

Outsourcing under Imperfect Protection of Intellectual Property

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Abstract

The paper examines possible reasons behind expanded outsourcing by modeling outsourcing decisions when intellectual property rights are imperfectly protected. Firms in the North develop higher quality levels of existing products and then decide whether to shift some stages of production to the South. Production in the South lowers costs but entails risk of imitation by Southern firms. In this setting, a lower risk of imitation or larger labor supplies can cause increased outsourcing, a higher rate of innovation, and a lower Northern relative wage. Damage due to lower incomes can be offset by gains in terms of better quality products.

1. Introduction

Globalization means many things to many people. Economies are becoming more integrated. National borders matter less for the exchange of goods and services. Many more countries are opening up to trade and exporting their products to increasingly global markets. One way these changes may be manifested is through growth in international outsourcing. US firms (and firms from other developed countries) have increasingly been outsourcing production to countries where production costs are lower.

Outsourcing can appear in the data through both imports and exports. When firms shift production of some components abroad and assemble the components into final goods at home, the components are imported. When firms produce some components at home and assemble the components into final goods abroad, the components are exported. Feenstra (1998) provides an excellent summary of data representing the increasing extent of international outsourcing. He suggests merchandise trade relative to value-added, and shifts in the composition of trade by end use, as measures.

Merchandise trade relative to value-added has been growing steadily for the major developed countries since at least 1960. As Table 1 shows, values for the United States have tripled from 9.6% to 35.8% over the 30-year period from 1960 to 1990. Other countries, such as the United Kingdom and Canada, have seen their values double, starting from higher initial levels (33.8% to 62.8%, and 37.6% to 69.8%, respectively).

Trade in capital goods provides a rough measure of trade in intermediate goods. Capital goods contain items such as machinery, electrical parts, and other components. Shares of capital goods in both imports and exports have been rising for the United States since at least 1925. As Table 2 shows, the US import share of capital goods rose from 0.4% to 33.6% from 1950 to 1995, and the export share rose from 8.7% to 42.4%.

Why has outsourcing been expanding and what are its consequences? This paper examines whether the effects of outsourcing depend on the reasons behind the

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Table 1. *Merchandise Trade Relative to Value-added (percentages)*

	<i>United States</i>	<i>United Kingdom</i>	<i>Canada</i>	<i>Germany</i>
1960	9.6	33.8	37.6	24.6
1970	13.7	40.7	50.5	31.3
1980	30.9	52.6	65.6	48.5
1990	35.8	62.8	69.8	57.8

Table 2. *Shares of Capital Goods in US Trade (percentages)*

	<i>Imports</i>	<i>Exports</i>
1925	0.4	8.7
1950	1.3	22.4
1965	7.1	31.4
1980	19.0	35.0
1995	33.6	42.4

expansion in outsourcing. Glass and Saggi (2001) constructed a North–South product-cycle model to help identify forces leading to increased outsourcing and a lower Northern relative wage. That work countered the claim that international outsourcing of production must be detrimental to the welfare of workers in industrialized countries by arguing that faster innovation could create gains sufficient to offset the decline in Northern wages. The Glass–Saggi model (hereafter, GS) assumed no Southern imitation for simplicity.

This paper adds imitation to address whether changes in exposure to imitation could be behind the expansion in outsourcing and whether, if so, the increased outsourcing occurs together with increased innovation. I find that an increase in the intensity of imitation decreases the rate of innovation and the extent of outsourcing, while increasing the Northern wage relative to the Southern wage. Thus an expansion in outsourcing, together with a decline in the Northern relative wage and faster innovation, could stem from a decline in imitation. Southern imitation may be declining due to efforts to strengthen protection of intellectual property in the South. The results suggest that as the TRIPs agreement becomes fully implemented, outsourcing may rise further.

In addition to examining the effects of imitation, the model is useful for determining how the effects of other parameters are altered by imitation. In the GS model, labor supplies did not affect the relative wage across countries. Thus, increased labor supplies (alone) could not account for the increase in outsourcing because the Northern relative wage would not fall in response, according to the original model. This feature was unfortunate because greater availability of labor in the South seems intuitively to be a plausible explanation.

