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Learning by Supplying and Competition Threat*

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Abstract

This study proposes a model of learning by supplying in an international outsourcing framework, where the supplier of a relationship-specific input can reverse engineer and become a competitor to its partner in the final goods market. Transmitting knowledge to a more capable supplier therefore creates competitive threat despite the benefits it brings within an outsourcing relationship. In particular, in markets with less differentiated products and for standard inputs that require less knowledge to be shared, choosing an intermediate capability level supplier prompts a strategic expansion of output to deter supplier entry in the final goods market, resulting in higher profits and welfare. A highly capable supplier is instead accommodated as a rival and is a source of royalty income when the relationship-specific input embeds more knowledge about the final product and when the competing varieties are differentiated.

J.E.L Classification: F12; F23; L13; L22; L24; D23; O34

Keywords: International outsourcing; Supplier heterogeneity; Competitive threat; Reverse engineering; Strategic predation; Technological capability; Learning by supplying; Royalty payment; Knowledge intensity

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1 Introduction

International outsourcing is by now a well-known channel of technology transfer to less developed countries (South). According to Becker's theory of human capital (Becker, 1964), firms from developed countries (North) transfer knowledge by fostering on-the-job skills training when engaging in business relationships with firms from the South. Kim (1997), Hobday (2000), and Cyhn (2002) also regard the original equipment manufacturing (OEM) system as a technology training school, because it provides opportunities for input suppliers to acquire know-how and technologies from their foreign, more advanced counterparts. Input suppliers with higher capability can better absorb technologies required for the relationship, but also have higher capacity to use it to innovate and introduce their own brand of the final good into the market. Some renowned examples of a transition from pure OEMs to own brand manufacturing (OBM) producers are Samsung's microwave ovens and South Korea's automobile industry.[1] Taiwanese firms Asus and Acer have also followed this path; in fact, Acer's own-brand notebooks are known to have harmed its contract-manufacturing relationship with Dell (Yu and Shih, 2014).[2] The development of Mitsubishi Heavy Industry's MRJ (Mitsubishi Regional Jet) is another recent example, where Mitsubishi acquired the know-how of modern airliners through the process of supplying, together with other major Japanese suppliers, 35% of the components for Boeing's 787 airliner.[3]

This natural phenomenon raises several interesting questions. For example, what are the determinants and consequences of a final good producer's choice to outsource production of a relationship-specific input to a supplier with lower or higher technological capability? What are some strategies for a final producer to mitigate or prevent losses that can arise from potential competition from its own supplier? How does such competitive threat affect profitability and welfare implications of arm's length transactions? This study takes a step towards providing some answers to these questions by incorporating the idea of "learning by supplying" in outsourcing relationships, where a trusted supplier can become a threatening competitor by entering the final goods market after acquiring and advancing the basic technology. We further examine the implications of supplier characteristics in terms of their technological capability in outsourcing relationships and the consequences on the equilibrium market structure, profits and welfare.

The notion of learning by supplying has recently been introduced in the business literature and empirical evidence, although rare, supports the idea that Southern firms successfully capitalize on their experience as an OEM supplying to major branded producers to become world-class players in their industry at the expense of previous market leaders (Alcacer and Oxley, 2014). This is indeed the case as

[1]Samsung developed its capability by undertaking GE's production. Please refer to pp.136-140 of Kim (1997), and pp.202-206 of Cyhn (2000). The Korean automobile industry instead began from basic assembly and input production for foreign automobile companies. Please refer to Kim (1997), pp. 105-130, for details.

[2]Chu (2009) provides a detailed illustration of the transition from OEM to OBM in East Asia, and finds that the Chinese and Korean firms tend to be more active in following this path than Taiwanese firms.

[3]Boeing Japan's report "Made with Japan: A Partnership on the Frontiers of Aerospace,", page 6. Available online at: http://www.boeing.jp/resources/ja_JP/Boeing-in-Japan/Made-with-Japan/1122_boeing_cb13_final.pdf. According to the report, Mitsubishi also designs and produces the wings of the 787. Furthermore, this is the first time that Boeing has entrusted such a critical component to an outside supplier.

outsourcing today routinely encompasses the manufacture and even design of complete products. While knowledge sharing may still generate significant mutual benefit through increased efficiency, there is a large possibility that it allows the supplier to accumulate the technological and marketing capabilities necessary to compete effectively against its customer. Alcacer and Oxley (2014) find a strong positive correlation between the accumulation of technological capabilities and supplying time and extent in the mobile handset industry, especially for suppliers with higher absorptive capacity. They show, however, that despite frequent moves by suppliers to introduce their own branded manufacturing (in the electronic industry), the progression is avoidable as leading producers respond to the credible competitive threat with attempts to limit suppliers' ability to develop the capabilities necessary to climb up the value chain.

We develop a theory of learning by supplying, in which a Northern final good producer outsources the production of an intermediate good to a Southern input supplier. The production of relation-specific inputs must meet the requirements of final good producers. A more knowledge intensive input therefore embeds more knowledge about the final product. The supplier is compelled to make the necessary investment to absorb and implement the associated technologies. Upon the completion of the input and the sales of the final good, the two firms split aggregate profits through a Nash bargaining process. At that stage, the input supplier can further engage in reverse-engineering to design and introduce its own variety of the final good into the market. Investment in both customization and reverse engineering is less costly for suppliers endowed with better technological capability. In addition, the more knowledge intensive the outsourced input, the easier it is for the supplier to invent around the patent and develop a competing final product. In this case, the Southern supplier (referred to as S hereafter) produces both the specific input and a final product that can be differentiated from that of the original Northern firm (henceforth N). Learning by supplying can hence potentially lead to the cannibalization of the final product market.

Although the profit of N depends on the capability of S due to Nash bargaining, it is not monotonically increasing in the latter as different market structures are formed. When supplier capability is low, a natural monopoly status by N is maintained as it is too costly for S to engage in reverse-engineering. When the technological capability of the supplier is in an intermediate range, N adopts a so-called strategic predation scheme, in the spirit of Zigic (2000) and Naghavi (2007), to protect its intellectual property (IP). That is, N perceives S not just as a partner, but also as a potential rival. This prompts N to adopt an overproduction strategy to deter entry of S into the final goods market.[4] Accordingly, the quantity of output by N is increasing in the capability of S, thus lowering prices and profits. As a result, the profit of N is first increasing in the capability level of the supplier as long as natural monopoly prevails, but takes an inverted-U shape once strategic predation becomes the optimal strategy. Suppliers with yet higher levels of capability always find their way into market by engaging in reverse-engineering and producing their own variety of the final good, leading to an oligopolistic market with Stackelberg competition. Once competition is the established market structure, N's profits continue to increase with supplier capability and royalties become an additional source of income.

[4] In Zigic (2000) and Naghavi (2007), an N engages in a predatory level of R&D to deter S from entering the final goods market.

When pairing with an S with intermediate technological capability, N can prevent competition by slightly expanding production, while still taking advantage of the supplier's capability. Competition threat therefore leads to outsourcing with overproduction, which prevents the rival S from competing, but generates a higher consumer surplus by lowering the price. As a result, the North can obtain a higher total surplus when the final producer chooses a moderately capable supplier that supports the strategic predation structure, as opposed to teaming with the best, which leads to Stackelberg competition. This is more relevant when the final products are less differentiated as in this case a highly capable supplier is more of a competitive threat due to a cannibalization effect in the final goods market, offsetting any benefits it can bring within the relationship.

Strategic predation as a tool to maintain market power is also more prevalent when the input is less knowledge intensive and does not require a great amount of knowledge to be shared, making it more difficult for the supplier to enter the final goods market. Outsourcing more knowledge intensive inputs instead makes it too costly for N to deter entry as it would require substantial overproduction to keep the supplier out. For more capable suppliers, accommodation is a more attractive option as a rival supplier in the final goods market can eventually serve as a source of revenue by generating royalty income, which is higher for more capable suppliers, differentiated final varieties, and low costs of reverse-engineering (knowledge intensive inputs embedded with more knowledge about the final product).[5]

The rest of the paper is organized as follows. Section 2 provides a literature review. Sections 3 introduces the model. Section 4 determines the equilibrium market structure. Section 5 provides a comparative static analysis to show how profits relate to supplier capability, input knowledge intensity, and product differentiation. Section 6 studies the welfare implications. Section 7 extends the model by incorporating alternative organizational forms into the model. Section 8 concludes.

2 Literature

The basis of our study is the literature on trade and firm organization that has provided substantial insights on the phenomenon of global sourcing and property rights. Grossman and Helpman (2002, 2003, 2005) studied the hold-up problem brought about by the transaction costs involved in outsourcing relationships in an incomplete contract framework. Another branch of this literature (Antràs 2003, 2005; Antràs and Helpman, 2004; Helpman, 2006; Acemoglu *et al.*, 2007; Antràs and Chor, 2013; Antràs, 2014) instead uses the property right framework to emphasize the incentive-creating role of outsourcing as a tool to avoid underinvestment in customization efforts by suppliers.[6] Our purpose is to introduce learning by

[5] For an overview of the literature on IP rights as an alternative determinant of reverse-engineering costs, see among others Chin and Grossman (1990), Deardorff (1992), Helpman (1993), Vishwasrao (1994), Zigic (1998, 2000), Saggi (1999), Yang and Maskus (2001), Markusen (2001), Glass and Saggi (2002), Glass (2004), Grossman and Lai (2004), Mukherjee and Pennings (2004), Naghavi (2007), Leahy and Naghavi (2010), Mukherjee (2017), Ghosh *et al.* (2018), and Ghosh and Ishikawa (2018).

[6] See also Acemoglu *et al.* (2007), Naghavi and Ottaviano (2009), Van Biesebroeck and Zhang (2014), and Schwarz and Suedekum (2014) for further applications of these models.

supplying and potential competition threat from a supplier into this literature. Doing so allows us to study the strategic behavior of final good producers under different prevailing market structures that hinge on supplier firm-level characteristics, as well as attributes of the outsourced input and of the final goods market.

Our model also adds to the literature on outsourcing when inputs and the associated production technologies are relation-specific. Particularly, Goswami (2013) and Naghavi *et al.* (2017) examine the impact of the input suppliers' technological capability on the outcome of outsourcing in the form of the host country's absorptive capacity and suppliers' technology endowment, respectively. Both of these studies find that the input suppliers associated with a higher technological capability improve joint profits from an outsourcing partnership. This strand of literature has so far considered the position of the input supplier to be somewhat passive, as it is restricted to producing only the intermediate inputs for the relationship. In our model, we allow input suppliers to transform into final good producers by engaging in reverse-engineering, endogenizing the number of goods in the market. Better technological capability can hence threaten profits of final good producer by potentially creating harsher competition, but could also produce larger royalty payments in case of entry in the product market.

We also relate to the literature on strategic outsourcing, which focuses on how outsourcing alters the final good market's competition structure.[7] Pack and Saggi (2001) argues that outsourcing can cause the production technology of an intermediate input to diffuse to other firms in the South. As a result, the costs to procure the intermediate input is lowered, which in turn intensifies competition by encouraging more final good producers to enter the market. The incentives for a multinational to share knowledge with its suppliers is thus reduced, limiting opportunities for supplier learning. In our context, this occurs when choosing a less capable supplier. Blalock and Gertner (2008) instead show that a foreign firm makes its technology widely available to local suppliers in emerging markets to avoid hold-up by any single supplier. This technology diffusion induces entry and more competition which lowers prices in the supply market, expanding spillover opportunities. In our framework this occurs with more capable suppliers. Another closely related work by Mukherjee and Tsai (2013) considers a two-period model in which the input suppliers learn the know-how to produce the final product on their own, at no additional cost, after the outsourcing of production. They argue that, by strategically outsourcing the input to as many suppliers as possible, the leading final good producer deters suppliers from entering the final good market in the second period to avoid competition. The present study adds to this branch of literature by incorporating heterogeneity in suppliers' capability into a comprehensive model of incomplete contracts with strategic behavior in order to understand how a supplier self-selects itself as either a pure input supplier or a follower in the final goods market.

Finally, we relate to existing theories on the relationship between FDI spillovers and technological gap between foreign investors and local firms (Wang and Blömstrom, 1992; Rodriguez-Clare, 1996). Several empirical studies since confirm the phenomenon of technological spillovers from foreign to lo-

[7]This includes Pack and Saggi (2001), Chen *et al.* (2004), Chen *et al.* (2011), and Mukherjee and Tsai (2013) among others.

cal firms and how they boost the productivity of the latter; see Javorcik (2004), Görg and Greenaway (2004), Haskel *et al.* (2007), Liu (2008), and Arnold and Javorcik (2009) among others. Kugler (2006) finds outsourcing relationships of multinationals with local upstream suppliers to be a key channel of technology diffusion. Crespo and Fontoura (2007) argue that the absorptive capacity of domestic firms is a precondition for FDI spillovers to occur. In this context, our results also imply that Southern firms must possess the capability to absorb Northern technology in order to induce spillovers. Our findings are also in line with evidence from Guadalope *et al.* (2012), which uses data on Spanish manufacturing firms to show that multinationals team with the most productive domestic firms, which, subsequently adopt foreign technologies and conduct more innovation, leading to higher productivity.

3 The Basics

We build a framework of the learning by supplying phenomenon to account for the possibility that S can transform from a pure intermediate input supplier to a firm producing both the intermediate input and the final product. In what follows, we start by describing the consumer and firm behavior.

3.1 Consumer

The consumers (workers) reside in the two regions, North and South, denoted by subscript $j = N, S$. The representative consumer in region j is endowed with L_j units of the total labor force, which is assumed to be freely mobile between the manufacturing and a homogeneous goods sector, but immobile across the regions. The utility function of the Northern representative consumer takes the form

$$U = q_N^0 + u(q), \tag{1}$$

where q_N^0 is a tradable homogeneous good (consumed in the North) and q denotes the varieties produced in the manufacturing sector. For sake of simplicity, we assume that the South only consumes the homogeneous good.[8] It is produced with a constant returns to scale technology and only uses labor. We normalize the price of the homogeneous good to 1, and assume that wages are higher in the North such that $w_N > w_S \geq 1$.[9]

To capture the tension between N and its Southern supplier, we follow the setting of Singh and Vives

[8]This assumption is also applied in Pack and Saggi (2001) and Naghavi and Ottaviano (2009) with the objective to highlight the cost-saving characteristic of offshoring with N only supplying the home market.

