agreement with M_2 receiving

$$P_2^* = (1 - \beta_O)(R - R_1) \tag{8}$$

and H having $R_1 - P_1 + \beta_O(R - R_1)$.

Next we analyze the first stage — the negotiation between H and M_1. If there is trade with M_1, H secures $R - P_1 - P_2^*$; otherwise, H is able to at least gain what he can reap from the scenario of outsourcing, i.e., $\beta_O R_2$.[9] Similarly, M_1 gets P_1 when the transaction is carried out, and zero otherwise. Thus the Nash bargaining yields a division of the surplus from trade: $R - P_2^* - \beta_O R_2 = R_1 + \beta_O(R - R_1) - \beta_O R_2$ between H and M_1, with M_1 receiving

$$P_1^* = (1 - \beta_I)(R_1 + \beta_O(R - R_1) - \beta_O R_2) \tag{9}$$

and H obtaining $R - P_1^* - P_2^*$.

Note that the final good producer has the outside option of $R_1 - P_1$ when bargaining with the external supplier and the outside option of $\beta_O R_2$ when bargaining with the internal supplier. In comparison with the zero outside option value under single sourcing, these outside options increase the share of payoff to the final good producer. Henceforth, the impacts of these increased outside options are referred to as the *cross-threat* effects.

Under the assumption of perfect foresight, H chooses h to maximize $R - P_1^* - P_2^* - wh$, M_1 chooses m_1 to maximize $P_1^* - wm_1$, and M_2 chooses m_2

ers, and find that the result is the same as that under the Nash bargaining solution. We thus use the Nash bargaining solution to study the bargaining between the headquarters and the two suppliers, with the headquarters first bargaining with one supplier and then with the other supplier. This framework allows us to have easy comparison with the bargaining solutions of single insourcing and single outsourcing, and it also offers a tractable way of examining how the headquarters' bargaining with one supplier is affected by its bargaining with the other supplier.

[9] $R - R_1$ collapses into R_2 when the internal supplier M_1 does not supply any manufactured component, i.e., $m_1 = 0$, and consequently $R_1 - P_1 + \beta(R - R_1)$ collapses into βR_2.

to maximize $P_2^* - wm_2$. Solving these optimization problems, we obtain the total payoff in this scenario of bi-sourcing as

$$\pi_B = \phi_B(\mu I)^{\frac{1}{1-\alpha}} Y^{-\frac{\alpha}{1-\alpha}} \theta^{\frac{\alpha}{1-\alpha}} - wf_B \tag{10}$$

where

$$\begin{aligned}
\phi_B &= \alpha^{\frac{\alpha}{1-\alpha}} T^{\frac{\alpha}{1-\alpha}\eta} (1-\beta_O)^{\frac{\alpha}{1-\alpha}(1-\eta)} w^{\frac{-\alpha}{1-\alpha}} [1 - \alpha(\eta T + (1-\eta)(1-\beta_O))], \\
T\left(\frac{1}{A}\right) &= \beta_O\beta_I + (1-\beta_O)\beta_I \left(\frac{1}{A}\right)^{\alpha(1-\eta)} + \beta_O(1-\beta_I)\left(1-\frac{1}{A}\right)^{\alpha(1-\eta)}, \\
A &= \left[\frac{1+\beta_O\beta_I - 2\beta_O}{(1-\beta_O)(1-\beta_I)}\right]^{\frac{1}{1-\alpha(1-\eta)}} > 1.
\end{aligned}$$

Using the same backward induction approach, we can analyze the case where the headquarters H first negotiates with the external supplier M_2 and then the internal supplier M_1. But we can show that, under this sequence of negotiation, bi-sourcing will collapse into single outsourcing. Specifically,

Lemma 1 *If the headquarters H negotiates with the external supplier M_2 before the internal supplier M_1, the bi-sourcing scenario is reduced to the single outsourcing case.*

The intuition of Lemma 1 rests upon the following two effects. (i) From the property rights theory of the firm, we know that the internal supplier has a lower incentive to invest than does the external supplier, because it does not own the assets for component manufacturing (called *ownership effect*). Mathematically, for any given investment level, the marginal return from investment of the internal supplier is always lower than that of the external supplier (i.e. $MR_1 < MR_2$). (ii) For each supplier, the marginal return from investment is decreasing (i.e. $MR_i(x+y) < MR_i(x)$, for any $x, y > 0$) (called *sequence effect*). When negotiated later, the internal supplier makes investment after the external supplier does. In this case, both the sequence effect and the ownership effect work against the internal supplier, with its marginal return from investment always lower than the wage rate, i.e., $MR_1(m_2 + m_1) < MR_1(m_2) < MR_2(m_2) = w$. Here the first inequality comes from the sequence effect, the second inequality reflects the ownership effect, and the last equation is the first-order condition of the external supplier's program in making investment choice. Hence the internal supplier would not make any investment and the case collapses to single outsourcing. Notice the same problem does not occur when the external supplier is negotiated later, because in that case the external supplier's disadvantage in the sequence effect could be overcome by its advantage in the ownership effect.