Along with increases in outsourcing, Southern (effective) labor supplies have been increasing. Young (1995) found evidence of factor accumulation due to rising participation rates (primarily for women), shifts in labor from agriculture to manufactures, improved education, and increased investment for the East Asian newly industrialized countries (Hong Kong, Singapore, Korea, and Taiwan). The fraction of the workforce

with at least a secondary education has essentially tripled (or more) in these countries over the past three decades. Also, the opening of China and other countries may act like an increase in the Southern labor supply available for outsourcing.

Adding imitation to the model allows increased Southern labor supplies to possibly explain increased outsourcing occurring with a reduction in the relative wage across countries. Once imitation is added, labor supplies do affect the relative wage across countries, indirectly through their effect on the rate of innovation. The relative wage across countries adjusts to keep the value of a firm (the present discounted value of profits) the same whether or not the firm outsources. Whether outsourcing or not, firms are always exposed to the chance that a rival will invent an even better generation of their product; however, when outsourcing, there is the additional risk of imitation. The rate of innovation alters the degree of discounting when outsourcing relative to when not: if innovation occurs frequently, the additional risk of imitation will be relatively less important.

Either increased labor supplies or decreased imitation could be raising the incentives for international outsourcing. What is the impact of these changes? Do both countries benefit or is there conflict between the interests of the North and the South? Does the impact of outsourcing depend on whether reduced imitation or increased labor supplies are the driving force?

Three separate welfare effects operate in this model: effects on expenditure, average price level, and average quality consumed. Decreased imitation and increased labor supplies increase the rate of innovation and thus the average quality of products consumed. On the other hand, they decrease expenditure and might increase the average price level. However, the growth effect (innovation) will dominate the level effects (expenditure and average price level) for each country provided the discount rate is sufficiently low (must be patient enough). Therefore, the South need not be hurt by reducing imitation through tighter protection of intellectual property. Furthermore, outsourcing need not hurt the North. Decreased imitation and increased labor supplies join the list in GS of forces that could increase outsourcing and yield welfare benefits for the North, despite declines in the Northern relative wage.

There is evidence that increased outsourcing reduces the gap in wages across countries. Egger and Pfaffermayr (2004, this issue) find that outsourcing generates convergence in average real wage rates across countries. Scheve and Slaughter (2002) examine a different type of concern of Northern workers: uncertainty in employment and wages due to outsourcing. Such concerns should act like level effects and thus benefits from faster innovation could more than compensate. Girma and Görg (2004, this issue) find that high wages are positively related to outsourcing decisions (including both domestic and international outsourcing), so the cost motive does seem important.

An innovator may shift production to the South by licensing a Southern firm or by forming a subsidiary for that purpose—foreign direct investment (FDI). Lai (1998) has argued that an increase in the intensity of imitation of multinationals' products causes a reduction in FDI and innovation. Here I consider the more general case where some, but not necessarily all, stages of production are shifted to the South and find a similar result. Additionally, in the Lai (1998) model, innovations are new varieties, whereas here they are quality improvements.

2. International Outsourcing Model

Each country is composed of a representative consumer and many firms. Consumers are willing to pay a premium for quality because they derive more utility from higher

quality levels of products. This premium gives Northern firms an incentive to develop quality improvements. Once successful in inventing a higher quality level of a product, a Northern firm can then outsource some stages of production to the low-cost South. However, by outsourcing, the Northern firm exposes itself to imitation. The degree that shifting production to the South lowers costs is determined endogenously through the relative wage across countries.

Consumers

Consumer preferences are as described in the quality ladders product cycle model of Grossman and Helpman (1991). Identical consumers live in one of two countries, North and South, $i \in \{N, S\}$. Consumers choose from a continuum of products indexed by $j \in [0, 1]$, where products are available in a discrete number of quality levels indexed by m . A consumer has additively separable intertemporal preferences given by lifetime utility

$$U = \int_0^{\infty} e^{-\rho t} \log u(t) dt, \quad (1)$$

where ρ is the common subjective discount rate, instantaneous utility is

$$\log u(t) = \int_0^1 \log \left[\sum_m \lambda^m x_m(j, t) \right] dj, \quad (2)$$

λ^m is the assessment of quality level m , and $x_m(j, t)$ is consumption of quality level m of product j at time t . Each quality level m is λ -times better than quality level $m - 1$, where λ denotes the size of the quality increment. By the definition of quality, higher quality levels are valued more: $\lambda > 1$.