[9]This assumption is justified by interpreting w_j as the productivity of labor in producing q_0 in region j. In other words, we assume that, in the North, a unit of labor is capable of producing θ_N units of q_0, while in the South, a unit of labor can only produce θ_S units of q_0, where $\theta_N > \theta_S$. Since the price for each unit of q_0 is 1 and the homogeneous sector is perfectly competitive, it must be that the wage of each unit of labor is equal to its marginal productivity. In other words, $p_0\theta_N = \theta_N = MPL_N = w_N$ and $p_0\theta_S = \theta_S = MPL_S = w_S$. We can further normalize Southern productivity such that $\theta_N > \theta_S = 1$ and, hence, $w_N > w_S = p_0 = 1$.

(1984) and Neary and Thakaran (2012) to specify that

$$u(q) = a(q_N + q_S) - \frac{1}{2}\left[q_N^2 + q_S^2 + 2eq_Nq_S\right], \tag{2}$$

where $e \in [0,1]$ denotes the inverse degree of differentiation between the final products produced by N and S. As e gets closer to 1, the final products produced by firms of the two regions are less differentiated (i.e., more homogeneous). In this case, competition is more intense and the cannibalization effect stronger if S enters the final goods market. The consumer's utility maximization problem yields the inverse demand functions for each variety:

$$p_N = a - q_N - e \cdot q_S, \tag{3}$$

$$p_S = a - q_S - e \cdot q_N. \tag{4}$$

In what follows, we let $p(q)$ denote the price when total supply of the final product is q.

Let $Y_j = w_jL_j + \Pi_j$ denote total income in region j composed of labor income and the profit of firms. It can be shown that demand for the homogeneous product in the North is

$$q_N^0 = Y_N - (q_N + q_S). \tag{5}$$

In the South, demand is

$$q_S^0 = Y_S, \tag{6}$$

as the Southern representative worker only consumes the homogeneous good. Moreover, since the labor force is mobile between sectors, labor market always clears, as long as both L_N and L_S are sufficiently large.

3.2 Firms

There is a Northern firm N and a continuum of identical prospect firms from the South. N has the ability to design and develop a final product, which requires a specific input to produce. N must form an outsourcing relationship with a supplier in the South to acquire the input. There is a random match between N and S, in an environment where all S are *ex ante* identical, but N cannot renege to rematch with other potential firms. In Section 7, we also consider the cases where N can also acquire its input by in-house production in the North or FDI in the South. We show that the equilibrium outcome is robust to the introduction of these two additional organization forms.

Firm S, in contrast, does not initially have the know-how to design and produce the final product. It has the facility to produce an specific input required by N, which can be converted into a final product on a one-to-one input/output basis at no extra cost, after a customization process that requires technology transfer from N. The cost of customization depends on the technological capability of S, $\zeta \geq 1$. Once S is matched with N, it observes its capability from a common known distribution $g(\zeta)$ and ζ is revealed,

S conducts customization at a cost $w_S \cdot I(\zeta)$ in terms of Southern labor, where $I'(\zeta) < 0$. Customization costs can be written as

$$I(\zeta) = \zeta^{-1}.$$

After observing ζ, N can enter the market through an outsourcing relationship with S under a contract, in which N offers the required technology to produce an intermediate input x and proposes an upfront transfer payment T, and S decides whether or not to accept the contract. The upfront payment is determined by Nash bargaining over the surplus from the outsourcing relationship, which, as will be made clear below, can be positive as a subsidy to create incentives or negative as a royalty fee. Following the literature, we assume that firms have an identical bargaining power of $1/2$. If S accepts the offer, the payment is transferred, and is required to conduct the customization process using the acquired technology. Customization is verifiable *ex post.* If S rejects the contract, both firms in the industry are forced to leave the market.

After S has accepted the contract, N specifies the quantity of the final product q_N to be produced using the inputs shipped back to the North. The joint operating profit from the outsourcing of production $(p_N - w_S) \cdot q_N$ is then split equally by both firms. As we assume that the intermediate input is fully customized, the outside option for S is 0.

The novelty of this study is that it allows S to experience a learning by supplying process, whereby S learns part of the required know-how behind the Northern final product. It can therefore engage in reverse-engineering after having produced the inputs for N. Doing so, it acquires the ability to design and produce in-house both the intermediate input and its own model of the final product, potentially distinct from the variety produced by N. S could then also convert inputs to final products and enjoy exclusive operating profits of $(p_S - w_S) \cdot q_S$ by producing and exporting a quantity q_S of its variety to the North. Since S must participate in the outsourcing relationship in the first stage to be able to learn the know-how, the profits from its own final product are implicitly considered as a part of the outsourcing production process.

While customization only depends on supplier capability, reverse-engineering also depends on the knowledge intensity of the input procured and costs $w_S \cdot C(\gamma, \zeta)$, where $\gamma > 1$ represents the inverse measure of knowledge intensity or the difficulty to invent around the patent and produce the complete final good due to the low knowledge content of the input, with properties $\frac{\partial}{\partial \zeta} C(\gamma, \zeta) \leq 0$ and $\frac{\partial}{\partial \gamma} C(\gamma, \zeta) \geq 0$. To make the model tractable, we assume that

$$C(\gamma, \zeta) = \frac{\gamma}{\zeta}. \tag{7}$$

Sourcing a less knowledge intensive input limits S's access to the technology required for developing the final product. Hence, S must exert additional effort for S to learn from supplying and produce its own version of the variety. Finally, our setting implies that $C(\gamma, \zeta) > I(\zeta)$ as S is more efficient in its core activity (input production), hence facing extra costs when it chooses to engage in the production of final goods.

4 The Model

In this section, we solve the model, which is divided into five stages. The timing is as follows:

Stage 1. N and S are randomly matched from a pool of suppliers and capability ζ is revealed.[10]

Stage 2. N proposes a contract: N provides the technology and upfront transfer payment T is negotiated. S engages in customization to produce a qualified input x if it accepts; firms exit otherwise.

Stage 3. N specifies the quantity of final product q_N (endogenously determining the market structure). S provides the required quantity of input and operating profits of the relationship are split equally between the two firms.

Stage 4. S decides whether to engage in reverse-engineering to start also producing q_S of its own variety of the final good and compete with N in the Northern market.

Stage 5. The payoffs are realized.

Using backward induction, we first characterize the decision of S in expanding its scope of operation to produce both the input and the final good. Next, we analyze N's optimal output and the resulting market structure will depend on ζ, due to the competitive threat from S. Finally, we analyze the contract proposed by N.

Let $R^D(q_N, q_S) \equiv [p_N(q_N, q_S) - w_S] \cdot q_N$ and $R^M(q_N) \equiv [p_N(q_N) - w_S] \cdot q_N$ denote total operating profits to be split between N and S, when S enters competition in the final goods market (superscript D for duopoly) and when it does not (superscript M for monopoly). Furthermore, $R_S(q_N, q_S) \equiv [p_S(q_N, q_S) - w_S] \cdot q_S$ is operating profits exclusive to S from the production of its own variety of the final good if it transforms into a rival for N.

The equilibrium is defined by three conditions: 1) entry decision of both N and S; 2) the equilibrium market structure, which embeds optimal output by N, the contract, and entry into the final goods market by S ; 3) the market clearing and the trade balance conditions. Here we focus on the equilibrium market structure, and the entry decisions of the firms. The market clearing and trade balance conditions are relegated to Appendix A.6.

[10]Note that supplier capability does not only apply to their effort within the relationship, but also to their learning and innovation capacity that determines their individual benefits. Firms can therefore obtain this information by observing supplier-specific characteristics, such as its history of patents.

4.1 The Southern Firm's Scope of Operation

S can decide whether or not to expand activities beyond intermediate input provision, given the outcome of the contract and the Northern firm's output (i.e., T and q_N). Should S decide not to engage in final good production, then no reverse-engineering takes place and its only source of profits comes the delivery of inputs, given by:

$$\Pi_S^M(q_N;T,\zeta) \equiv \frac{1}{2}R^M(q_N) - w_S \cdot I(\zeta) + T.$$

If S decides to become a final good producer, reverse-engineering is conducted at a cost $w_S C(\zeta,\gamma)$, resulting in exclusive operating revenues from its sales to Northern consumers, $R_S(q_N,q_S)$. Total profit for S in this case becomes:

$$\Pi_S^D(q_N,q_S;T,\zeta) = \frac{1}{2}R^D(q_N,q_S) + R_S(q_N,q_S) - w_S \cdot I(\zeta) - w_S \cdot C(\zeta,\gamma) + T.$$

In this case, the optimal quantity of the final good produced by S is

$$q_S^*(q_N;e) = \frac{m}{2} - \frac{3}{4} \cdot e \cdot q_N, \tag{8}$$

where $m \equiv a - w_S$ captures the willingness to pay of a representative consumer, a.

It is natural that S would only enter the final goods market if q_N is not too large, so that competition in the final goods market is not too harsh. Otherwise, becoming a final good producer would bring smaller profits for S, as it would reduce both its revenues from within the relationship $R^D(q_N,q_S)$ and outside $R_S(q_N,q_S)$ by lowering the price of both the Northern and the Southern final goods. There exists a critical quantity

$$q_N^P(e,\zeta) = \frac{2}{3}\frac{\left(m - 2\sqrt{\frac{w_S\gamma}{\zeta}}\right)}{e}, \tag{9}$$

above which S does not engage in reverse-engineering and continues solely as an input supplier. Moreover, $q_N^P(e,\zeta) \geq 0$ holds whenever

$$\zeta \geq w_S\gamma\left(\frac{m}{2}\right)^{-2} \equiv \zeta_0.$$

Proposition 1 thus follows:

Proposition 1. *The decision of S to become a final good producer is characterized as follows:*

(1) If $\zeta < \zeta_0$, S remains as an input supplier only.

(2) If $\zeta \geq \zeta_0$, S reverse-engineers and produces at $q_S^*(q_N;e) = \frac{m}{2} - \frac{3e}{4}q_N$ if and only if $q_N < q_N^P(e,\zeta)$. Otherwise, S does not reverse-engineer and $q_S^*(q_N;e) = 0$.

(3) The upper bound q_N^P below which S enters the final goods market is higher for (i) more capable suppliers, and (ii) more differentiated products, and (iii) more knowledge intensive inputs (i.e., $\frac{\partial q_N^P(e,\zeta)}{\partial\zeta} \geq 0$, $\frac{\partial q_N^P(e,\zeta)}{\partial e} \leq 0$, and $\frac{\partial q_N^P(e,\zeta)}{\partial\gamma} \leq 0$).

Proof. See Appendix A.1. □

Proposition 1 claims that decision of S to become a final good producer depends on the choice of q_N by N. S always transforms into a rival if N specifies a quantity $q_N < q_N^P$. In contrast, N can always deter S from transforming into a rival by setting $q_N \geq q_N^P$. Proposition 1 also suggests that higher technological capability (larger ζ), more differentiated products (smaller e), and more knowledge intensive inputs (smaller γ) increase the profitability of entry for S up to a higher level of q_N. While more capability increases profits of S as an independent rival, product differentiation makes the prices of the final products less sensitive to competition, allowing S to earn positive profits for a larger range of q_N. Similarly, access to more knowledge intensive inputs makes it easier for S to reverse-engineer and produce the final good.

4.2 Northern Firm's Output

Following Proposition 1, profits of N given the upfront payment T is

$$\Pi_N(q_N;T) = \begin{cases} \Pi_N^D(q_N, q_S(q_N);T) \equiv \frac{1}{2}R^D(q_N, q_S(q_N)) - T & \text{if } q_N < q_N^P(e,\zeta) \\ \Pi_N^M(q_N, q_S;T) \equiv \frac{1}{2}R^M(q_N) - T & \text{if } q_N \geq q_N^P(e,\zeta) \end{cases}. \tag{10}$$

Equation (10) suggests that the quantity produced by N yields the market structure endogenously by influencing the decision of S on whether or not to engage in reverse-engineering. There are three possible market structures, given the level of $q_N^P(e,\zeta)$. If $q_N > q_N^P(e,\zeta)$, a natural monopoly by N emerges. In contrast, choosing a quantity $q_N < q_N^P(e,\zeta)$ leads to a Stackelberg structure, where N acts as the leader. In this case, N can still keep its status as a monopolist by strategically choosing $q_N = q_N^P(e,\zeta)$, i.e., strategic predation (Zigic, 2000; Naghavi, 2007). Below, we first study N's output decision under each market structure, followed by its optimal contract for different supplier capabilities and the resulting market structure.

If N is a natural monopolist, it can be readily verified that its optimal production is given by

$$q_N^M = \arg\max_{q_N} \Pi_N^M(q_N, q_S;T) = \frac{m}{2}, \tag{11}$$

as long as $q_N^M > q_N^P(e,\zeta)$. If instead $q_N^M < q_N^P(e,\zeta)$, N can only maintain its monopoly status by choosing $q_N = q_N^P(e,\zeta)$. In other words, by overproducing the final good, N can effectively prevent direct competition from S, because the price of the Southern product will be too low for S to have any incentives to engage in reverse-engineering to enter the final goods market. The overproduction strategy is, however, not costless for N: it also drives down the price of the Northern final product, dropping N's profits. N can nonetheless benefit from this strategy as long as the extent of overproduction $q_N^P(e,\zeta) - q_N^M$ is within limits. For large $q_N^P(e,\zeta) - q_N^M$ strategic predation becomes unprofitable as it would cause a drastic reduction in prices. It will be seen that very high values of $q_N^P(e,\zeta)$ can even make it preferable for N to accommodate rivalry from S and take a Stackelberg leader position. If N becomes a Stackelberg leader, then its optimal quantity is defined by

$$q_N^D = \arg\max_{q_N} \Pi_N^D\left(q_N, q_S\left(q_N\right); T\right) = \frac{m}{2} \frac{4-2e}{4-3e^2}, \tag{12}$$

where $q_N^D < q_N^P(e,\zeta)$. Figure 1 illustrates an example in which N strategically produces at $q_N^P(e,\zeta)$.

Our analysis implies that both e and ζ are crucial in determining the endogenous market structure. Recall that a higher ζ or a lower e makes it less likely for a natural monopoly to survive. For very large ζ or small values of e, $q_N^P(e,\zeta)$ becomes so large that N chooses $q_N = q_N^D$ over $q_N = q_N^P(e,\zeta)$ because it would be too costly to deter S from becoming a final good producer. Consider the threshold capabilities

$$\zeta^P = \left[\frac{m}{2} \frac{1}{\sqrt{w_S \gamma}} \left(1 - \frac{3}{4} e\right)\right]^{-2}, \tag{13}$$

and

$$\zeta^D = \left(\frac{m}{8} \frac{1}{\sqrt{w_S \gamma}} f(e)\right)^{-2}, \tag{14}$$

where

$$f(e) \equiv \frac{(4-3e)\left(4-3e^2\right) - 6e\sqrt{e(1-e)\left(4-3e^2\right)}}{4-3e^2}.$$

The threshold capability ζ^P determines the border between natural and strategic monopoly, i.e., $q_N^P(e,\zeta) = q_N^M$. This implies that N can only maintain its monopoly status by adopting an overproduction strategy for suppliers with capability levels $\zeta \geq \zeta^P$. It can be readily checked that the critical value ζ^P is increasing in e. The threshold ζ^D instead is the supplier capability level that makes N indifferent between choosing $q_N^P(e,\zeta)$ to keep its monopoly status, and q_N^D as to accommodate S in the final goods market and compete as a Stackelberg leader. The argument is formally characterized by Lemma A.1 in Appendix A.2.