It is clear from the above discussion that, in our setting, dual outsourcing will be reduced to single outsourcing, because the two external suppliers have the same ownership effect but the sequence effect works against the second external supplier. Similarly, dual insourcing will be reduced to single insourcing. These results imply that, while dual insourcing or outsourcing may have impacts on production cost or consumer demand as studied in the industrial organization literature, neither arrangement has any different effect on the incentives for investment from those of single insourcing or outsourcing in the framework of incomplete contracts. The focus of this paper, however, is about the impacts of sourcing strategies on the incentives for investment. Bi-sourcing has been shown to impact the incentives for investment differently from single insourcing or single outsourcing.

3.3 Choice of Organizational Form

With *ex ante* lump-sum transfers, the headquarters will pick the organization with the highest total payoff. It is clear from equations (6) and (10) that the total payoff (π_i) in any scenario is a linear function of $(\mu I)^{\frac{1}{1-\alpha}} Y^{-\frac{\alpha}{1-\alpha}} \theta^{\frac{\alpha}{1-\alpha}}$, and it just differs in the slope and the intercept term across the scenarios. The intercept terms are the negative of the fixed organization costs, and their comparison is straightforward. So we will focus on the comparison of the slope term, ϕ_i, which will be referred to as *production efficiency* in the rest of this paper. Production efficiency is in turn determined by the equilibrium investment levels (m for components and h for headquarters service).

We will first show that, under fairly general conditions, bi-sourcing has higher production efficiency than do both insourcing and outsourcing.

Lemma 2 *So long as β_I is not sufficient large, the equilibrium investment levels under bi-sourcing are higher than those under both insourcing and outsourcing.*

>From the work of Grossman and Hart (1986) and Antràs and Helpman (2004), we know the headquarters has a higher incentive to invest under insourcing than under outsourcing. It is because the headquarters has higher effective bargaining power under insourcing than under outsourcing. As shown in Figure 1, the optimal reaction curve of the headquarters under insourcing (denoted by h_I^*) lies above that of outsourcing (denoted by h_O^*). Under bi-sourcing, the headquarters bargains with both the internal and external suppliers, and as a result its "combined" effective bargaining power should presumably be between that of insourcing and that of outsourcing. However, the headquarters can make use of the *cross-threat* in bargaining

with both the internal and external suppliers — i.e., use its payoff from one supplier as its outside option in bargaining with the other supplier — to enhance its incentive to invest. It is shown in the Appendix (available upon request) that so long as β_I is not sufficiently large, the cross-threat effect dominates so that the headquarters has a higher incentive to invest under bi-sourcing scenario than she does in insourcing. Thus, the optimal reaction curve of the headquarters under bi-sourcing (denoted by h_B^*) is above that of insourcing (denoted by h_I^*), as illustrated in Figure 1.

Meanwhile, as shown in Lemma 1, under bi-sourcing, it is optimal for the headquarters to bargain with the internal supplier first and then with the external supplier. The component investment can be viewed as the internal supplier first making investment m_1, and then the external supplier making investment m_2. As the external supplier is the later one of the two suppliers making the component investment, the optimal reaction curve for component investment under bi-sourcing (denoted by m_B^*) should be the same as that of outsourcing (denoted by m_O^*), as shown in Figure 1. Furthermore, based on the work of Grossman and Hart (1986) and Antràs and Helpman (2004), the optimal reaction curve for component investment under outsourcing is located to the right of that under insourcing (denoted by m_I^*), because the external supplier owns the assets and thus has more incentives to invest.

Taken together, the equilibrium point under bi-sourcing (represented by point B in Figure 1) is determined by the intersection of the optimal reaction curve of the headquarters and that of the supplier, and it is located to the northeast of the equilibrium points under single sourcings (denoted by O and I for outsourcing and insourcing, respectively). As investment levels under any sourcing strategy are below the first-best ones, greater investment levels imply higher production efficiency. It follows that the investments under bi-sourcing are higher than those under both insourcing and outsourcing, and so are the production efficiency.

The comparison of insourcing and outsourcing has been analyzed by Antràs and Helpman (2004). In a headquarters-intensive industry, the headquarters' investment is more important to the production process than is the component supplier's. Hence it can be shown that the production efficiency is higher under insourcing than under outsourcing. In a component-intensive industry, the component supplier plays a more important role in the cooperative relationship than the headquarters does, and hence production efficiency is higher under outsourcing than under insourcing. Thus, in combination with Lemma 2, we have the following lemma.