Since preferences are homothetic, aggregate demand can be found by maximizing lifetime utility (1) subject to the aggregate intertemporal budget constraint

$$\int_0^{\infty} e^{-R(t)} E(t) dt \leq A(0) + \int_0^{\infty} e^{-R(t)} Y(t) dt, \quad (3)$$

where $R(t) = \int_0^t r(s) ds$ is the cumulative interest rate up to time t and $A(0)$ is the aggregate value of initial asset holdings. Aggregate income is

$$Y(t) = \sum_i L_i w_i(t), \quad (4)$$

where $w_i(t)$ is the wage in country i at time t and L_i is the labor supply in country i , so $L_i w_i(t)$ is the total labor income in country i at time t . Labor and wages are measured in efficiency units. Aggregate spending is

$$E(t) = \int_0^1 \left[\sum_m p_m(j, t) x_m(j, t) \right] dj, \quad (5)$$

where $p_m(j, t)$ is the price of quality level m of product j at time t .

The consumer's maximization problem can be broken into three stages: the allocation of lifetime wealth across time, the allocation of expenditure at each instant across products, and the allocation of expenditure at each instant for each product across available quality levels. In the first stage, each consumer evenly spreads lifetime spending for each product across time; in the second stage, each consumer evenly spreads spending at each instant across products; see Grossman and Helpman (1991) for

details. In the final stage, each consumer allocates spending for each product at each instant to the quality level with the lowest quality adjusted price, p_m/λ^m . Thus, consumers are willing to pay a premium of λ for a one-quality-level improvement in a product.

Producers

To produce a given quality level of a product, a firm must first design it. However, due to assumed differences in technological knowledge across countries, only Northern firms innovate: innovation by Southern firms is assumed to be sufficiently difficult that it does not occur. The innovation process is the same as in Grossman and Helpman (1991). Assume innovation races occur simultaneously for all products, with all Northern firms able to target the quality level above the current highest quality level for each product. Normalize the Southern wage to one, $w_S = 1$, so $w \equiv w_N/w_S = w_N$ is the Northern wage relative to the Southern wage. Assume undertaking innovation intensity ι for a time interval dt requires $a\iota dt$ units of labor at a cost of $wa\iota dt$ and leads to success with probability ιdt .

In Grossman and Helpman’s model, Northern firms must produce only in the North. Similar to Glass and Saggi (2001), in my model Northern firms can purchase some stages of production from Southern firms. Normalize the unit labor requirement in production to one. Of the one unit of labor needed to produce one unit of the final product, the fraction β can be outsourced and the remaining $(1 - \beta)$ cannot. The output of any stage is a tradable intermediate good so different stages of production can be located in different countries. Production of components could occur in the South and assembly in the North, or the reverse, or other more complicated divisions of the production process between countries.

To outsource production, a firm must first adapt its production process for the South. For simplicity, assume this adaptation process is costless (but uncertain). Undertaking outsourcing intensity ϕ for a time interval dt leads to success with probability ϕdt . If successful at its efforts, a firm outsources the fixed fraction β of production. The uncertain process involved with outsourcing could involve a search for appropriate licensing partners.

A firm’s problem can be broken down into two stages. First, when undertaking innovation, the firm chooses its intensity of innovation to maximize its expected value, given the innovation intensities of other firms. Once successful in innovation, the firm then chooses the price of its product and intensity of adaptation to maximize its value, given the prices and innovation intensities of other firms. Current producers do not undertake any innovation due to the familiar profit destruction argument (Grossman and Helpman, 1991).