4.3 The Contract

In the contract, N determines the optimal transfer payment T according to the Nash bargaining solution. Since N perfectly anticipates the decision of S, the Nash bargaining problem is thus given as

$$\max_T \left(\frac{1}{2} R^M(q_N) - T\right)^{\frac{1}{2}} \left(\frac{1}{2} R^M(q_N) - \frac{w_S}{\zeta} + T\right)^{\frac{1}{2}} \text{ when } \zeta < \zeta^D$$

$$\max_T \left(\frac{1}{2} R^D(q_N, q_S(q_N)) - T\right)^{\frac{1}{2}} \left(\frac{1}{2} R^D(q_N, q_S(q_N)) + R_S - \frac{w_S}{\zeta} - \frac{w_S \gamma}{\zeta} + T\right)^{\frac{1}{2}} \text{ when } \zeta \geq \zeta^D.$$

The optimal payment T^* is determined by

$$T^*(\zeta) = \begin{cases} \frac{1}{2} \frac{w_S}{\zeta} & \text{when } \zeta < \zeta^D, \\ \frac{1+\gamma}{2} \frac{w_S}{\zeta} - \frac{m^2}{4} \frac{1}{4-3e^2} \left(\frac{15e^4 + 36e^3 - 52e^2 - 64e + 64}{16 - 12e^2}\right) & \text{when } \zeta \geq \zeta^D. \end{cases}, \tag{15}$$

It follows that

Lemma 1. *The optimal transfer payment $T^*(\zeta)$ from N to S is always positive with strategic predation, but is lower under Stackelberg competition and becomes negative for high levels of supplier capability.*

Proof. See Appendix A.4. □

Since N and S equally share the *ex post* aggregate profits from the partnership, their profits are given as

$$\Pi_N^*(\zeta) = \Pi_S^*(\zeta) \equiv \Pi^*(\zeta) = \begin{cases} \frac{1}{2}\cdot\left(\frac{m^2}{4} - \frac{w_S}{\zeta}\right) & \text{when } \zeta < \zeta^P, \\ \frac{1}{2}\cdot\left[\frac{2\cdot\left(m-2\sqrt{\frac{w_S\gamma}{\zeta}}\right)\cdot\left(4\sqrt{\frac{w_S\gamma}{\zeta}}+3e\cdot m-2m\right)}{9e^2} - \frac{w_S}{\zeta}\right] & \text{when } \zeta \in \left[\zeta^P, \zeta^D\right), \\ \frac{1}{2}\cdot\left[\frac{m^2}{16}\frac{3e^4+84e^3-84e^2-128e+128}{\left(4-3e^2\right)^2} - (1+\gamma)\frac{w_S}{\zeta}\right] & \text{when } \zeta \geq \zeta^D. \end{cases} \tag{16}$$

Given that N has entered the market and ζ has been realized, it always proposes the contract as long as $\Pi_N^*(\zeta) \geq 0$ holds, and S always accepts the offer.

While the aggregate profit are equally shared between N and S, Lemma 1 implies that the profit structure depends on the potential market structure. N keeps its monopoly status whenever S's capability is no larger than ζ^D. In this case, N is required to subsidize S by the sum $T = \frac{1}{2}\frac{w_S}{\zeta}$ to uphold the outsourcing agreement. As a result, N's profit comes solely from its sales in the final goods market. In contrast, when $\zeta \geq \zeta^D$, S is highly capable to reverse-engineer and competition prevails. For high enough supplier capability, N can also extract rents from S's sales of its own variety, as the transfer turns into a royalty payment. In this case, N's profit consists of both its sales and the royalty charged from S.

4.4 Equilibrium Market Structure

Consider the threshold capability, which makes both N and S break even in the natural monopoly structure,

$$\zeta^M = \left(\frac{m}{2}\frac{1}{\sqrt{w_S}}\right)^{-2}. \tag{17}$$

Combining this with the optimal output, the contract, and the decision of S whether or not to produce the final good, the equilibrium market structure is given as follows:[11]

Proposition 2. *After N and S have entered the market,*

(1) for $\zeta < \zeta^M$, both N and S exit.

(2) for $\zeta \in \left[\zeta^M, \zeta^P\right)$, N sets $q_N^* = q_N^M$ and the natural monopoly structure emerges.

(3) for $\zeta \in \left[\zeta^P, \zeta^D\right)$, N sets $q_N^* = q_N^P(e,\zeta)$ creating a strategic predation structure.

(4) for $\zeta \geq \zeta^D$, N sets $q_N^* = q_N^D$ and competes with S as a Stackelberg leader in the final goods market.

[11] We focus only on the interesting case where $e < \overline{e}$.

Proof. Lemma A.1 in Appendix A.2 derives the optimal quantity of output. To complete the proof of the proposition, we show in Appendix A.5 that optimality in the contract requires that N and S agree on the outsourcing partnership and make positive equilibrium profits as long as $\zeta \geq \zeta^M$. □

In sum, N can maintain its status as a natural monopolist when the capability of S is not too high. When S has an intermediate level of capability, the Northern firm can still keep its monopolist status strategically. However, when S has high capability, N accommodates entry of S into the final goods market and acts as a Stackelberg leader. We also confirm that N is more likely to keep its monopoly status when the final products are less differentiated. Note that ζ^D is increasing in e. An increment in e lowers $q_N^P(e,\zeta)$, necessitating a smaller level of production to prevent S from manufacturing the final good. For N to concede to the Stackelberg scheme in this case, ζ must be high enough to compensate for products being less differentiated and maintain a high level of $q_N^P(e,\zeta)$.[12]

Figure 2 illustrates the outcomes of Proposition 2. It characterizes the equilibrium market structure based on the production of the optimal quantity of the final good. It is clear that both firms agree to the outsourcing contract when the capability of S is not too low (i.e., $\zeta \geq \zeta^M$). Since S never seeks to enter the final goods market when $\zeta \in [\zeta^M, \zeta^P)$, the natural monopoly structure is supported. When the capability of S increases ($\zeta \in [\zeta^P, \zeta^D)$), N engages in overproduction to deter S from entry, yielding the strategic predation structure. When the capability becomes sufficiently high (i.e., $\zeta \geq \zeta^D$), N has no incentives to engage in overproduction because this leads to very low prices, yielding less profits from the final goods market and, thus, giving rise to the Stackelberg structure.

In equilibrium, both N and S must make non-negative expected profits. Proposition 2 and equation (16) ensure that both N and S make equally positive expected profit $E(\Pi^*)$ for all exogenous parameters (e, a, γ, w_S).

5 Profits

To gain a better understanding of how profits earned by N change with supplier capability in the presence of competitive threat, let us first illustrate the equilibrium *ex post* profits in Proposition 3 and Figure 3.

Proposition 3. *Following equation (16), the ex post profit of N has the following properties:*

(1) It is increasing in ζ when $\zeta \in [\zeta^M, \zeta^P)$.

(2) It is first increasing, and then decreasing in ζ when $\zeta \in [\zeta^P, \zeta^D)$.

(3) It jumps upwards at ζ^D, and is then increasing in ζ when $\zeta \geq \zeta^D$.

Proof. Refer to Appendix A.7 for details. □

[12] Let $\bar{e} \equiv \frac{\sqrt{33}}{3} - 1 \approx 0.915$. ζ^D tends to infinity when $e \to \bar{e}$ (Please refer to Appendix A.3). For $\zeta \geq \zeta^P$, when e is larger than $\bar{e}$, the effect of e on $q_N^P(e,\zeta)$ always dominates the effect of ζ, causing $q_N^P(e,\zeta)$ to be very small. As a result, N would never prefer the Stackelberg scheme in this case and strategic predation always prevails.

As shown in Figure 3, Proposition 3 suggests that profits of N are not monotonic in ζ. When ζ is so low that S does not have the capacity to reverse-engineer, N keeps its natural monopoly position and a more capable supplier increases profits by requiring a lower amount of subsidy to engage in customization. Beyond ζ^P, higher capability also increases the amount of output necessary to keep S out of the market. The second effect reduces profits by lowering the equilibrium final good price, until it eventually dominates to give N's profits an inverted-U shape in ζ. When competition prevails for capabilities ζ^D and above, the required subsidy is reduced until it turns to a positive royalty payment from S's sales of its own variety ($R_S - w_S C$), the amount of which rises with supplier capability.

Finally, because the profit structure differs, product differentiation e and the (inverse) level of input knowledge intensity γ entail asymmetric effects on N's profit under different market structures:

Proposition 4. *Less product differentiation and low input knowledge intensity raise N's profit when $\zeta \in \left[\zeta^P, \zeta^D\right)$, but reduce it when $\zeta \geq \zeta^D$.*

Proof. See Appendix A.8. □

Recall from Propositions 1-(3) and 3-(2) that under strategic predation profits are higher for less differentiated products (large e) and less knowledge intensive inputs (large γ), as a lower extent of over-production $q_N^P(e, \zeta)$ is required to deter entry by S in the final goods market. Such product and input characteristics instead erode profits under Stackelberg by creating a cannibalization effect because of intense competition (both by cutting R_N^D and increasing T due to a lower R_S) and making reverse-engineering more costly (higher T, which translates to larger subsidies or less extractable royalties).

On the contrary, a low γ can result in large royalty payments under Stackelberg, producing higher profits, more so when paired with high-ζ suppliers. Supplier capability and input knowledge intensity therefore have a reinforcing effect on the profits of N.[13] However, this supermodular relationship is not true under predation because for less knowledge intensive inputs profits are of higher magnitude (see Appendix A.8) and peak when pairing with a more capable supplier (ζ_{max} occurs at a higher level of ζ, see Appendix A.7.1). In sum:

Lemma 2. *Whereas under Stackelberg N's earnings are highest when procuring more knowledge intensive inputs from more capable suppliers, under predation it is best off when sourcing less knowledge intensive inputs from more capable suppliers.*

Proof. Derives from Appendix A.7.1 and Proposition 4). □

The reasoning behind Lemma 2 is simply that under predation N can exploit the supplier's high capability within the relationship while less knowledge sharing about the final product makes it easier to avoid competition. Panels 3-1 and 3-2 of Figure 3 illustrate this comparison. In Panel 3-1 the maximum

[13] This is reminiscent of Defever and Toubal (2013) who show profits from outsourcing to rise with firm productivity, with the effect magnified for contract intensive inputs, a proxy obtained by measuring input relation-specificity (Nunn, 2007). In a parallel manner, pairing with a more capable supplier in our framework increases profits, but more so when sourcing more knowledge intensive inputs.

profits for N occur in the strategic predation structure (line B). Stackelberg profits are never large enough to dominate strategic predation even in the limit (line A). In contrast, in Panel 3-2 Stackelberg structure yields the highest profit when ζ is sufficiently large (line C).

6 Welfare

We now investigate the welfare effects of pairing with suppliers of different capabilities. In particular, we show how do the *ex post* profit, consumer surplus, and total surplus vary with the capability of S. In addition, what look at the level of capability that maximizes these welfare indicators.

Let us first consider consumer surplus in the North CS, defined as $\frac{1}{2}(a-p_N)q_N+\frac{1}{2}(a-p_S)q_S$ if the Stackelberg structure emerges. This gives

$$CS(\zeta)=\begin{cases}\frac{m^2}{8}\equiv CS^M & \text{when } \zeta\in\left[\zeta^M,\zeta^P\right),\\ \frac{2}{9}\left(\frac{m-2\sqrt{\frac{w_S\gamma}{\zeta}}}{e}\right)^2\equiv CS^P(\zeta) & \text{when } \zeta\in\left[\zeta^P,\zeta^D\right),\\ \frac{m^2}{32}\frac{33e^4+36e^3-156e^2-32e+128}{\left(4-3e^2\right)^2}\equiv CS^D & \text{when } \zeta\geq\zeta^D.\end{cases} \tag{18}$$

It can be shown that $CS^D\geq CS^M$ and $\frac{\partial CS^P}{\partial\zeta}\geq 0$. Moreover, $CS^P\left(\zeta^D\right)>CS^D$ holds for all $e\in[0,\overline{e})$.[14] In other words, predation always gives a higher consumer surplus than competition when N is paired with a supplier endowed with the maximum capability feasible for the strategic predation market structure. Sourcing from a more capable supplier increases predation consumer surplus by reducing the price of the final good and can surpass Stackelberg consumer surplus, which is unaffected by ζ. The resulting gain is higher for more knowledge intensive inputs and more differentiated products because of a higher level of overproduction.

Next, we examine total surplus in the North, which is defined as the sum of consumer surplus and profits,

$$TS(\zeta)=\begin{cases}\frac{m^2}{4}-\frac{w_S}{2\zeta}\equiv TS^M(\zeta) & \text{when } \zeta\in\left[\zeta^M,\zeta^P\right),\\ \frac{m}{3e}\left(m-2\sqrt{\frac{w_S\gamma}{\zeta}}\right)-\frac{w_S}{2\zeta}\equiv TS^P(\zeta) & \text{when } \zeta\in\left[\zeta^P,\zeta^D\right),\\ \frac{m^2}{8}\frac{9e^4+30e^3-60e^2-40e+64}{\left(4-3e^2\right)^2}-\frac{1+\gamma}{2}\frac{w_S}{\zeta}\equiv TS^D(\zeta) & \text{when } \zeta\geq\zeta^D.\end{cases}$$

Proposition 5 summarizes our findings:

Proposition 5. *Total surplus in the North in equilibrium*

(1) is increasing in ζ in each market structure.

(2) jumps upward (downward) at ζ^D when the products are more (less) differentiated.

[14] We can easily show that $\frac{CS^P\left(\zeta^D\right)}{CS^D}=\frac{4\left(4-4e^2+e\left(4-3e^2\right)+2e\sqrt{e(1-e)\left(4-3e^2\right)}\right)^2}{e^2\left(128-32e-156e^2+36e^3+33e^4\right)}>1$ holds throughout $e\in[0,\overline{e})$.

(3) is higher for more knowledge intensive inputs (lower γ) under both predation and competition.