Lemma 3. *In a headquarters-intensive industry, production efficiency is the highest under bi-sourcing, followed by insourcing and then outsourcing.*

In a component-intensive industry, production efficiency is the highest under bi-sourcing, followed by outsourcing and then insourcing.

The three sourcing strategies also differ in fixed costs as detailed in equation (5). Together we have:

Proposition 1 *(1) In a headquarters-intensive industry, the firms with high productivity adopt the bi-sourcing strategy, the firms with low productivity adopt the outsourcing strategy and those intermediate firms choose the insourcing strategy. (2) In a component-intensive industry, the firms with high productivity adopt the bi-sourcing strategy while those with low productivity adopt the outsourcing strategy.*[10]

4 Bi-sourcing in the Global Economy

Now we turn to the open-economy case where there are the high-waged North and the low-waged South. Let w^N denote the wage rate in the North and w^S denote that in the South where $t \equiv \frac{w^N}{w^S} > 1$. For simplicity, it is assumed that the headquarters service (h) can only be produced in the North, whereas the manufactured component (m) can be produced either in the North or in the South. As single sourcing strategies have been analyzed by Antràs and Helpman (2004), we will only examine bi-sourcing strategies in the global economy. There are four types of bi-sourcing: *(i)* bi-sourcing in the North (denoted by NN), *(ii)* bi-sourcing in the South (denoted by SS), *(iii)* bi-sourcing with insourcing in the North and outsourcing in the South (denoted by NS), and *(iv)* bi-sourcing with insourcing in the South and outsourcing in the North (denoted by SN).

As in the closed-economy setting, the choice among the four bi-sourcing arrangements depends on the interplay between the organizational fixed cost and the production efficiency. However, we know that the organizational fixed costs have predictable impacts on the organizational choice (the higher-productivity firms versus lower-productivity firms arguments). Thus, in this section we would like to focus on the production efficiency (denoted by ϕ) as the key criterion for determining the optimal bi-sourcing strategy. Indeed, the insights from the property-rights theory of the firm are about the impacts of organizational choice on the incentive to invest and production efficiency. It is straightforward to show that production efficiency under bi-sourcing in

[10] In this case, insourcing is always dominated by outsourcing because of its lower production efficiency and higher fixed costs.

the North (NN) is strictly lower than that under bi-sourcing in the South (SS) due to the higher wage in the North. Thus, we will only compare SN, NS, and SS in the following analysis.

4.1 Cost Effect and Balancing Effect

Following the same line of analysis as in Section 3.2, we derive the production efficiency (ϕ) under SN, NS, and SS as follows.[11]

$$\begin{cases} \phi^{SS} = T\left(x^{SS}\right)^{\frac{\alpha}{1-\alpha}\eta}\left[t(1-\beta_O)\right]^{\frac{\alpha}{1-\alpha}(1-\eta)}\left(\frac{\alpha}{w^N}\right)^{\frac{\alpha}{1-\alpha}}\left[1-\alpha\left(\eta T\left(x^{SS}\right)+(1-\eta)(1-\beta_O)\right)\right] \\ \phi^{NS} = T(x^{NS})^{\frac{\alpha}{1-\alpha}\eta}[t(1-\beta_O)]^{\frac{\alpha}{1-\alpha}(1-\eta)}\left(\frac{\alpha}{w^N}\right)^{\frac{\alpha}{1-\alpha}}\left[1-\alpha\left(\eta T(x^{NS})+(1-\eta)(1-\beta_O)\left(\frac{t+x^{NS}-1}{x^{NS}}\right)\right)\right] \\ \phi^{SN} = T(x^{SN})^{\frac{\alpha}{1-\alpha}\eta}(1-\beta_O)^{\frac{\alpha}{1-\alpha}(1-\eta)}\left(\frac{\alpha}{w^N}\right)^{\frac{\alpha}{1-\alpha}}\left[1-\alpha\left(\eta T(x^{SN})+(1-\eta)(1-\beta_O)\frac{tx^{SN}-t+1}{tx^{SN}}\right)\right] \end{cases} \tag{11}$$

where[12]

$$\begin{cases} T(x^i) = \beta_O\beta_I + (1-\beta_O)\beta_I\left(x^i\right)^{\alpha(1-\eta)} + \beta_O(1-\beta_I)\left(1-x^i\right)^{\alpha(1-\eta)}, i \in \{SS, NS, SN\} \\ x^{SS} = \left[\frac{(1-\beta_O)(1-\beta_I)}{1+\beta_O\beta_I-2\beta_O}\right]^{\frac{1}{1-\alpha(1-\eta)}} \\ x^{NS} = \left[\frac{(1-\beta_O)(1-\beta_I)}{t(1-\beta_O)-\beta_O(1-\beta_I)}\right]^{\frac{1}{1-\alpha(1-\eta)}} \\ x^{SN} = \left[\frac{t(1-\beta_O)(1-\beta_I)}{(1-\beta_O)-t\beta_O(1-\beta_I)}\right]^{\frac{1}{1-\alpha(1-\eta)}} \end{cases}$$