To generate a finite intensity of innovation, expected gains must not exceed cost, with equality when innovation occurs with positive intensity

$$v_N \leq wa, \quad \iota > 0 \Leftrightarrow v_N = wa, \tag{6}$$

where v_N is the value a firm gains from successful innovation. Costs exceeding benefits would choke off innovation, whereas benefits exceeding costs would lead to innovation at an infinite intensity (and could not persist given free entry into innovation races). Similarly, expected gains from international outsourcing must not exceed the cost of zero, with equality when outsourcing occurs with positive intensity

$$v_O - v_N \leq 0, \quad \phi > 0 \Leftrightarrow v_O - v_N = 0, \tag{7}$$

where $v_O - v_N$ is the capital gain from outsourcing production.

Why doesn't outsourcing provide any excess returns? If the value from outsourcing were to exceed the value from keeping all production located in the North, then the intensity of outsourcing would be infinite, and so all successful innovators would outsource immediately. We are interested in cases where some but not all Northern firms outsource production (to see how changes in imitation risk affect outsourcing decisions), so we assume that firms earn the same value of their present discounted profits regardless of whether they choose to outsource. For equilibria with both innovation and outsourcing, both of these conditions must hold with equality and thus $v_N = v_O = wa$.

The reward to innovation is the discounted stream of profits from production. A Northern firm that successfully innovates earns the reward

$$\begin{aligned} v_N &= \frac{\pi_N + \phi v_O}{\rho + \phi + \iota}, \\ (\rho + \phi + \iota)v_N &= \pi_N + \phi v_O, \\ (\rho + \iota)v_N &= \pi_N + \phi(v_O - v_N), \\ v_N &= \frac{\pi_N + \phi(v_O - v_N)}{\rho + \iota} = \frac{\pi_N}{\rho + \iota}, \end{aligned} \tag{8}$$

where I have used $v_N = v_O$ to simplify the expression. Because outsourcing yields no excess returns, the reward to innovation v_N is not directly affected by the opportunity to outsource. Upon successfully adapting its technology for Southern production, the firm's value becomes

$$v_O = \frac{\pi_O}{\rho + \iota + M} \tag{9}$$

until rival innovation or imitation terminates its value, where M is the intensity of Southern imitation. As in Helpman (1993) and Lai (1998), the intensity of imitation can be interpreted as reflecting the degree of intellectual property protection in the South (with stronger protection leading to lower values of M).

Note that the value of a firm being the same regardless of whether outsourcing $v_N = v_O$ implies that profits when outsourcing must be larger relative to profits when not outsourcing in proportion to the intensity of imitation:

$$\frac{\pi_O}{\pi_N} = \frac{\rho + \iota + M}{\rho + \iota} = 1 + \frac{M}{\rho + \iota} > 1. \tag{10}$$

In general, imitation might also target goods even when they are produced entirely in the North, in which case the relevant ratio would be $(\rho + \iota + M)/(\rho + \iota + \underline{M})$, where \underline{M} is the imitation intensity targeting Northern production and the risk of imitation rises with outsourcing $M > \underline{M}$. The model should be robust to allowing imitation of Northern production; increases in M would then be thought of as occurring relative to \underline{M} .

Under Bertrand competition, the most recent innovator for each product engages in limit pricing behavior by choosing a price that just keeps its closest rival from earning a positive profit from production. Each most recent innovator has a one-quality-level lead over the closest rival and so chooses a price equal to λ times the rival's marginal cost.

Assume all old technologies have full international outsourcing potential. Old technologies are designs that have already been improved. Once technologies no longer

yield profits in equilibrium, these old technologies become fully available to Southern firms. This assumption provides a common marginal cost of production of one for all technologies that are no longer produced in equilibrium.