Proof. Refer to Appendix A.9. □

Proposition 5-(1) states that a higher ζ always increases welfare. Although output and hence consumer surplus are independent of ζ under natural monopoly or Stackelberg, a higher ζ raises N's profit through the transfer payment (lower subsidy or higher royalty). Welfare is also increasing in ζ when an overproduction strategy for predation is adopted, despite N's profits having an inverted U-shape. This is because a higher ζ results in a larger extent of overproduction, generating a higher consumer surplus that offsets the potential welfare loss from lower profit. Proposition 5-(2) occurs because as we have established in Proposition 4, more product differentiation increases Stackelberg profits by reducing T and lowers predation profits by raising $q_N^P(e,\zeta)$. On the contrary, in the case of more homogeneous goods when predation is a more likely outcome, it also leads to higher total surplus. In this case, we can deduce:

Lemma 3. *Strategic predation can be welfare-improving when products are not differentiated by preventing S from entering competition, with the threat also leading to overproduction, lower prices, and higher consumer surplus. This is particularly true when outsourcing less knowledge intensive inputs.*

Proof. Derives directly from equations (16) and (18). □

When N blocks entry to keep its monopoly status, it also indirectly increases consumer surplus through overproduction. Looking back at Proposition 4, these benefits in welfare are biased more toward producers when sourcing less knowledge intensive inputs. Alternatively, (18) suggests that consumer surplus is the key source of welfare gains from predation for more knowledge intensive inputs. Hence, Proposition 5-(3) tells us that transferring technology through a high content of knowledge embodied in outsourced inputs increases Northern welfare by increasing consumer (producer) surplus under predation (Stackelberg). All in all, though, Lemma 3 concludes that since predation can always generate higher consumer surplus than Stackelberg and that predation (Stackelberg) profits are highest (lowest) for less knowledge intensive inputs, it is these types of outsourcing contracts for which predation is most likely to result in a higher relative total surplus.

Panels 4-1 to 4-3 of Figure 4 illustrate a comparison of welfare between predation and Stackelberg, and highlight the interactions between ζ, e, and γ. Northern welfare is highest with a moderately capable S that allows N to strategically monopolize the market when the sourced input requires less knowledge sharing (high γ) and products are sufficiently homogeneous (large e).[15] This can be seen in Panel 4-3, where strategic predation prevails as the structure with the highest total surplus (line B). In Panel 4-2, although products are less differentiated, Stackelberg yields a higher total surplus due to the high knowledge content of the input (line C). When final products are highly differentiated (e.g., e is close to 0), the Stackelberg structure always yields the highest welfare (line A in Panel 4-1). Interestingly, one can

[15] To see this, in Appendix A.7 and A.9 we show that the Stackelberg limit profit and total surplus are independent of γ, while the maximum profit and total surplus with strategic predation are always increasing in γ, and outperform those under Stackelberg if e is sufficiently large.

also reasonably argue that Stackelberg brings the highest level of technology spillovers to local suppliers for a combination of high supplier absorptive capability, knowledge intensive inputs, and a differentiated product market.

Learning by Supplying

To further highlight the role of learning by supplying, we compare our model with the case without learning by supplying. Because the Southern firm never have a chance to compete in this case, natural monopoly prevails for all $\zeta \geq \zeta^M$. The resulting consumer, producer, and total surpluses in the North are respectively given by

$$\begin{aligned} CS^{no} &= \frac{m^2}{8} \\ PS^{no} &= \frac{1}{2} \cdot \left(\frac{m^2}{4} - \frac{w_S}{\zeta} \right) \\ TS^{no} &= \frac{m^2}{4} - \frac{w_S}{2\zeta}. \end{aligned}$$

Moreover, the difference in the total surplus in cases with and without learning by supplying is

$$TS - TS^{no} = \begin{cases} 0 & \text{when } \zeta \in \left[\zeta^M, \zeta^P\right), \\ 4m - 8\sqrt{\frac{w_S \gamma}{\zeta}} - 3me & \text{when } \zeta \in \left[\zeta^P, \zeta^D\right), \\ \frac{m^2}{8} \frac{(4-3e)(2-e)}{4-3e^2} - \frac{\gamma}{2} \frac{w_S}{\zeta} & \text{when } \zeta \geq \zeta^D. \end{cases} \tag{19}$$

In Appendix A.10 we show that this difference is always non-negative, implying that total surplus with learning by supplying is superior at all times. The key to this result is that learning by supplying partly eliminates N's market power via competition when ζ corresponds to the strategic predation structure, compelling it to overproduce. Consequently, allocation is closer to the optimal (perfectly competitive) level than natural monopoly.[16] When ζ corresponds to Stackelberg, N's market power is reduced by the introduction of S's final product. While revenues may decrease due to competition, they are compensated by higher consumer surplus and lower subsidies, and the introduction of royalty earnings for highly capable suppliers.[17] We can state:

[16] Note that learning by supplying in this case raises the consumer surplus but reduces the producer surplus. To see that the consumer surplus increases in this case, recall that the consumer surplus equals $\frac{1}{2}(a - p_N) q_N$ for $\zeta < \zeta^D$. Because $q_N^P(e,\zeta) > q_N^M$ and hence $p\left(q_N^M\right) > p\left(q_N^P(e,\zeta)\right)$, it follows that $CS^D \geq CS_{no}$. To see that the producer surplus decreases for $\zeta \in \left[\zeta^M, \zeta^D\right)$, note that $q_N^P > q_N^M$ implies that $R^M(q_N) \geq R^M\left(q_N^P\right)$. Since PS^{no} equals to the profit under natural monopoly, it follows that $PS^{no} \geq \Pi_N^*$.

[17] To see that the consumer surplus increases, note that direct comparison between CS^D and CS^{no} shows that $CS^D \geq CS^{no}$ if and only if $-3e^4 + 36e^3 - 60e^2 - 32e + 64 \geq 0$. It is readily checked that this condition holds for $e \in (0,1)$. To see the possibility that the producer surplus can decrease, note that PS^{no} equals to the profit under natural monopoly, and is greater than $\Pi_N\left(q_N^P(e,\zeta)\right)$ for all ζ. Recall from Proposition 3 that at ζ^D, Π_N^* jumps downwards from $\Pi_N\left(q_N^P\left(e,\zeta^D\right)\right)$ to $\Pi_N\left(q_N^D,\zeta^D\right)$, we conclude that $PS^{no} \geq \Pi_N\left(q_N^D,\zeta\right)$ holds for some range of $\zeta > \zeta^D$.

Proposition 6. *Learning by supplying enhances social welfare in the North.*

Proof. Follows from Lemma 3, Appendix A.10, and equation (19) using the above argument. □

7 Alternative Organization Forms

A more capable Southern supplier allows N to form an outsourcing partnership at a lower cost; however, it exposes N to competition threat, prompting it to seek other organization forms to avoid risk. Here, we investigate N's organizational choice by considering two alternatives: in-house production and vertical integration.

In-house Production

We assume that N can determine whether to engage in outsourcing or in-house production after observing S's capability ζ. By choosing to produce the input in-house, the production takes place in the North and the only input is the Northern labor. Since S takes no part in the production process, N remains to be the monopolist in the final good market, and it's profit given by

$$\pi_{NH} = (a - q_N)\, q_N - w_N q_N.$$

The optimal output and the resulting profit are thus

$$\begin{aligned} q_{NH}^{*} &= \frac{m_N}{2} \\ \pi_{NH}^{*} &= \frac{m_N^2}{4}, \end{aligned}$$

where $m_N \equiv a - w_N$. If N engages in outsourcing, the results in Proposition 3 apply. Given the realization of ζ, N prefers outsourcing over in-house production if and only if $\Pi_N^{*}(\zeta) \geq \pi_{NH}^{*}$.

Since in-house production yields a flat return that depends on w_N only, the resulting equilibrium allocation is thus similar to the pattern indicated in Proposition 3 and Figure 3. Whether N prefers outsourcing over in-house production depends on the variable production costs (w_N for in-house production and w_S for outsourcing) and S's capability. For high enough w_N or low enough w_S, in-house production may become too costly so that N prefers outsourcing for some ranges of ζ. The condition depends on the potential market structure under outsourcing, which is formally given as follows:[18]

$$\begin{cases} \zeta \in \left[\zeta^M, \zeta^P\right): & \frac{m^2}{2}\left[1-\frac{1}{\gamma}\left(1-\frac{3}{4}e\right)^2\right] \geq m_N^2 \\ \zeta \in \left[\zeta^P, \zeta^D\right): & \frac{4m^2(3e+2\gamma-2)}{16\gamma+9e^2} \geq m_N^2 \\ \zeta \geq \zeta^D: & \frac{m^2}{8}\frac{3e^4+84e^3-84e^2-128e+128}{\left(4-3e^2\right)^2} \geq m_N^2. \end{cases} \tag{20}$$

Condition (20) suggests that the potential market structure under outsourcing crucially determines N's organizational choice. For the range of ζ that corresponds to natural monopoly, outsourcing occurs when N is matched with a more capable S under condition (20) because a higher ζ reduces the transfer payment required to form the partnership. Similarly, when ζ corresponds to Stackelberg, outsourcing also occurs for a more capable S. As for ζ that corresponds to strategic predation, outsourcing dominates in-house production when suppliers have an intermediate level of capability. This is because profits from outsourcing have an inverted U-shape in ζ as increasing the latter creates a trade-off between a lower transfer payment and tougher competition threat.

Integration

We next consider vertical integration as N buys and takes full control of S. It eliminates competition threat but inflicts a fixed payment and a management cost. To integrate with S, N proposes a fixed payment F and S decides whether to accept. If S agrees, N produces its input in the South, where the production involves a variable labor cost w_S and a fixed management cost $w_S f_M$. Thus, N's profit from vertical integration is given by

$$\pi_{NI} = (a - q_N)\, q_N - w_S q_N - F - w_S f_M.$$

The lower the management cost and the fixed payment, the more likely is integration. The timing is as follows.

1. Upon observing ζ, N makes the integration offer by proposing F.

2. If S accepts, N pays the fee F, specifies q_N, and produces its input in the South. If S rejects, outsourcing occurs and the model proceeds as in the original framework.

With integration, N keeps its monopoly status, and optimal output and resulting profits for N and S

[18] This is done by simply comparing π_{NH} with the maximum profit in each market structure when outsourcing emerges, i.e., $\Pi\left(\zeta^P\right)$ for natural monopoly, (26) for strategic predation, and (27) for Stackelberg.

are

$$
\begin{aligned}
q_{NI}^{*} =& \frac{m}{2} \\
\pi_{NI} =& \frac{m^2}{4} - F - w_S f_M \\
\pi_{SI} =& F.
\end{aligned}
$$

If the integration offer is rejected, profits are given by (16). S accepts the offer if the fixed payment is no less than its profit under outsourcing Π_S^*. Under integration, N maximizes profit by setting $F = \Pi_S^* (= \Pi_N^*)$. It thus prefers outsourcing if and only if

$$
\Pi_N^* \geq \frac{m^2}{4} - \Pi_N^* - w_S f_M. \tag{21}
$$

Equation (21) implies that whether the N prefers outsourcing over integration depends on how large the management cost $w_S f_M$ is, because $F = \Pi_N^*$. For a large enough management cost f_M, integration becomes too costly, thus N prefers outsourcing over integration for some range of ζ. The condition depends on the potential market structure under outsourcing, which is formally given as follows:[19]

$$
\begin{cases}
\zeta \in \left[\zeta^M, \zeta^P\right): & w_S f_M \geq \frac{m^2}{4} \frac{1}{\gamma} \left(1 - \frac{3}{4}e\right)^2 \\
\zeta \in \left[\zeta^P, \zeta^D\right): & w_S f_M \geq \frac{m^2}{4} \frac{(4-3e)^2}{16\gamma + 9e^2} \\
\zeta \geq \zeta^D: & w_S f_M \geq \frac{m^2}{16} \cdot \frac{(2-e)\left(-33e^3 + 18e^2 + 48e - 32\right)}{\left(4 - 3e^2\right)^2}.
\end{cases} \tag{22}
$$

Equation (22) yields a similar pattern of organization form as in Proposition 3 and Figure 3. When ζ correspond to natural monopoly, a higher ζ not only raises profits from outsourcing, but also entails a higher fixed payment F required to integrate S. As a result, outsourcing occurs when N is matched with a more capable supplier. Similarly, when ζ corresponds to Stackelberg, outsourcing is more attractive when suppliers are more capable and produce large royalties. When ζ corresponds to strategic predation, outsourcing occurs when ζ lies along an intermediate range. This is because Π_N^* has an inverted U-shape in ζ due to the trade-off between tougher competition threat and a lower transfer payment.

A final outtake from the comparison of different organizational forms can be summarized below:

Proposition 7. *Supplier capability and organizational form:*

(1) Outsourcing with low-ζ suppliers is only based on cost-saving motives brought about by lower wages in the South or lower management costs.

[19] We can rewrite equation (21) as $2\Pi_N^* \geq \frac{m^2}{4} - w_S f_M$. Observe that its left-hand side depends on ζ, while its right-hand side is a constant independent of ζ. Therefore, the condition for outsourcing to emerge is derived by replacing Π_N^* on the left-hand side of (21) with the maximum profit in each market structure, i.e., $\Pi\left(\zeta^P\right)$ for natural monopoly, (26) for strategic predation, and (27) for Stackelberg.

(2) When pairing with high-ζ suppliers, royalties collected from the rival take importance and distinguish between profits under outsourcing and other organizational forms.

(3) A higher ζ in both cases reinforces N's benefits from outsourcing, except under strategic predation, where overproduction associated with a higher ζ diminishes profits.

Proof. The proposition follows from the discussions in this section. □

8 Conclusion

We have developed a theoretical framework under which the pure intermediate suppliers also have the potential to produce the final product and compete with their original partners when they engage in reverse-engineering after having manufactured N's intermediate input. This learning by supplying specification allows us to capture the transformation of S from a pure supplier of the intermediate input to a firm producing both the input and the final good. The potential switch in manufacturing threatens the monopoly status of N in the final goods market, which, in turn, implies that N may want to set its production target strategically according to the technological capability level of S. Thus, we determine the organizational form of S and the market structure in the final goods market endogenously. As a result of competitive threats, the profits of N are not monotonically increasing in the capability of S. In particular, when products are less differentiated or inputs are less knowledge intensive, pairing with a moderately capable supplier facilitates entry deterrence through overproduction, yielding higher profits and total surplus in the Northern market. Moreover, we find that competition in the final goods market is more prevalent when choosing highly capable suppliers, and yield higher profits through royalties when final products are more differentiated (smaller cannibalization effect) and when knowledge intensity of the outsourced input is high (less costly reverse engineering).