Similar to what is shown in the proof of Lemma 2 in the Appendix (available upon request), $T(x^i)$ is the slope of the headquarters' optimal reaction curve under bi-sourcing, and thus it represents the headquarters' incentive to invest. x^i is the share of manufactured component made by the internal supplier.[13]

As in our analysis of bi-sourcing in the closed economy (Section 3.3), the production efficiency (ϕ^i) is determined by the equilibrium investment levels, which are an outcome of the intersection between the headquarters' optimal reaction curve (h_i^*) and the external supplier's optimal reaction curve (m_i^*).[14]

The difference among the three bi-sourcing strategies (SS, SN, and NS) lies in the location choice for the internal and external suppliers. When the

[11] It is assumed that the effective bargaining power between the headquarters and the suppliers remains constant across the locations (See Grossman, Helpman and Szeidle (2004) for making the same assumption.)

[12] It is noteworthy that in order to have the SN case, the wage difference between the South and the North cannot be too large, i.e., $t < \frac{1-\beta}{1-\beta_I}$, otherwise the SN case reduces to single insourcing in the South.

[13] Note that $T(x^i)$ is same in functional form as $T\left(\frac{1}{A}\right)$ in the close-economy case of Section 3.2.

[14] Recall that it is the external supplier who makes investment after the internal supplier does, and who effectively determines the total component supply ($m_1 + m_2$).

external supplier moves from the high-wage North (i.e. SN) to the low-wage South (i.e. SS or NS), its optimal reaction curve shifts to the right (i.e., from curve m^*_{SN} to curve m^*_{NS} or m^*_{SS} as in Figure 2 and Figure 3), thereby lifting the production efficiency. Henceforth this effect is called the *cost effect.*

Meanwhile, the location choice for the internal and external suppliers affects the equilibrium component manufacturing by the two suppliers, and consequently the share of manufactured component made by the internal supplier (x^i). It is straightforward to show that $x^{SN} > x^{SS} > x^{NS}$. Intuitively, the internal supplier produces the most relative to that of the external supplier when it is located in the low-wage South but the external supplier is located in the high-wage North. Hence the firm can make use of the location choice to alter the relative production share of the internal and external suppliers (i.e., x^i) and thus adjust the headquarters' bargaining power vis-a-vis that of the component suppliers to increase the headquarters' incentives to invest (i.e., $T(x^i)$), which subsequently leads to a shift of the headquarters' optimal reaction curve. This effect is called the *balancing effect.* However, the relative position of the headquarters' optimal reaction curves under the three types of bi-sourcing strategies is not straightforward, which will be analyzed in the next subsection.

4.2 Characterization of Optimal Bi-sourcing Strategy

To characterize the optimal bi-sourcing strategy in the global economy, we need to compare the magnitude of the balancing effect (i.e., $T(x)$) across the three types of bi-sourcing strategies. It can be shown that $T(x)$ is concave in x. Let x^* be the x that maximizes $T(x)$. It can be further shown that there exists a value of β_I, denoted by β_I^*, under which $x^{SS} = x^*$ (the proof is provided in the Appendix which is available upon request). For illustration, we give a numerical example.

Numerical example: Set $\alpha = 0.2$, $\eta = 0.5$, and $\beta_O = 0.5$.[15] It is easy to derive $x^* = \left[\left(\frac{1-\beta_I}{\beta_I}\right)^{\frac{1}{0.9}} + 1\right]^{-1}$ and $x^{SS} = \left(\frac{1-\beta_I}{\beta_I}\right)^{\frac{1}{0.9}}$. By equating x^* to x^{SS}, we can derive $\beta_I^* = \left[\left(\frac{\sqrt{5}-1}{2}\right)^{0.9} + 1\right]^{-1} \approx 0.6$.

When $\beta_I = \beta_I^*$, bi-sourcing strategy SS has the highest balancing effect, and in combination with its advantageous cost effect, SS emerges as the

[15]We follow Krugman and Venables (1995) in setting the values of α and η. And we assume equal bargaining between the headquarters and the external suppiler (i.e., $\beta = 0.5$), which is commonly used in the literature on the theory of the firm.

optimal bi-sourcing strategy. When β_I is not equal to β_I^*, there exist two possible scenarios: one is $\beta_I < \beta_I^*$ (called "strong internal supplier") and the other is $\beta_I > \beta_I^*$ (called "weak internal supplier").