Thus each producing Northern firm charges price $p = \lambda$ and makes sales $x = E/\lambda$ (as aggregate expenditure is price times sales $E = px$) regardless of whether the firm outsources production. International outsourcing does affect production costs, and thus profits (price minus costs times sales). Let $\delta \equiv 1/\lambda$. Firms that do not outsource production have marginal cost w , yielding instantaneous profits

$$\pi_N = (\lambda - w) \frac{E}{\lambda} = E(1 - w\delta). \tag{11}$$

Firms that outsource production have marginal cost $c \equiv \beta + (1 - \beta)w$, a weighted average of costs in the North and the South, where $0 < \beta < 1$ represents the labor share in outsourced production, yielding instantaneous profits

$$\pi_O = E(1 - c\delta) = E[1 - w\delta + \beta\delta(w - 1)]. \tag{12}$$

I assume that there are sufficiently many potential suppliers in the South that Northern firms are able to purchase items at cost. Even though outsourcing lowers costs, Northern firms do not lower their prices because they price at a markup relative to the cost of Southern firms.

Comparing the profit expressions, profits rise with outsourcing in proportion to the size of the cost savings, the fraction of production outsourced, and the volume of sales: $\pi_O - \pi_N = E\delta\beta(w - 1)$. Or in terms of ratios:

$$\frac{\pi_O}{\pi_N} = \frac{E[1 - w\delta + \beta\delta(w - 1)]}{E(1 - w\delta)} = 1 + \frac{\beta\delta(w - 1)}{1 - w\delta} > 1. \tag{13}$$

The cost savings of outsourcing increase profits, which provides an incentive for firms to outsource, despite the increased risk of imitation. Combining (10) and (13) yields

$$1 + \frac{M}{\rho + \iota} = 1 + \frac{\beta\delta(w - 1)}{1 - w\delta} \rightarrow \frac{M}{\beta} = \frac{\delta(w - 1)(\rho + \iota)}{1 - w\delta}. \tag{14}$$

Inserting profits (11, 12) into the producing firm valuations (8, 9) and inserting those values into the innovation and adaptation conditions (6, 7), under equality, yields the valuation conditions

$$E(1 - w\delta) = wa(\rho + \iota), \tag{15}$$

$$E[1 - w\delta + \beta\delta(w - 1)] = wa(\rho + \iota + M), \tag{16}$$

which must hold for an equilibrium with both innovation and outsourcing.

The assumption that all production never occurs in the South is supported by more fundamental assumptions. Suppose that, while the unit labor requirement in basic production in the South is one (by normalization), the unit labor requirement in advanced production in the South is $\zeta > 1$. Provided the unit labor requirement in advanced production in the South is greater than the Northern wage in equilibrium $\zeta > w$, producing the basic stage will be cheaper in the South while producing the advanced stage will be cheaper in the North.

Additionally, outsourcing all production could expose the firm to imitation at an intensity substantially higher than M , say $\bar{M} \gg M$ (with $\bar{M} > M/\beta$), so that the additional cost savings do not justify the much larger imitation risk

$$\frac{\bar{M}}{\rho + \iota} \gg \frac{\delta(w-1)}{1-w\delta}. \quad (17)$$

Or equivalently the valuation condition for full outsourcing is an inequality:

$$E(1-\delta) < wa(\rho + \iota + \bar{M}). \quad (18)$$

The structure of the model suggests that if firms are free to split the production process across borders to any degree and face an imitation risk M increasing in the fraction outsourced β , firms will pick β to minimize M/β . The condition (14) needed for both valuation conditions to hold simultaneously fixes the ratio of M/β . If a firm were to choose a β that led to a higher M/β , its outsourcing would lead to a lower rate of return than the outsourcing of other firms. While it would reap additional cost savings, the additional exposure to imitation would be excessive.

Market Measures and Resources

A quality level of a product is produced entirely in the North following innovation, partially in the North, and partially in the South once outsourced, and entirely in the South following imitation. Let n_N denote the fraction of products produced entirely in the North, n_O denote the fraction of products outsourced, and n_S denote the fraction of products produced entirely in the South. In a steady state, the flows into must equal flows out of outsourcing, so that the fraction of products outsourced n_O remains constant. The flows into outsourcing are ϕn_N while the flows out are $(\iota + M)n_O$; therefore

$$\phi n_N = (\iota + M)n_O. \quad (19)$$

Similarly, the flows into and out of pure Southern production must be the same. The flows into pure Southern production are Mn_O while the flows out are u_S ; therefore

$$Mn_O = u_S. \quad (20)$$

These product measures must sum to one:

$$n_N = 1 - n_O - n_S. \quad (21)$$

These last two equations can be rewritten and combined as $n_S = Mn_O/\iota$ and $n_N = 1 - n_O(1 + M/\iota)$.