One of the insights of this analysis is that technology transfer embodied through trade can be welfare improving for Northern agents, which is a relevant consideration in cases where Northern governments are engaged in trade disputes on behalf of their citizens. This finding can for example be associated with the recent US-China trade disputes (e.g. the USTR Section 301 investigation against China).[20] The Chinese government reportedly pressures or requires foreign firms to transfer their valuable intellectual property to Chinese entities. While this is deemed as unfair practice by the report, our analysis provides an alternative view of how such international technology transfer can be beneficial to both sides. In our model this is brought about by inducing competition through a mechanism of learning by supplying, which improves consumer surplus in the country of origin and creates large royalty payments for multinational firms paired with highly capable suppliers.

Our model can be extended to consider the Southern government's policy on technology transfer. Such policies should benefit the local firms via technology upgrading, and even help them become latecomers in the final good market. It would therefore be interesting to understand the optimal policy of the

[20]See https://ustr.gov/issue-areas/enforcement/section-301-investigations/section-301-china/investigation.

governments to encourage North-South licensing, and at the same time set stage for product innovation and entry into the final goods market by domestic firms. This can for example by done by pursuing the idea presented in Ghosh *et al*. (2018) and study the impact of competitive pressure on incremental innovation (to differentiate an existing product) by firms. One can also introduce IP rights into the model, the lack of which could undermine rents form royalty payments, in turn impacting technology spillover possibilities to local Southern firms. Another possible avenue of research would be to introduce and study the effects of IP rights enforcement on product innovation both upstream and downstream in our outsourcing framework of learning by supplying that assimilates a licensing environment as in Greene and Scotchmer (1995) and Gilbert and Kristiansen (2018). The amount of royalties in a licensing contract, the degree of substitutability between products, and the knowledge intensity of the input outsourced have important interactions and implications for creating incentives to innovate on both sides of the market.

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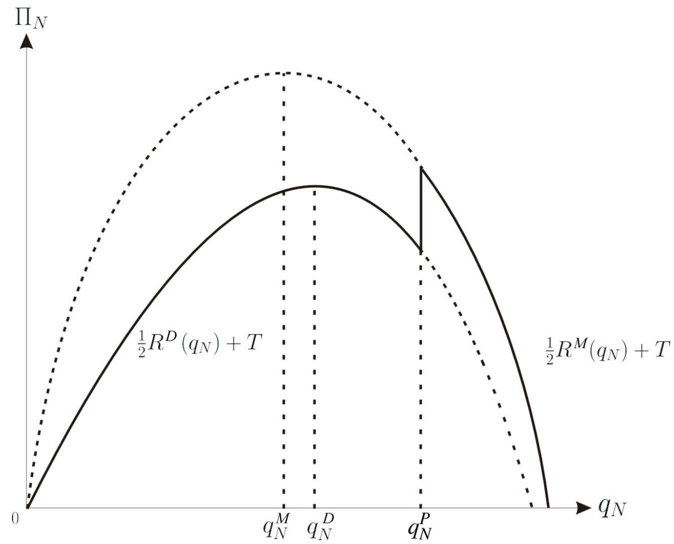

Figure 1: The Northern Profit Function Given the Up-front Transfer Payment

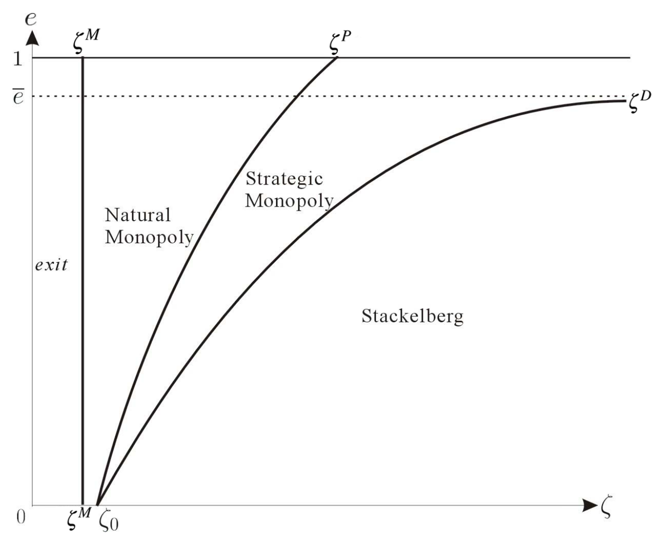

Figure 2: Equilibrium Market Structure

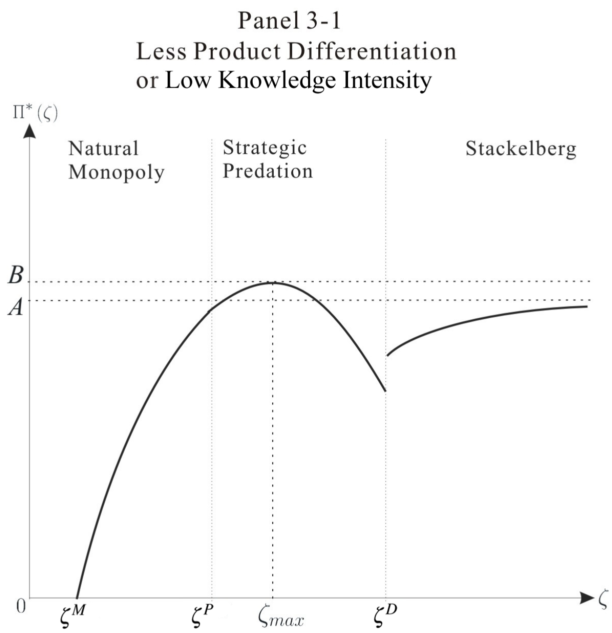

Figure 3: The Schedule of Northern Equilibrium Profit over ζ

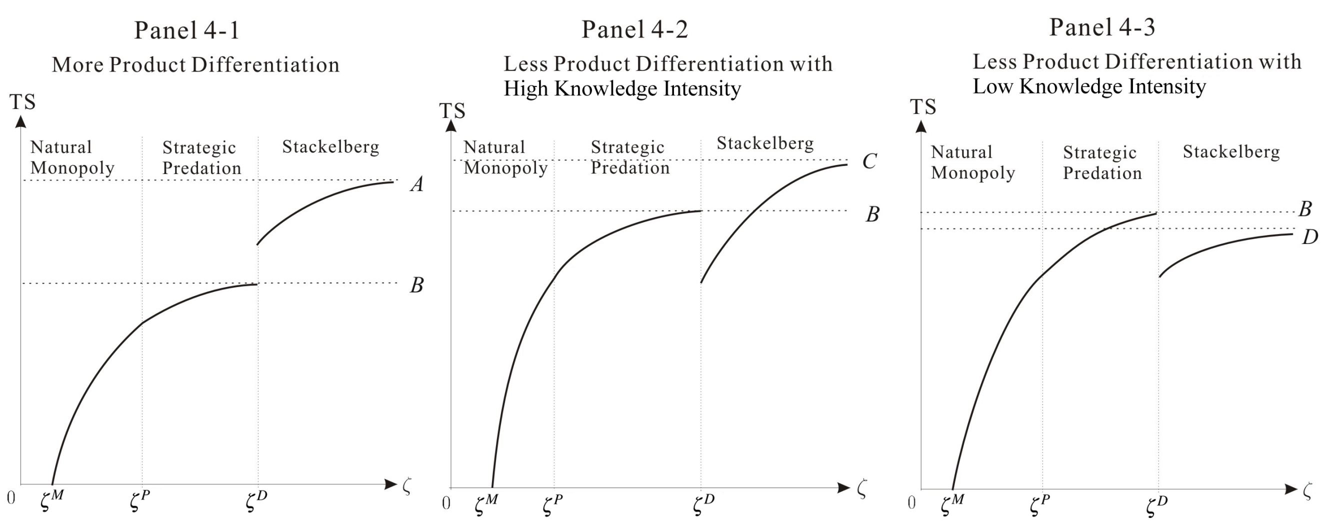

Figure 4: The Total Surplus in the Northern Final Good Market over ζ

A Appendix (For Online Publication Only)

For technical simplicity, throughout the Appendix we adopt the notation $Z \equiv \sqrt{\frac{1}{\zeta}}$. The notation Z is interpreted as the inverse of the capability for S, i.e., an increase in ζ is represented by a decrease in Z. The ranking between two different levels of ζ can be accordingly restated, say, $\zeta_1 \geq \zeta_2$ is represented by $Z_2 \geq Z_1$, and $\max\{\zeta_1, \zeta_2\}$ is represented by $\min\{Z_1, Z_2\}$. It thus follows that $Z \in (0, \infty]$, $w_S \cdot I(\zeta) = w_S Z^2$ and $w_S \cdot C(\zeta, \gamma) = w_S \gamma Z^2$. The results involving ζ in the main text are accordingly denoted with Z. In particular,

$$q_N^P(e, Z) \equiv \frac{2}{3} \frac{m - 2\sqrt{w_S \gamma} Z}{e},$$

$\zeta^M = \left(Z^M\right)^{-2}$, $\zeta^P = \left(Z^P\right)^{-2}$ and $\zeta^D = \left(Z^D\right)^{-2}$ where

$$Z^M \equiv \frac{m}{2} \frac{1}{\sqrt{w_S}},$$

$$Z^P \equiv \frac{m}{2} \frac{1}{\sqrt{w_S \gamma}} \left[1 - \frac{3}{4} e\right],$$

$$Z^D = \frac{m}{8} \frac{1}{\sqrt{w_S \gamma}} \frac{(4 - 3e)\left(4 - 3e^2\right) - 6e\sqrt{e(1-e)\left(4 - 3e^2\right)}}{4 - 3e^2} \equiv \frac{m}{8} \frac{1}{\sqrt{w_S \gamma}} f(e).$$

A.1 Proof of Proposition 1.

When the Northern firm's output is large enough, i.e., $q_N \geq \frac{2m}{3e}$, the Southern firm always chooses $q_S^* = 0$ thus reverse engineering never takes place. When $q_N < \frac{2m}{3e}$, the Southern firm reverse engineers when the resulting profit is larger than not to do so. The condition is formally given by $\Pi_S^D\left(q_N, q_S^*(q_N); T, \zeta\right) - \Pi_S^M(q_N; T, \zeta) \gtreqless 0$, which is equivalent to

$$\frac{1}{16} \cdot \left(2m + 4\sqrt{\frac{w_S \gamma}{\zeta}} - 3eq_N\right) \cdot \left(2m - 4\sqrt{\frac{w_S \gamma}{\zeta}} - 3eq_N\right) \gtreqless 0.$$

Observe that the left-hand side of the above equation is convex and decreasing in q_N. Hence, whenever $\zeta \geq \zeta_0$ and, given the requirement that $q_N \leq \frac{2m}{3e}$, the critical quantity $q_N^P(e, \zeta)$ is uniquely defined as in equation (9), such that $\Pi_S^D\left(q_N, q_S^*(q_N); T, \zeta\right) \geq \Pi_S^M(q_N; T, \zeta)$ when $q_N \leq q_N^P(e, \zeta)$.[21] Since $q_N^P(e, \zeta) \leq \frac{2m}{3e}$ trivially holds, Proposition 1-(1) is thus obtained. Proposition 1-(2) is straightforward, because if $\zeta \leq \zeta_0$ we have a negative $q_N^P(e, \zeta)$, which implies that the Northern firm deters the Southern firm from reverse-engineering by producing at any $q_N \geq 0$. In contrast, when $\zeta > \zeta_0$, the Northern firm needs to produce above $q_N^P(e, \zeta)$ in order to deter the Southern firm. Proposition 1-(3) follows immediately from simple calculations.

[21] Note that the other solution to the equation $q_N = \frac{2}{3} \frac{m + 2\sqrt{\frac{w_S \gamma}{\zeta}}}{e}$ is not a meaningful critical quantity: it does not satisfy the requirement that $q_N \leq \frac{2}{3} \frac{e}{m}$ and, thus, always leads to $q_S(q_N) < 0$, implying that S never finds transformation profitable in this case.

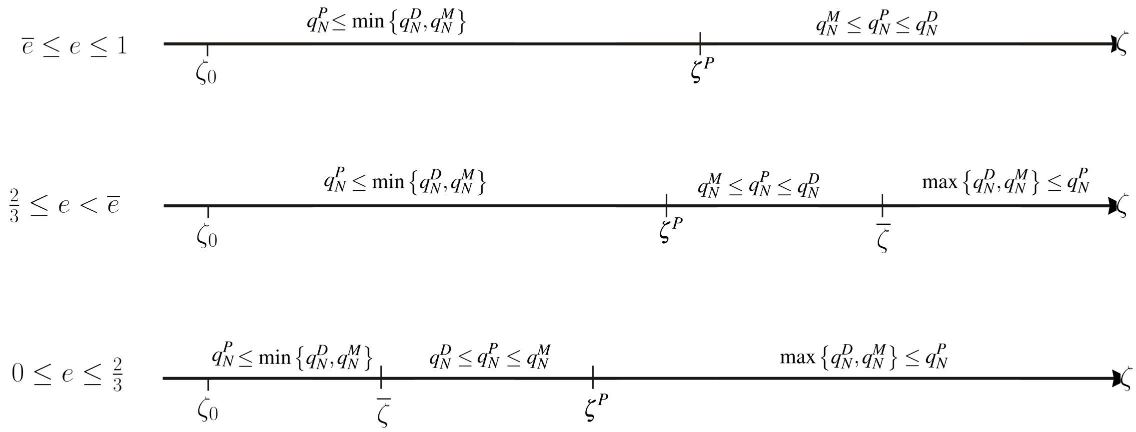

Figure 5: The Relationship between q_N^M, q_N^D and q_N^P over e and ζ

A.2 Optimal Output.

In this section we show that the optimal output is given by the following lemma.

Lemma A.1 *The Northern firm's optimal output given the Southern firm's capability ζ is as follows:*

(1) *If $\zeta < \zeta^P$, N sets $q_N^* = q_N^M$ and keeps its status as a monopoly in the final goods market.*

(2) *If $\zeta^P \le \zeta < \zeta^D$, N sets $q_N^* = q_N^P(e,\zeta)$ to keep its monopoly status.*

(3) *If $\zeta^D \le \zeta$, N specifies $q_N^* = q_N^D$ and becomes a Stackelberg leader in the final goods market.*

To proof Lemma A.1, we first introduce an auxiliary lemma regarding how ζ and e affect the ranking between q_N^M, q_N^D and $q_N^P(e,Z)$. It is readily checked that $q_N^D = q_N^P(e,Z)$ at $\overline{\zeta} = \left(\overline{Z}\right)^{-2}$ where

$$\overline{Z} \equiv \frac{m}{2}\frac{1}{\sqrt{w_S\gamma}} \cdot \left(1 - \frac{3}{4}e\frac{4-2e}{4-3e^2}\right).$$

The following Lemma A.2 thus follows, and its results are illustrated in Figure 5.