The case of "strong internal supplier" is illustrated by Figure 2. Intuitively, when the internal supplier has too strong bargaining power compared with the external supplier, the headquarters would have too strong cross-threat in negotiating with the external supplier but too weak cross-threat in negotiating with the internal supplier. Such imbalance is the most serious when the headquarters orders the internal supply from the low-cost South and external supply from the high-cost North (i.e., bi-sourcing strategy SN), implying that the headquarters' optimal reaction curve under SN lies below those under SS and NS (see Figure 2 for an illustration). However, by relocating the internal supplier from the cost-advantageous South to the cost-disadvantageous North (i.e., from bi-sourcing strategy SS to bi-sourcing strategy NS), the headquarters can achieve a better balancing effect, which will increase its incentives for investment (i.e., the optimal reaction curve h_{NS}^* lies above h_{SS}^* in Case A of Figure 2) so long as the wage difference between the North and the South (i.e., t) is not too large. In this case, the equilibrium investment levels under bi-sourcing strategy NS (represented by point NS in Case A of Figure 2) lies to the northeast of equilibrium points SS and SN, implying that bi-sourcing strategy NS has the highest production efficiency. When the wage difference between the North and the South is too big, however, the shift from SS to NS would dampen the internal supplier's incentive to invest so much that the headquarters' optimal reaction curve $h_{NS'}^*$ lies below h_{SS}^* as illustrated in Case B of Figure 2. In this case, bi-sourcing strategy SS turns out to have the highest production efficiency.

To summarize, we have the following proposition

Proposition 2 *In the case of strong internal supplier (i.e., $\beta_I < \beta_I^*$): (i) locating insourcing in the North and outsourcing in the South (NS) is the optimal bi-sourcing strategy so long as the wage difference between the two countries is not sufficiently large; (ii) otherwise, locating both insourcing and outsourcing in the South is the optimal bi-sourcing strategy.*

In the case of "weak internal supplier", the internal supplier has too weak bargaining power as compared with the external supplier. Such imbalance is the most severe when the weak internal supplier is located in the cost-disadvantageous North but the strong external supplier is in the cost-advantageous South, implying that the headquarters' optimal reaction curve under NS lies below those under SS and SN (see Figure 3 for an illustration). When the wage difference between the North and the South is not sufficiently large, however, the headquarters can achieve a better balancing effect by moving the external supplier from the South to the North (i.e., from bi-sourcing strategy SS to bi-sourcing strategy SN), with the headquarters' optimal reaction curve of SN lying above that of SS (see Case A of Figure 3). In this case, the equilibrium investment levels of SS are higher than those of NS, but the comparison between equilibrium investment levels of SS and those of SN is not obvious. It can be formally proved that the production efficiency under SS is higher than that under SN, implying the optimally of bi-sourcing strategy SS. When the wage rate in the North is too much higher than that in the South, moving the external supplier from the South to the North would overly correct the imbalance of power between the internal and external suppliers, causing the headquarters' optimal reaction curve of SN to lie below that of SS (see Case B of Figure 3 for an illustration). In this case, it is obvious that the equilibrium point of bi-sourcing strategy SS lies in the northeast of those of SN and NS, implying the optimally of bi-sourcing strategy SS again. To summarize, we have:

Proposition 3 *In the case of weak internal supplier (i.e., $\beta_I > \beta_I^*$), locating both suppliers in the South is always the optimal bi-sourcing strategy.*

Before concluding our analysis, we give a numerical example illustrating the results of Propositions 2 and 3. As shown in Table 1, for the case of strong internal supplier ($\beta_I = 0.501 < \beta_I^*$), the bi-sourcing strategy of NS is the optimal one when t is small (i.e., $t = 1.05$), but the bi-sourcing strategy of SS becomes the optimal strategy when t is large (i.e., $t = 1.1$). For the case of weak internal supplier ($\beta_I = 0.700 > \beta_I^*$), however, the bi-sourcing strategy of SS is always the optimal strategy.

5 Conclusion

In this paper, we extend the framework of Antràs and Helpman (2004) to study the growing business strategy of bi-sourcing, that is, firms adopt insourcing and outsourcing simultaneously in acquiring the same set of intermediate inputs. We show that by conducting bi-sourcing firms can take advantage of the cross-threat in trilateral negotiations to mitigate the inherent problems of both insourcing and outsourcing. Given that bi-sourcing contains the fixed costs of both insourcing and outsourcing, our model predicts that only the most productive firms will be able to adopt bi-sourcing strategy.