The labor constraints for each country will complete the model. The fixed supply of labor is allocated between innovation and production in the North. All products are targeted for innovation and hence the labor demand for innovation is at . Sales by Northern firms are $x_N = x_O = E\delta$ regardless of whether a product is outsourced. The fraction n_N of products are produced entirely in the North and the fraction n_O have only some stages produced in the North, so labor demand for production in the North is $n_N E\delta + (1 - \beta)n_O E\delta$. The North has a fixed labor supply of L_N and so the Northern labor constraint is

$$at + [n_N + (1 - \beta)n_O]E\delta = L_N. \quad (22)$$

Labor is used only for production in the South since Southern firms are assumed to not innovate and imitation is assumed to be costless. The South produces only some stages in markets with outsourcing and all stages for products that have been imitated. Labor demand for production of outsourced products is $\beta n_o E \delta$. I assume that following imitation, all Southern firms become able to produce the entire product and thus set price equal to the cost of production of one (need one unit of labor to produce one unit of output by normalization, and the Southern wage is one by normalization). Thus, sales of imitated products are $x_s = E$ and labor demand for pure Southern production is $n_s E$. The South has a fixed labor supply of L_s and so the Southern labor constraint is

$$(\beta n_o \delta + n_s) E = L_s. \tag{23}$$

Studying the two labor constraints reveals that an increase in the fraction of products that are outsourced, n_o , or in the fraction of labor demand for outsourced production, β , leads to a shift in labor demand from the North to the South.

Define the extent of international outsourcing as the fraction of all production outsourced to the South, $\chi \equiv \beta n_o$, the fraction of products outsourced times the fraction of production outsourced for each product. Since $n_o = \chi / \beta$, the steady-state constant measure conditions $n_s = M n_o / \iota$ and $n_N = 1 - n_o (1 + M / \iota)$ can be rewritten in terms of the extent of outsourcing as $n_s = M \chi / (\beta \iota)$ and $n_N = 1 - (\chi / \beta) (1 + M / \iota)$. The market measures can then be eliminated from the resource constraints, leaving the Northern labor constraint

$$a \iota + \left[1 - \chi \left(1 + \frac{M}{\beta \iota} \right) \right] E \delta = L_N \tag{24}$$

as $n_N + (1 - \beta) n_o = 1 - \chi [1 + M / (\beta \iota)]$, and the Southern resource constraint

$$\chi E \left(\delta + \frac{M}{\beta \iota} \right) = L_s \tag{25}$$

as $\beta n_o \delta + n_s = \chi \delta + M \chi / (\beta \iota) = \chi [\delta + M / (\beta \iota)]$. An increase in the extent of outsourcing, χ , not only shifts labor demand for production from the North to the South, it also increases the overall demand for labor since imitated products have lower prices and thus larger sales.

These two resource constraints, (24) and (25), combined with the two valuation conditions, (15) and (16), comprise the system. The four equations determine aggregate spending E , the Northern relative wage w , the rate of innovation ι , and the extent of international outsourcing χ .

3. Steady-state Equilibrium with Outsourcing and Imitation

The primary goal of this paper is to determine the effect of the intensity of imitation M on the rate of innovation ι and the extent of outsourcing χ , as well as on aggregate expenditure E and the Northern relative wage w . To determine these effects, solve the four equations for the four endogenous variables in turn. Start by solving the innovation valuation condition (15) and the outsourcing valuation condition (16) for aggregate expenditure

$$E = \frac{a \left[\frac{M}{\beta} + \delta (\iota + \rho) \right]}{\delta (1 - \delta)} > 0 \tag{26}$$