Lemma A.2 *Suppose that $Z \le \frac{m}{2}\frac{1}{\sqrt{w_S\gamma}}$ holds, the ranking between q_N^M, q_N^D and $q_N^P(e,Z)$ are obtained as follows:*

(1) $q_N^P(e,Z) \le \min\left\{q_N^M, q_N^D\right\}$ *when $\overline{Z} \le Z$ and $e \le \frac{2}{3}$, or when $Z^P \le Z$ when $e \ge \frac{2}{3}$.*

(2) $q_N^M \le q_N^P(e,Z) \le q_N^D$ *when $Z \in \left[\overline{Z}, Z^P\right]$ and $e \in \left[\frac{2}{3}, \overline{e}\right)$, or $Z \le Z^P$ and $e \ge \overline{e}$.*

(3) $q_N^D \le q_N^P(e,Z) \le q_N^M$ *when $Z \in \left[Z^P, \overline{Z}\right]$ and $e \le \frac{2}{3}$.*

(4) $q_N^P(e,Z) \geq \max\left\{q_N^M, q_N^D\right\}$ *when* $Z \leq \min\left\{\overline{Z}, Z^P\right\}$ *and* $e < \overline{e}$.

(5) $\overline{Z}$ *can only be positive when* $e < \overline{e}$.

(6) *Both* $\overline{Z}$ *and* Z^P *are decreasing in e.*

Proof. It is readily checked that $q_N^M \gtreqless q_N^P(e,Z)$ holds if and only if $Z \gtreqless Z^P$, $q_N^D \gtreqless q_N^P(e,Z)$ holds if and only if $Z \gtreqless \overline{Z}$, and the relationship that $Z^P \gtreqless \overline{Z}$ holds if and only if $e \gtreqless \frac{2}{3}$. Both Z^P and $\overline{Z}$ must be positive because ζ is positive. Since $e \in [0,1]$ by setting, the requirement that $Z^P > 0$ holds trivially. Simple calculation also suggests $\overline{Z} > 0$ holds if and only if $e < \overline{e} \equiv \frac{\sqrt{33}}{3} - 1 \approx 0.915$. Claims (1) to (5) thus follow. Since $e \in [0,1]$ ensures both $\frac{\partial Z^P}{\partial e} < 0$ and $\frac{\partial \overline{Z}}{\partial e} < 0$ to hold, claim (6) accordingly follows. Finally, both Z^P and $\overline{Z}$ are no larger than $\frac{m}{2}\frac{1}{\sqrt{w_S\gamma}}$, thus the requirement that $Z \leq \frac{m}{2}\frac{1}{\sqrt{w_S\gamma}}$ never fails. $\square$

With Lemma A.2, we complete the proof of Lemma A.1 by combining the following arguments. Notice that, the following arguments suggests that ties take place at $Z = Z^P$ where both $q_N^P(e,Z)$ and q_N^M can be supported in equilibrium, and at $Z = Z^D$ where both $q_N^P(e,Z)$ and q_N^D can be supported. We thus impose the tie-breaking condition, where $q_N^* = q_N^P(e,Z)$ when $Z = Z^P$, and $q_N^* = q_N^D$ when $Z = Z^D$.

A.2.1 Optimal Output when $q_N^P(e,Z) \leq \min\left\{q_N^D, q_N^M\right\}$.

This situation takes place under two cases: 1) $Z \geq \overline{Z}$ and $e \leq \frac{2}{3}$, and 2) $Z \geq Z^P$ when $e \geq \frac{2}{3}$. In either cases, it is clear that N always keeps its monopoly status by setting $q_N = q_N^M$, which entails a profit $\Pi_N^M\left(q_N^M;T\right) = \frac{1}{2}R^M\left(q_N^M\right) - T$. Moreover, S reverse-engineers and produces the final good only if N sets a level that is below $q_N^P(e,Z)$. Because $R^D(q_N)$ is concave in q_N, it follows that $R^D\left(q_N^D\right) > R^D(q_N)$ holds for all $q_N^D > q_N$. Therefore, if the Northern firm wants to be a Stackelberg leader its optimal output will be $q_N = q_N^P(e,Z) - \varepsilon$ where ε is infinitesimal. The profit evaluated locally is thus $\Pi_N^D\left(q_N^P(e,Z);T\right) = \frac{1}{2}R^D\left(q_N^P(e,Z)\right) - T$. The concavity of $R^M(q_N)$ implies that $R^M\left(q_N^M\right) > R^M(q_N)$ holds for all $q_N^M > q_N$. Also note that $R^M(q_N) \geq R^D(q_N)$ holds for all q_N. We can thus conclude that

$$
\begin{aligned}
\Pi_N^D\left(q_N^P(e,Z);T\right) \leq & \Pi_N^M\left(q_N^P(e,Z);T\right) \\
< & \Pi_N^M\left(q_N^M;T\right).
\end{aligned}
$$

As a result, the Northern firm's optimal decision in this case is choosing $q_N^* = q_N^M$ and monopolizing the market.

A.2.2 Optimal Output when $q_N^M \leq q_N^P(e,Z) \leq q_N^D$.

The case takes place under two situations: when (1) $Z \in \left[\overline{Z}, Z^P\right]$ and $e \in \left[\frac{2}{3}, \overline{e}\right)$, or when (2) $Z \leq Z^P$ and $e \geq \overline{e}$. The argument is similar to the case above. The concavity of both $R^M(q_N)$ and $R^D(q_N)$ implies that N either sets $q_N = q_N^P(e,Z)$ to monopolize the market, or sets $q_N = q_N^P(e,Z) - \varepsilon$ where ε is infinitesimal then acts as the Stackelberg leader. Since $R^M(q_N) \geq R^D(q_N)$ holds for all q_N, we conclude that (in the limit) $\Pi_N^M\left(q_N^M;T\right) > \Pi_N^D\left(q_N^P(e,Z);T\right)$. Therefore, the optimal decision by N is to set $q_N^* = q_N^P(e,Z)$ and monopolize the market.

A.2.3 Optimal Output when $q_N^D \le q_N^P(e,Z) \le q_N^M$.

This case only takes place when $Z \in \left[Z^P, \overline{Z}\right]$ and $e \le \frac{2}{3}$. Given the transfer payment T and the property that the Southern firm never engages in reverse-engineering when $q_N \ge q_N^P(e,Z)$, the Northern firm's output is either q_N^M or q_N^D. The Southern firm engages in reverse-engineering if N chooses the former and does not do so if it chooses the latter. The resulting profits of the Northern firm in the two cases are respectively $\Pi_N^D\left(q_N^D;T\right) = \frac{m^2}{8}\cdot\frac{(2-e)^2}{4-3e^2} - T$ and $\Pi_N^M\left(q_N^M;T\right) = \frac{m^2}{8} - T$. It is clear that $\Pi_N^M\left(q_N^M;T\right) \ge \Pi_N^D\left(q_N^D;T\right)$ holds for all $e \le \frac{2}{3}$. Therefore, the Northern firm produces $q_N^* = q_N^M$ and S does not engage in reverse-engineering.

A.2.4 Optimal Output when $\max\left\{q_N^D, q_N^M\right\} \le q_N^P(e,Z)$.

This case occurs when either (1) $Z \le Z^P$ and $e \le \frac{2}{3}$, or when (2) $Z \le \overline{Z}$ and $e \in \left[\frac{2}{3}, \overline{e}\right)$. We can equivalently state these conditions as $Z \le \min\left\{\overline{Z}, Z^P\right\}$ and $e < \overline{e}$. N either sets q_N^D and become a Stackelberg leader, or sets $q_N^P(e,Z)$ to deter S from entry in the final goods market. The resulting profits are respectively $\Pi_N^D\left(q_N^D\right) = \frac{m^2}{8}\cdot\frac{(2-e)^2}{4-3e^2} - T$ and $\Pi_N^M\left(q_N^P(e,Z)\right) = \frac{\left(m-2\sqrt{w_S\gamma Z}\right)\cdot\left(4\sqrt{w_S\gamma Z}+3em-2m\right)}{9e^2} - T$. It is readily verified that $\Pi_N^D\left(q_N^D\right) - \Pi_N^M\left(q_N^P(e,Z)\right) \gtreqless 0$ holds if and only if

$$\underbrace{\frac{8}{9e^2}w_S\gamma Z^2}_{+} - \underbrace{\frac{2m}{9e^2}\cdot(4-3e)\sqrt{w_S\gamma}Z}_{+} + \underbrace{\frac{m^2}{8}\cdot\frac{(2-e)^2}{4-3e^2} - \frac{m^2}{9}\cdot\frac{3e-2}{e^2}}_{+} \gtreqless 0. \tag{23}$$

The left-hand side of (23) is convex in Z, which reaches its minimum value $\frac{m^2}{2}\frac{e(e-1)}{4-3e^2} < 0$ at Z^P and takes a positive value when $Z = 0$. Therefore, $\Pi_N^D\left(q_N^D\right) - \Pi_N^M\left(q_N^P(e,Z)\right)$ is decreasing in Z for the following two cases: when $e \le \frac{2}{3}$ and $Z \le Z^P$, and when $e \in \left[\frac{2}{3}, \overline{e}\right)$ and $Z \le \overline{Z}\left(< Z^P\right)$. We therefore know that there exists a cutoff $Z^D \in \left(0, Z^P\right]$ such that $\Pi_N^D\left(q_N^D\right) - \Pi_N^M\left(q_N^P(e,Z)\right) \ge 0$ holds for $Z \le Z^D$.

Observe that when $e \le \frac{2}{3}$ we must have $Z^D \in \left(0, Z^P\right]$. Thus, in this case we know that $q_N^* = q_N^D$ when $Z \le Z^D$ and $q_N^* = q_N^P$ when $Z > Z^D$. But for the case that $e \in \left[\frac{2}{3}, \overline{e}\right)$, we further require $Z^D < \overline{Z}$ for both q_N^D and q_N^M to be possible equilibrium outcome within the interval $\left[0, \overline{Z}\right]$. To check this, note that

$$\Pi_N^D\left(q_N^D\right) - \Pi_N^M\left(q_N^P\left(e,\overline{Z}\right)\right) = \frac{m^2}{8}\frac{e(2-e)\left(3e^2+6e-8\right)}{\left(4-3e^2\right)^2},$$

and is negative for $e \in \left[\frac{2}{3}, \overline{e}\right)$. Since $\Pi_N^D\left(q_N^D\right) - \Pi_N^M\left(q_N^P\left(e,\overline{Z}\right)\right)$ is positive at $Z = 0$, and is 0 at Z^D, we conclude that in this case $Z^D \in \left[0, \overline{Z}\right]$. Thus, $q_N^* = q_N^D$ when $Z \le Z^D$ and $q_N^* = q_N^P$ when $Z > Z^D$. $\square$

A.3 $\frac{\partial}{\partial e}\zeta^D \geq 0$ and $\lim\limits_{e\to\bar{e}}\zeta^D = \infty$

Observe that ζ^D depends on e through $f(e)$ only. Moreover,

$$\frac{\partial f(e)}{\partial e} = \frac{3\cdot\left[e^2\cdot\left(-6e^3+3e^2+16e-12\right)-\left(4-3e^2\right)\cdot\sqrt{e^3\cdot(1-e)\cdot(4-3e^2)}\right]}{(4-3e^2)\cdot\sqrt{e^3\cdot(1-e)\cdot(4-3e^2)}}.$$

It can be checked that this value is non-positive within $e\in[0,\bar{e})$, and that $\lim\limits_{e\to\bar{e}}Z^D = 0$. We thus conclude that $\frac{\partial}{\partial e}\zeta^D \geq 0$ and $\lim\limits_{e\to\bar{e}}\zeta^D = \infty$.

A.4 Proof of Lemma 1.

From the bargaining function, it is readily shown that the optimal transfer payment is given by

$$T^* = \begin{cases} \frac{1}{2}\frac{w_S}{\zeta} \equiv T^M(\zeta) & \text{when } \zeta < \zeta^D \\ \frac{1}{2}\left(\frac{w_S}{\zeta}+w_S\frac{\gamma}{\zeta}-R_S\left(q_N,q_S^*(q_N)\right)\right) \equiv T^D(\zeta) & \text{when } \zeta \geq \zeta^D. \end{cases}$$

Note that the above equation is equivalent to (15) by plugging-in R_S, and observe that both $T^M(\zeta)$ and $T^D(\zeta)$ are decreasing in ζ. Obviously $T^* = T^M(\zeta) > 0$ holds when $\zeta < \zeta^D$. For the case that $\zeta \geq \zeta^D$, note that $q_S^* > 0$ holds, and that in Appendix A.1 the inequality $\Pi_S^D\left(q_N,q_S^*(q_N);T,\zeta\right) > \Pi_S^M(q_N;T,\zeta)$, or equivalently

$$\frac{1}{2}R_N^D(q_N,q_S^*(q_N)) + R_S(q_N,q_S^*(q_N)) - w_S\frac{\gamma}{\zeta} \geq \frac{1}{2}R_N^M(q_N),$$

holds strictly for the Southern firm. Because $R_N^M(q_N) > R_N^D\left(q_N,q_S^*(q_N)\right)$ holds given q_N, it thus follows that $w_S\frac{\gamma}{\zeta} - R_S\left(q_N,q_S^*(q_N)\right) < 0$ holds in such a case. As a result, $T^D(\zeta) < \frac{1}{2}\frac{w_S}{\zeta} = T^M(\zeta)$ holds for all $\zeta \geq \zeta^D$.

Observe that $\lim_{\zeta\to\infty}T^D(\zeta) = -\frac{1}{2}R_S < 0$ and that $T^D(\zeta) < 0$ holds if and only if

$$\zeta > \frac{(1+\gamma)w_S}{m^2}\frac{16\left(4-3e^2\right)^2}{(5e^2+2e-8)(3e^2+6e-8)} \equiv \zeta^T.$$

Recall ζ^D, we know that

$$\frac{\zeta_T}{\zeta_D} = \underbrace{\frac{1+\gamma}{\gamma}}_{\in[1,2]}\underbrace{\frac{\left[(4-3e)\left(4-3e^2\right)-6e\sqrt{e(1-e)(4-3e^2)}\right]^2}{4(5e^2+2e-8)(3e^2+6e-8)}}_{\leq 1,\text{decreasing in } e,\ e\in[0,\bar{e}]},$$

and is greater than 1 for low enough γ and e. Because $T^D(\zeta)$ is decreasing in ζ, we know that $T^D(\zeta) < 0$ holds only for large enough ζ under given parameters (γ, e) (for small enough γ and e all $\zeta \geq \zeta^D$ are large enough). The above results together implies that T^* is decreasing in ζ, jumps downward at ζ^D, and becomes negative for high enough ζ that corresponds to Stackelberg.