When conducting bi-sourcing in the global economy, multinational enterprises need to choose the location of internal and external suppliers, i.e., in the high-waged North or low-waged South. We identify two factors. One is the cost effect resulting from the wage differences between the North and South, and the other is the balancing effect in keeping a balance in bargaining power between the internal and external suppliers. Our analysis shows that in many cases locating both suppliers in the low-cost South generates the highest production efficiency. When one supplier is too strong relative to the other supplier in bargaining power, however, multinational enterprises may choose to locate the strong supplier in the cost-disadvantageous North and the weak supplier in the cost-advantageous South to achieve a better balancing effect.

In concluding, it should be pointed out that there are other possible reasons for the use of bi-sourcing strategy. For example, in-house production units may face capacity constraints, under which it could be optimal to meet the fluctuations in demand through external supply. It is also possible that external suppliers may face less problems of unionization than internal production units as in the case of the U.S. automotive industry. Yet another possible reason for bi-sourcing is the use of external suppliers as a source of learning the best practices by internal production units. These possibilities of bi-sourcing are worth investigating in the future.

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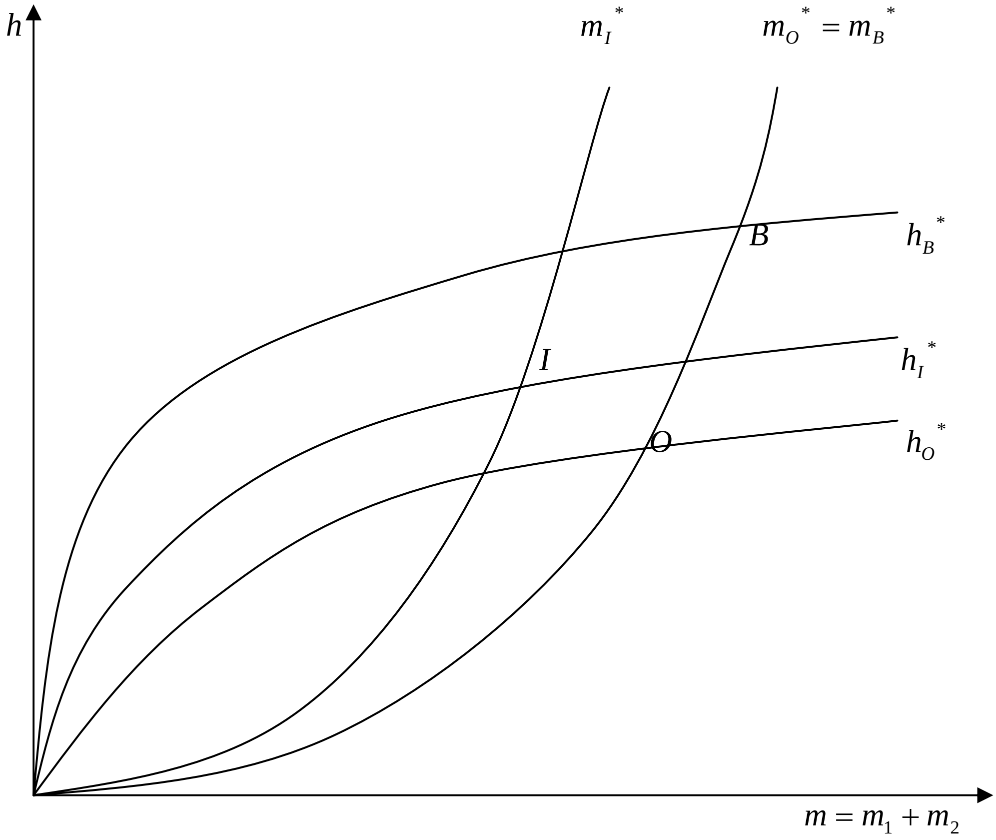
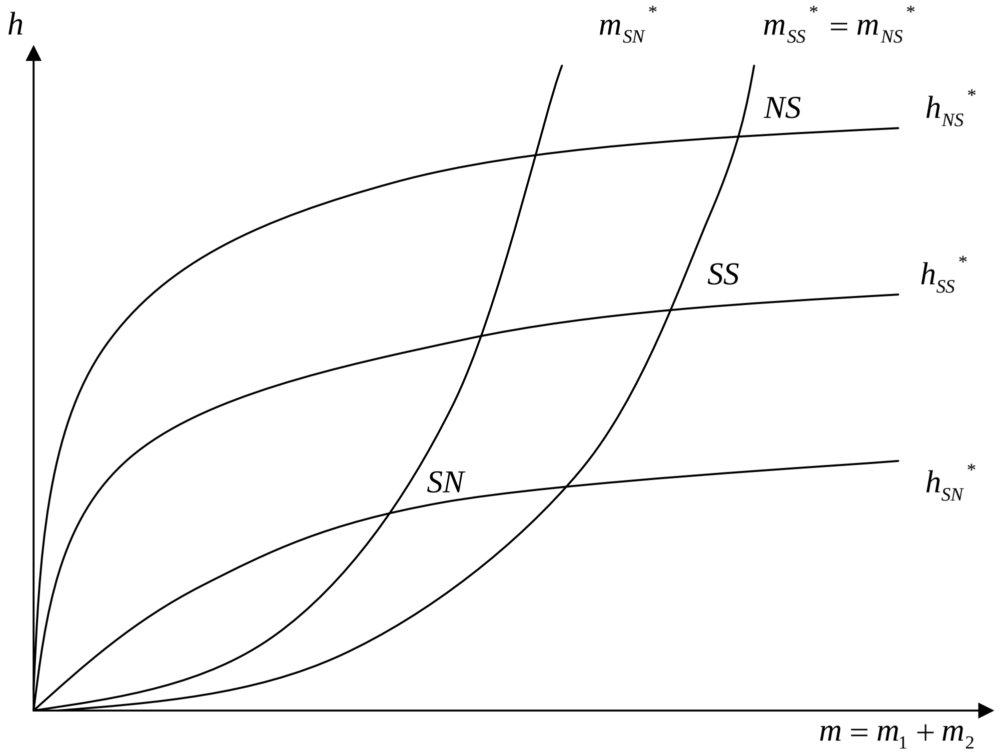
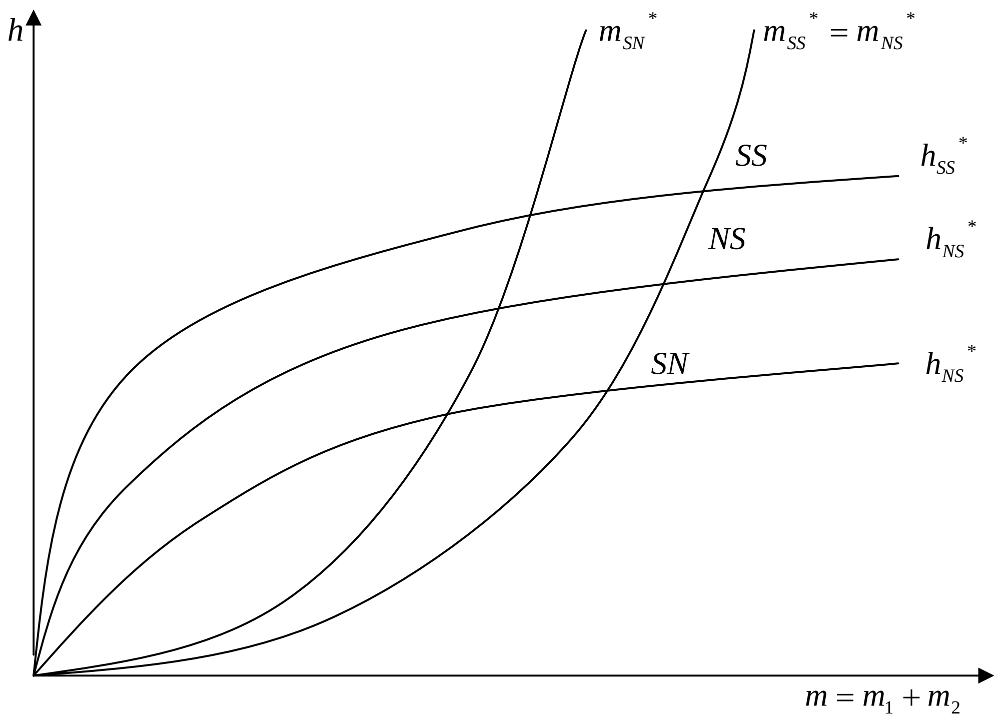