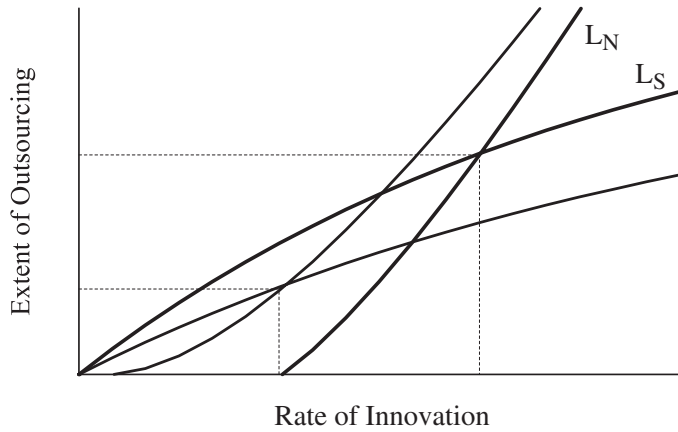


Figure 1. Effect of Imitation on Outsourcing and Innovation

and the relative wage

$$w = \frac{\frac{M}{\beta} + \delta(t + \rho)}{\frac{M}{\beta}\delta + \delta(t + \rho)} > 1 \tag{27}$$

(noting $\delta \equiv 1/\lambda < 1$ as $\lambda > 1$) consistent with innovation and outsourcing occurring in equilibrium. A higher aggregate expenditure increases the incentives for both innovation and outsourcing through larger sales. A higher relative wage reduces the incentives for innovation (due to lower profits in the product market) and expands the incentives for international outsourcing of production (due to larger cost savings).

For various extents of international outsourcing $\chi \in (0, \beta)$, Figure 1 traces the rate of innovation t that equates labor demand and labor supply in each country. The Northern resource constraint is represented by

$$L_N = at + \left[1 - \chi \left(1 + \frac{M}{\beta t} \right) \right] \left[\frac{a \left[\frac{M}{\beta} + \delta(t + \rho) \right]}{\delta(1 - \delta)} \right] \delta \tag{28}$$

and the Southern resource constraint by

$$L_S = \chi \left[\frac{a \left[\frac{M}{\beta} + \delta(t + \rho) \right]}{\delta(1 - \delta)} \right] \left(\delta + \frac{M}{\beta t} \right). \tag{29}$$

The intersection of the two resource constraints indicates the equilibrium extent of outsourcing and rate of innovation.

Imitation Intensity

An increase in the intensity of imitation M clearly shifts the Southern resource constraint down: for any given rate of innovation t , the extent of outsourcing χ must fall.

More imitation raises the measure of Southern production $n_S = \chi M/(\beta t)$, holding t and χ fixed, so more labor is needed for Southern production. In addition, aggregate expenditure (26) rises with M , and the larger volume of sales raises demand for labor both in Southern production and in outsourcing of production in the South.

The shift in the Northern resource constraint due to an increase in M is less clear. More imitation reduces the measure of Northern production $n_N = 1 - \chi(1 + M/\beta t)$ but increases aggregate expenditure. However, the production shifting effect dominates, so the Northern resource constraint shifts up with a larger extent of outsourcing for any given rate of innovation. Consequently, the new intersection occurs at a lower extent of outsourcing and a slower rate of innovation.

To demonstrate the effects on χ and t more formally, solve the Southern resource constraint (25) for the extent of outsourcing

$$\chi = \frac{L_S \delta t (1 - \delta)}{a \left(\delta t + \frac{M}{\beta} \right) \left[\frac{M}{\beta} + \delta(t + \rho) \right]} > 0 \tag{30}$$

consistent with the labor demand for production equaling the labor supply in the South. A higher extent of outsourcing increases the demand for labor in the South and decreases the demand for labor in the North by shifting production to the South. Finally, differentiate the Northern resource constraint with respect to the rate of innovation and the intensity of imitation (the Northern labor constraint involves squared terms of t and so solving for t is not convenient) to find

$$\frac{dt}{dM} = - \frac{a(\beta \delta t + M)^2 + L_S \beta^2 \delta t (1 - \delta)^2}{\beta [a(\beta \delta t + M)^2 - L_S \beta \delta M (1 - \delta)^2]} < 0 \quad \text{if } \rho < \bar{\rho}, \tag{31}$$

where $\bar{\rho} \equiv (L_S/a)(1 - \delta)(t + M\delta)/(M + t\beta\delta)$, which should be true since the discount rate should be quite small (virtually zero)—see the Appendix for details. So indeed an increase in the intensity of imitation decreases the rate of innovation.