A.5 Proof of Proposition 2.

The optimal output and contract together yields the profits of both the Northern and the Southern firms as equation (16). The profits must be positive thus the contract can be accepted for both firms to operate. Here we show that that the profits are positive if and only if $Z \leq Z^M$ by combining the following discussions to the four cases suggested by Lemma A.1. The subscripts N and S to Π are suppressed since in equilibrium both firms shares the aggregate profit equally. Also notice that, we impose the tie-breaking condition where $q_N^* = q_N^P(e,Z)$ when $Z = Z^P$, and $q_N^* = q_N^D$ when $Z = Z^D$.

A.5.1 There exists $Z^M \geq \max\left\{\overline{Z}, Z^P\right\}$ when $q_N^P(e,Z) \leq \min\left\{q_N^D, q_N^M\right\}$.

This case takes place when either (1) $e \leq \frac{2}{3}$ and $Z \geq \overline{Z}$, or (2) $e \geq \frac{2}{3}$ and $Z \geq Z^P$. The optimal contract in this case suggests that N sets T^* such that $\Pi^M\left(q_N^M, T^*; Z\right) = \frac{1}{2}\left(\frac{m^2}{4} - w_S Z^2\right)$. It is thus clear that $Z \leq Z^M$ must hold so N offers the contract, and S accepts it.

When $e \leq \frac{2}{3}$, it is readily checked that the $Z^M/\overline{Z} = \sqrt{\gamma}/\left(1 - \frac{3}{4}e\frac{4-2e}{4-3e^2}\right)$ reaches its minima at $\gamma = 1$ with a denominator that is no greater than 1. When $e > \frac{2}{3}$, the ratio $Z^M/Z^P = \sqrt{\gamma}/\left(1 - \frac{3}{4}e\right)$ reaches its minima at $\gamma = 1$ and its denominator is no greater than 1. We thus conclude that $Z^M \geq \max\left\{\overline{Z}, Z^P\right\}$ holds for all $e \in [0,1]$, hence both firms agree with the contract whenever $Z \in \left[\max\left\{\overline{Z}, Z^P\right\}, Z^M\right]$.

A.5.2 No Firms Exit the Market when $q_N^D \leq q_N^P(e,Z) \leq q_N^M$.

This case occurs when $e \leq \frac{2}{3}$ and $Z \in \left[Z^P, \overline{Z}\right]$. Given the optimal output, the optimal contract implies that N sets T^*, which gives $\Pi^M\left(q_N^M, T^*; Z\right) = \frac{1}{2}\left(\frac{m^2}{4} - w_S Z^2\right)$. This requires $Z \leq Z^M$ for N to be willing to offer the contract to S. We have shown that $Z^M/\overline{Z} \geq 1$ holds when $e \leq \frac{2}{3}$. Accordingly, both firms agree with the contract when $e \leq \frac{2}{3}$ and $Z \in \left[Z^P, \overline{Z}\right]$.

A.5.3 No Firms Exit the Market when $q_N^M \leq q_N^P(e,Z) \leq q_N^D$.

This case occurs when (1) $Z \in \left[\overline{Z}, Z^P\right]$ and $e \in \left[\frac{2}{3}, \overline{e}\right)$, or when (2) $Z \in \left(0, Z^P\right]$ and $e \geq \overline{e}$. Within the required interval we show that $\Pi^M\left(q_N^P(e,Z), T^*; Z\right) = R^M\left(q_N^P(e,Z)\right) - w_S Z^2 > 0$ holds for sure, and so N always offers the contract to S.

The optimal contract and output together yields

$$\Pi^M\left(q_N^P(e,Z), T^*; Z\right) = \frac{1}{2}\left[\underbrace{-\left(\frac{16}{9e^2} + \frac{1}{\gamma}\right) \cdot w_S \gamma Z^2}_{-} + \underbrace{\frac{4m \cdot (4-3e)}{9e^2}\sqrt{w_S \gamma} Z}_{+} + \frac{2m^2}{9e^2} \cdot (3e-2)\right], \tag{24}$$

which is quadratic concave in Z. Since $e \geq \frac{2}{3}$ ensures that $\frac{2m^2}{9e^2} \cdot (3e-2) \geq 0$, it follows that $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) \geq 0$ holds for all $Z \in \left[0, Z^{c1}\right]$ where

$$Z^{c1} \equiv \frac{m \cdot \left(8\gamma - 6\gamma e + 3 \cdot \sqrt{2} \cdot \sqrt{e^2 \gamma \cdot (2\gamma + 3e - 2)}\right)}{16\gamma + 9e^2} \frac{1}{\sqrt{w_S \gamma}} > 0,$$

is the largest root for $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) = 0$ to hold. Note that when $Z = Z^P$,the assumption that $\gamma \geq 1$ ensures that $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) \geq 0$, i.e.,

$$\Pi^M \left(q_N^P\left(e, Z^P\right), T^*; Z^P\right) = \underbrace{\frac{1}{2} \cdot \frac{m^2}{64\gamma}}_{+} \cdot \left[\underbrace{16 \cdot (\gamma - 1)}_{+ \because \gamma \geq 1} + \underbrace{3e \cdot (8 - 3e)}_{+}\right] \geq 0. \tag{25}$$

Since $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) \geq 0$ holds for all $Z \in \left[0, Z^{c1}\right]$, (25) implies that $Z^P < Z^{c1}$. We thus conclude that $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) \geq 0$ holds for $Z \in \left[\overline{Z}, Z^P\right]$ when $e \in \left[\frac{2}{3}, \overline{e}\right)$, and $Z \in \left(0, Z^P\right]$ when $e \geq \overline{e}$.

A.5.4 No Firms Exit the Market when $\max\left\{q_N^D, q_N^M\right\} \leq q_N^P(e,Z)$.

This case occurs when (1) $Z \leq Z^P$ and $e \leq \frac{2}{3}$, or when (2) $Z \leq \overline{Z}$ and $e \in \left[\frac{2}{3}, \overline{e}\right)$. Moreover, when $Z^D < Z$, N sets q_N^P to deter S from becoming a final good producer; while when $Z \leq Z^D$, N sets $q_N^* = q_N^D$ to compete as a Stackelberg leader. Accordingly, the current case is further categorized into the following three situations.

(1) $e \in \left[\frac{2}{3}, \overline{e}\right)$ **and** $Z \in \left[Z^D, \overline{Z}\right]$**:**

In this situation N sets $q_N^* = q_N^P(e,Z)$ to deter S from entering the final goods market. Each firm's equilibrium profit is thus captured by equation (24). As we have shown earlier, when $e \geq \frac{2}{3}$ both firms make nonnegative equilibrium profits thus the contract is offered and accepted.

(2) $e \leq \frac{2}{3}$ **and** $Z \in \left(Z^D, Z^P\right]$**:**

This situation is similar to the previous one, except that it takes place when $e \leq \frac{2}{3}$, thus the interception term in equation (24) is no longer positive. As a result, $\Pi^M \left(q_N^P(e,Z)\right) \geq 0$ holds for all $Z \in \left[Z^{c2}, Z^{c1}\right]$, where Z^{c2} and Z^{c1} are both nonnegative and such that $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) = 0$. To verify our claim that $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) \geq 0$ holds for all $Z \in \left(Z^D, Z^P\right]$, we show that $\Pi^M \left(q_N^P(e,Z), T^*; Z\right) \geq 0$ holds at Z^D and Z^P thus we can conclude that the interval $Z \in \left(Z^D, Z^P\right]$ is included in $\left[Z^{c2}, Z^{c1}\right]$.

When $Z = Z^P$, the profit is nonnegative under the setting that $\gamma \geq 1$ as shown by equation (25). When

$Z \to Z^D$, we have $\Pi^M \left(q_N^P \left(e, Z^D\right), T^*; Z^D\right) \to \frac{1}{2} \frac{m^2}{64\gamma \cdot \left(4-3e^2\right)} \cdot X$, where

$$X \equiv \underbrace{\left(16e^2 - 64e + 64\right)}_{+} \cdot \gamma + 63e^4 - 108e^3 + 12e^2 + 96e - 64 + \left(48e - 36e^2\right) \cdot \sqrt{e \cdot (1-e) \cdot (4-3e^2)}.$$

is increasing in γ. Our setting that $\gamma \geq 1$ implies that the minimum of X takes place when $\gamma = 1$. It is checked that X is positive within $e \in \left[0, \frac{2}{3}\right]$. Hence, we conclude that $\Pi^M \left(q_N^P \left(e, Z^D\right), T^*; Z^D\right) \geq 0$ within $e \in \left[0, \frac{2}{3}\right]$ for all $\gamma \geq 1$. Therefore, Z^D and Z^P are both included in the interval $\left[Z^{c2}, Z^{c1}\right]$, which implies that $\Pi^M \left(q_N^P \left(e, Z^D\right), T^*; Z^D\right) \geq 0$ holds throughout the interval $\left(Z^D, Z^P\right]$ when $e \leq \frac{2}{3}$.

(3) $e \in \left[\frac{2}{3}, \bar{e}\right)$ **and** $Z \in \left[0, Z^D\right]$**, or** $e \leq \frac{2}{3}$ **and** $Z \in \left[0, Z^D\right]$**:**

This case is equivalent to the case that $e < \bar{e}$ and $Z \leq Z^D$. In this case the Stackelberg structure emerges and the profit $\Pi^D \left(q_N^D, T^*; Z\right)$ is decreasing in Z. Since we have shown that $\Pi^M \left(q_N^P \left(e, Z^D\right), T^*; Z^D\right) \geq 0$ for all $e \in [0, \bar{e})$ earlier, we can complete the proof by showing that $\Pi^D \left(q_N^D, T^*; Z^D\right) \geq \Pi^M \left(q_N^P \left(e, Z^D\right), T^*; Z^D\right)$. With this property established, it is thus straightforward that $\Pi^D \left(q_N^D, T^*; Z\right) \geq 0$ holds for all $Z \leq Z^D$.

Notice that $R^D \left(q_N^D\right) = R^M \left(q_N^P \left(e, Z^D\right)\right)$ holds since Z^D is such that N is indifferent between producing at the Stackelberg level and the strategic predation level, i.e., $\frac{1}{2} R^D \left(q_N^D\right) - T = \frac{1}{2} R_N^M \left(q_N^P \left(e, Z^D\right)\right) - T$. We therefore obtain

$$\Pi^D \left(q_N^D, T^*; Z^D\right) = \frac{1}{2} \left[R_S \left(q_N^D\right) - w_S \gamma \cdot \left(Z^D\right)^2 + R^M \left(q_N^P \left(e, Z^D\right)\right) - w_S \cdot \left(Z^D\right)^2\right].$$

The underlying case implies that $\max \left\{q_N^D, q_N^M\right\} \leq q_N^P (e, Z)$ holds. Therefore, by Proposition 1, S always prefers to expand operations and produce the final good if N chooses $q_N = q_N^D$, i.e.,

$$\frac{1}{2} \left[R_S \left(q_N^D\right) - w_S \gamma Z^2 + R^D \left(q_N^D\right) - w_S Z^2\right] \geq \frac{1}{2} \left[R^M \left(q_N^D\right) - w_S Z^2\right]$$

holds for $Z \leq Z^D$. Since $R^M (q_N) > R^D (q_N)$ holds for all $q_N \geq 0$ when $q_S > 0$, the inequality above implies that

$$R_S \left(q_N^D\right) - w_S \gamma \cdot Z^2 \geq R^M \left(q_N^D\right) - R^D \left(q_N^D\right) > 0 \; \forall Z \leq Z^D.$$

Recall that $R^D \left(q_N^D\right) = R^M \left(q_N^P \left(e, Z^D\right)\right)$, it follows that

$$\begin{aligned}
&\Pi^D \left(q_N^D, T^*; Z^D\right) - \Pi^M \left(q_N^P \left(e, Z^D\right), T^*; Z^D\right) \\
=& R_S \left(q_N^D\right) - w_S \gamma \cdot \left(Z^D\right)^2 + R^D \left(q_N^D\right) - R^M \left(q_N^P \left(e, Z^D\right)\right) \\
=& R_S \left(q_N^D\right) - w_S \gamma \cdot \left(Z^D\right)^2 > 0.
\end{aligned}$$

Consequently, both N and S make positive profit when the Stackelberg structure takes place so they agree with the contract.

A.6 Trade Balance Condition.

The labor markets in each region clear as long as $L_j = \sum_k L_j^k$, where $k = \{M, 0\}$ denotes the manufacturing and homogeneous sectors respectively. We can further decompose the labor devoted to the homogeneous sector in region j as $L_j^0 = L_j^{0X} + L_j^{0D}$, where L_j^{0D} (L_j^{0X}) denotes the labor force producing the homogeneous product supplying the domestic (foreign) market. The supply of the homogeneous product in the South in equilibrium is thus $q_S^0 = w_S L_S^{0D} + w_N L_N^{0X}$. The Southern demand to the homogeneous product in equilibrium is defined as $q_S^0 = w_S L_S^{M*} + w_S L_S^{0D} + w_S L_S^{0X} + E\left(\Pi_S^*\right)$.