Figure 1

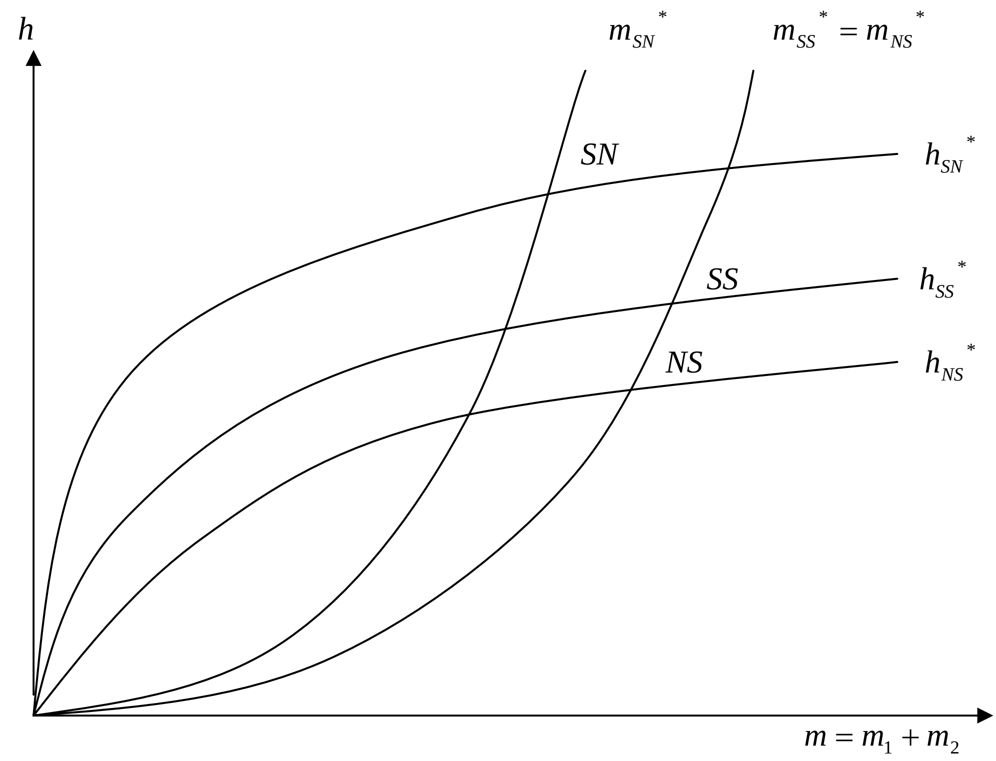


Case A: when t is not sufficiently large

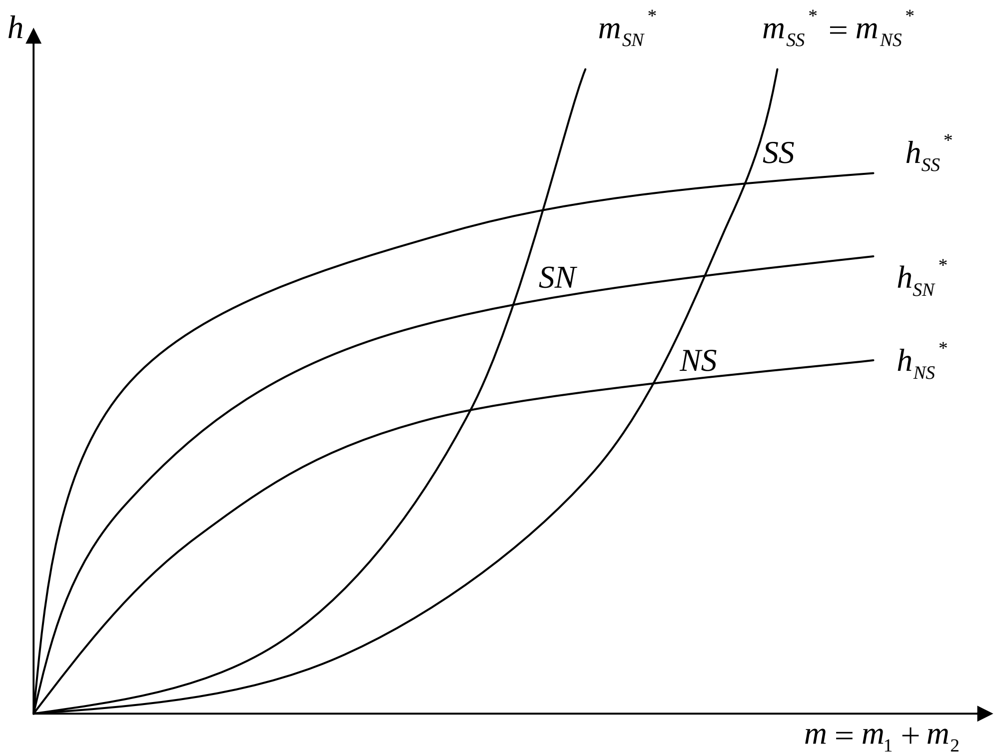


Case B: when t is sufficiently large

Figure 2: when $\beta_I < \beta_I{}^*$



Case A: when t is not sufficiently large



Case B: when t is sufficiently large

Figure 3: when $\beta_I > \beta_I^*$

Table 1: Numerical Results

	$\beta_I = 0.501$		$\beta_I = 0.700$	
	$t = 1.05$	$t = 1.10$	$t = 1.05$	$t = 1.10$
	ϕ	ϕ	ϕ	ϕ
NS	**0.5401**	0.5640	0.5407	0.5611
SS	0.5398	**0.5655**	**0.5450**	**0.5710**
SN	0.5092	0.5122	0.5225	0.5251

Note: set $\alpha = 0.2$, $\eta = 0.5$, $\beta_O = 0.5$, and $w^N = 1$. $t = w^N / w^S$. ϕ is the production efficiency.