Let $\Phi^{\varnothing}$, Φ^M , Φ^P, and Φ^D denote the sets of ζ such that outsourcing does not emerge on the market, the natural monopoly structure, the strategic predation structure, and the Stackelberg structure, respectively. According to Proposition 2, the sets of capability are defined as

$$\Phi^{\varnothing} = \left\{\zeta | \zeta < \zeta^M\right\},$$
$$\Phi^D = \left\{\zeta | \zeta^D \leq \zeta \cap e < \bar{e}\right\},$$
$$\Phi^M = \left\{\zeta | \zeta \in \left[\zeta^M, \zeta^P\right)\right\},$$
$$\Phi^P = \begin{cases} \left\{\zeta | \zeta \in \left[\zeta^P, \zeta^D\right)\right\} & \text{if } e < \bar{e}, \\ \left\{\zeta | \zeta^P \leq \zeta\right\} & \text{if } e \geq \bar{e}. \end{cases}$$

Equating the demand and supply, the trade balance condition in equilibrium is therefore

$$w_S L_S^{0X} - w_N L_N^{0X} = -w_S L_S^M - E\left(\Pi_S^*\right),$$

where the equilibrium levels of $E\left(\Pi_S^*\right)$ is defined by

$$\begin{aligned} E\left(\Pi^*\right) = \frac{1}{2} \cdot \Bigg\{ & \int_{\zeta \in \Phi^M} \left(\frac{m^2}{4} - \frac{w_S}{\zeta}\right) g(\zeta)\, d\zeta \\ & + \int_{\zeta \in \Phi^P} \left[\frac{2 \cdot \left(m - 2\sqrt{w_S \gamma \frac{1}{\zeta}}\right) \cdot \left(4\sqrt{w_S \gamma \frac{1}{\zeta}} + 3e \cdot m - 2m\right)}{9e^2} - \frac{w_S}{\zeta}\right] g(\zeta)\, d\zeta \\ & + \int_{\zeta \in \Phi^D} \left[\frac{m^2}{16} \frac{3e^4 + 84e^3 - 84e^2 - 128e + 128}{\left(4 - 3e^2\right)^2} - (1+\gamma)\frac{w_S}{\zeta}\right] g(\zeta)\, d\zeta \Bigg\}, \end{aligned}$$

and $w_S L_S^{M*}$ is obtained as follows by our analysis in the main text:

$$\begin{aligned} w_S L_S^{M*} = & \int_{\zeta \in \Phi^M} w_S q_N^M g(\zeta)\, d\zeta + \int_{\zeta \in \Phi^P} w_S q_N^P(e, \zeta) g(\zeta)\, d\zeta + \int_{\zeta \in \Phi^D} w_S q_N^D g(\zeta)\, d\zeta + \int_{\zeta \in \Phi^D} w_S q_S^D g(\zeta)\, d\zeta \\ & + \int_{\zeta \notin \Phi^{\varnothing}} w_S I(\zeta) g(\zeta)\, d\zeta + \int_{\zeta \in \Phi^D} w_S C(\zeta, \gamma) g(\zeta)\, d\zeta. \end{aligned}$$

It is clear to see that $w_S L_S^{0X} - w_N L_N^{0X} < 0$, namely, the South imports the homogeneous product form the North with the income generated from the manufacturing sector.

With the assumption that L_N and L_S are sufficiently large, the labor markets in both countries clear by $L_N^{0X} = L_N - L_N^{0D}$ and $L_S^{0X} = L_S - L_S^{M*} - L_S^{0D}$. Rearranging we have $L_S^{0X} - L_N^{0X} = \left(L_S - L_N - L_S^{M*}\right) + L_N^{0D} -$

L_S^{0D}. Therefore, for any large enough L_N and L_S, and any pairs of $\left(L_S^{0X}, L_N^{0X}\right)$ satisfying the trade balance condition, there exists some pair of $\left(L_S^{0D}, L_N^{0D}\right)$ such that the labor markets clear. Hence, in equilibrium there always exists some $\left(L_S^{0X*}, L_N^{0X*}, L_S^{0D*}, L_N^{0D*}\right)$.

A.7 Proof of Proposition 3.

Appendix A.7.1 inspects the shape of the profit schedule. In particular, it shows that the profit has a local maximum in the interval $\zeta \in \left[\zeta^P, \zeta^D\right)$, and tends to a constant as ζ becomes arbitrarily large. In Appendix A.7.2 we inspect the conditions for which of the above two profit level is larger than the other. These findings suggest that the schedule of the Northern equilibrium profit over Z follows the pattern suggested in Figure 3.

A.7.1 The Shape of the Profit Schedule.

It is clear that $\Pi^M\left(q_N^M, T^*; Z\right)$ is decreasing in Z. We also find that $\Pi^M\left(q_N^M, T^*; Z^P\right)$ equals $\Pi^M\left(q_N^P\left(e, Z^P\right), T^*; Z^P\right)$ following the fact that Z^P is such that $q_N^M = q_N^P(e, Z)$ holds. The shape when $\zeta \in \left[\zeta^M, \zeta^P\right)$ thus follows.

Next we turn to the case that $\zeta \in \left[\zeta^P, \zeta^D\right)$. First notice that $\Pi^M\left(q_N^P(e, Z), T^*; Z\right)$ is concave in Z by equation (24), and is maximized at

$$Z_{max} = \frac{1}{\sqrt{w_S \gamma}} \frac{2m\gamma \cdot (4-3e)}{16\gamma + 9e^2}.$$

It is readily checked that $Z_{max} \leq Z^P$ holds for any $e \geq 0$. Moreover, the ratio $\frac{Z^D}{Z_{max}} = \frac{f(e)}{8} \cdot \frac{16\gamma+9e^2}{2\gamma\cdot(4-3e)}$ is decreasing in γ so we can conclude that Z^D/Z_{max} is maximized at $\gamma = 1$ by the setting that $\gamma \geq 1$. Furthermore, it is checked that the ratio Z^D/Z_{max} evaluated at $\gamma = 1$ is no larger than 1 for all $e \in [0, \bar{e}]$. We can thus conclude that the profit is inverted U-shaped in ζ, and is maximized at ζ_{max} when $\zeta \in \left[\zeta^P, \zeta^D\right)$. Note also that as γ increases, the peak of the profit schedule under strategic predation shifts to the right in the space of ζ, i.e.,

$$\frac{d\zeta_{max}}{d\gamma} = 2\zeta_{max}^{\frac{3}{2}} \frac{(4-3e)\,m}{\sqrt{w_S\gamma}} \frac{\left(16\gamma - 9e^2\right)}{\left(16\gamma + 9e^2\right)^2} > 0.$$

For the case that $\zeta \geq \zeta^D$, it is clear that $\Pi^D\left(q_N^D, T^*; Z\right)$ is decreasing in Z and tends to a finite value when $Z \to 0$. Moreover, A.5.4-(3) suggests that $\Pi^D\left(q_N^D, T^*; Z^D\right) \geq \Pi^M\left(q_N^P\left(e, Z^D\right), T^*; Z^D\right)$ holds for all $e \in [0, \bar{e})$. Therefore we conclude that when $\zeta \geq \zeta^D$ the profit is increasing in ζ with an upward jump at ζ^D, and tends to a finite level when $\zeta \to \infty$.

A.7.2 The Maximum of the Profit.

When the strategic predation structure emerges, the maximum profit occurs at Z_{max} as

$$\Pi^M\left(q_N^P(e, Z_{max}), Z_{max}\right) = \frac{1}{2} \frac{2m^2 \cdot (3e + 2\gamma - 2)}{16\gamma + 9e^2}. \tag{26}$$

When the Stackelberg structure takes place, the profit is increasing in ζ and has a limiting value by

$$\lim_{\zeta\to\infty}\Pi^{D}\left(q_N^D\right)=\frac{1}{2}\frac{m^2}{16}\cdot\frac{3e^4+84e^3-84e^2-128e+128}{\left(4-3e^2\right)^2}. \tag{27}$$

Accordingly, we have

$$\frac{\partial}{\partial\gamma}\left(\Pi^{D}\left(q_N^D\right)-\Pi^{M}\left(q_N^P\left(e,Z_{max}\right),Z_{max}\right)\right)=-\frac{1}{2}\frac{4m^2\cdot(3e-4)^2}{\left(16\gamma+9e^2\right)^2}<0 \tag{28}$$

and

$$\begin{aligned}\frac{\partial}{\partial e}\left(\Pi^{D}\left(q_N^D\right)-\Pi^{M}\left(q_N^P\left(e,Z_{max}\right),Z_{max}\right)\right)=&\frac{1}{2}\cdot\left\{\frac{m^2}{4}\cdot\frac{63e^4-114e^3-36e^2+216e-128}{\left(4-3e^2\right)^3}\right.\\&\left.-\frac{6m^2\cdot(4-3e)\cdot(4\gamma+3e)}{\left(16\gamma+9e^2\right)^2}\right\}\\<&0.\end{aligned} \tag{29}$$

Note that last line of (29) follows from the fact that the first term is negative and that the second term is positive for all $e\in[0,\bar{e})$.

Equations (28) and (29) suggest that the $\Pi^{D}\left(q_N^D\right)\geq\Pi^{M}\left(q_N^P\left(e,Z_{max}\right),Z_{max}\right)$ is more likely to hold when either γ or e is small. Here we provide two illustrative examples using simulations to show this possibility. Considering the case that $\gamma=1$, inequality $\Pi^{D}\left(q_N^D\right)\geq\Pi^{M}\left(q_N^P\left(e,Z_{max}\right),Z_{max}\right)$ holds only when $e\leq\acute{e}\approx 0.827$. Also, considering the case where $e=\frac{3}{4}$, inequality $\Pi^{D}\left(q_N^D\right)\geq\Pi^{M}\left(q_N^P\left(e,Z_{max}\right),Z_{max}\right)$ holds only when γ is less than 15.809.

A.8 Proof of Proposition 4.

It readily follows from (16) that e and γ does not affect the profit for $\zeta<\zeta^P$. For the case that $\zeta\in\left[\zeta^P,\zeta^D\right)$, note that both e and γ affects the profit via

$$V\equiv\frac{\left(m-2\sqrt{\frac{w_S\gamma}{\zeta}}\right)\cdot\left(4\sqrt{\frac{w_S\gamma}{\zeta}}+3e\cdot m-2m\right)}{e^2}$$

only. It follows that

$$\frac{d\ln V}{d\ln e} = -\frac{8\sqrt{\frac{w_S\gamma}{\zeta}}+3em-4m}{4\sqrt{\frac{w_S\gamma}{\zeta}}+3em-2m}$$

$$\begin{aligned}\frac{d\ln V}{d\ln\gamma} =& \frac{2\sqrt{\frac{w_S\gamma}{\zeta}}}{4\sqrt{\frac{w_S\gamma}{\zeta}}+3em-2m} - \frac{\sqrt{\frac{w_S\gamma}{\zeta}}}{m-2\sqrt{\frac{w_S\gamma}{\zeta}}} \\ \propto& -\frac{8\sqrt{\frac{w_S\gamma}{\zeta}}+3em-4m}{\left(4\sqrt{\frac{w_S\gamma}{\zeta}}+3em-2m\right)\left(m-2\sqrt{\frac{w_S\gamma}{\zeta}}\right)}.\end{aligned}$$

Note that strategic predation require $\zeta \in \left[\zeta^P, \zeta^D\right)$. It is readily checked $m-2\sqrt{\frac{w_S\gamma}{\zeta}} > 0$ holds since its minimum occurs at ζ^P and is positive. The fact that $V > 0$ holds within $\zeta \in \left[\zeta^P, \zeta^D\right)$ implies that $4\sqrt{\frac{w_S\gamma}{\zeta}}+3e\cdot m-2m > 0$ holds. It is readily verified that $8\sqrt{\frac{w_S\gamma}{\zeta}}+3em-4m < 0$ holds since its maximum occurs at ζ^P and equals 0. Accordingly, $d\ln V/d\ln e > 0$ and $d\ln V/d\ln\gamma > 0$.

For the case that $\zeta \geq \zeta^D$, it follows from (16) that a higher γ reduces the profit. For the effect of e, note that the case can only emerge when $e < \bar{e} \equiv \frac{\sqrt{33}}{3} - 1 < 1$, and

$$\begin{aligned}\frac{\partial}{\partial e}\frac{3e^4+84e^3-84e^2-128e+128}{(4-3e^2)^2} =& 4\frac{63e^4-114e^3-36e^2+216e-128}{(4-3e^2)^3} \\ \propto& 63e^4-114e^3-36e^2+216e-128 \\ <& 0.\end{aligned}$$

As a result, a higher e lowers the profit in this case.

A.9 Proof to Proposition 5.

Proposition 5-(1) is self-evident. For Proposition 5-(2), notice that at ζ^D we have

$$\begin{aligned}TS^P\left(\zeta^D\right) - TS^D\left(\zeta^D\right) &= \frac{m^2}{128}\frac{1}{4-3e^2}\cdot\left[-63e^4+108e^3-60e^2+64e-64\right., \\ &\quad \left.+\left(36e^2-48e+64\right)\sqrt{e\left(1-e\right)\left(4-3e^2\right)}\right].\end{aligned}$$

where the RHS is greater than 0 when $e \in [\widetilde{e}, \overline{e})$ where $\widetilde{e} \approx 0.3178$. For the last property, observe that

$$\begin{aligned} TS^P\left(\zeta^D\right) - TS^D\left(\zeta \to \infty\right) &= \frac{m^2}{128}\frac{1}{\left(4-3e^2\right)\gamma} \cdot \left[\left(-48e^2+160e-128+64\sqrt{e\left(1-e\right)\left(4-3e^2\right)}\right)\gamma \right. \\ &\quad \left. +63e^4-108e^3+12e^2+96e-64+\left(48e-36e^2\right)\sqrt{e\left(1-e\right)\left(4-3e^2\right)}\right] \\ &\equiv \frac{m^2}{128}\frac{1}{\left(4-3e^2\right)\gamma} \cdot \left(A\gamma+B\right), \end{aligned}$$

where $B \leq 0$ for all $e \in [0, \overline{e})$ and $A \geq 0$ when $e \in [\widehat{e}, \overline{e})$ where $\widehat{e} \approx 0.529$. This implies that the strategic predation structure yields the highest total surplus when $e \in [\widehat{e}, \overline{e})$ and $\gamma \geq \frac{-B}{A}$.

A.10 Total Surplus

Note that (19) is increasing in ζ in each segments. Thus, we show that $TS > TS^{no}$ by showing that $TS^P\left(\zeta^P\right) \geq TS^{no}$ and $TS^D\left(\zeta^D\right) \geq TS^{no}$. It is readily checked that

$$\begin{aligned} TS^P\left(\zeta^P\right) - TS^{no} =& \frac{m}{12e}\left(4m - 8\sqrt{w_S\gamma}\frac{m}{2}\frac{1}{\sqrt{w_S\gamma}}\left(\frac{4-3e}{4}\right) - 3me\right) \\ =& 0. \end{aligned}$$

The condition $TS^D\left(\zeta^D\right) \geq TS^{no}$ holds if and only if

$$\begin{aligned} \frac{m^2}{8}\frac{\left(4-3e\right)\left(2-e\right)}{4-3e^2} \geq& \frac{\gamma}{2}\frac{w_S}{\zeta^D} \\ \Rightarrow \left(\frac{m}{8}\frac{1}{\sqrt{w_S\gamma}}f\left(e\right)\right)^{-2} \geq& \frac{\gamma}{2}w_S\frac{8}{m^2}\frac{4-3e^2}{\left(4-3e\right)\left(2-e\right)} \\ \Rightarrow \frac{1}{f\left(e\right)^2} - \frac{1}{16}\frac{4-3e^2}{\left(4-3e\right)\left(2-e\right)} \geq& 0. \end{aligned}$$

It is checked that the above condition holds for $e \in [0, \overline{e}]$.