The effects on the other endogenous variables can then be determined using the chain rule. The extent of outsourcing increases with the rate of innovation

$$\frac{\partial \chi}{\partial t} = \frac{L_S \beta^2 \delta (1 - \delta) [M(M + \beta \delta \rho) - \beta^2 \delta^2 t^2]}{a(\beta \delta t + M)^2 [M + \beta \delta (t + \rho)]^2} \tag{32}$$

if $M(M + \beta \delta \rho) > \beta^2 \delta^2 t^2$, and decreases with the intensity of imitation

$$\frac{\partial \chi}{\partial M} = - \frac{L_S \beta^2 \delta t (1 - \delta) [2M + \beta \delta (2t + \rho)]}{a(\beta \delta t + M)^2 [M + \beta \delta (t + \rho)]^2} < 0. \tag{33}$$

An increase in the intensity of imitation therefore alters the extent of outsourcing according to

$$\frac{\partial \chi}{\partial M} = \underbrace{\frac{\partial \chi}{\partial M}}_{-} + \underbrace{\frac{\partial \chi}{\partial t}}_{?} \underbrace{\frac{dt}{dM}}_{-}. \tag{34}$$

Using the expressions for the partials establishes that an increase in the intensity of imitation must decrease the extent of outsourcing $d\chi/dM < 0$ —see the Appendix.

The relative wage decreases with the rate of innovation

$$\frac{\partial w}{\partial t} = -\frac{\beta M(1-\delta)}{\delta(M+\beta(t+\rho))^2} < 0, \quad (35)$$

and it increases with the intensity of imitation

$$\frac{\partial w}{\partial M} = \frac{\beta(1-\delta)(t+\rho)}{\delta(M+\beta(t+\rho))^2} > 0; \quad (36)$$

but it does not depend directly on the extent of outsourcing. An increase in the intensity of imitation therefore increases the relative wage.

$$\frac{dw}{dM} = \underbrace{\frac{\partial w}{\partial M}}_+ + \underbrace{\frac{\partial w}{\partial t}}_- \underbrace{\frac{dt}{dM}}_- > 0. \quad (37)$$

Aggregate expenditure increases with the rate of innovation

$$\frac{\partial E}{\partial t} = \frac{a}{1-\delta} > 0, \quad (38)$$

and it increases with the intensity of imitation

$$\frac{\partial E}{\partial M} = \frac{a}{\beta\delta(1-\delta)} > 0; \quad (39)$$

but it does not depend directly on the extent of outsourcing. An increase in the intensity of imitation therefore increases aggregate expenditure if the direct effect dominates:

$$\frac{dE}{dM} = \underbrace{\frac{\partial E}{\partial M}}_+ + \underbrace{\frac{\partial E}{\partial t}}_+ \underbrace{\frac{dt}{dM}}_- \quad (40)$$

Using the expressions for the partial establishes that aggregate expenditure does indeed increase with the imitation intensity $dE/dM > 0$ —see the Appendix.

PROPOSITION 1. *An increase in the intensity of imitation reduces the rate of innovation, reduces the extent of international outsourcing, increases the relative wage, and increases aggregate expenditure.*

Note that in the partial solutions for aggregate expenditure (26) and for the relative wage (27)—which can take the place of the two valuation conditions—and in the Northern and Southern labor constraints (28) and (29), the intensity of imitation M enters only relative to the fraction of production that is basic enough to be outsourced, β . Similarly, β enters those four equations only in relation to M .

Suppose Northern firms can choose β , but face a tradeoff between a larger share of production outsourced β and a larger intensity M . An increase in both M and β would act like an increase in M for a given β (at least in terms of the direction of effects) if M/β rises. So if firms choose to outsource a larger fraction of the production of their products (a larger β), and as a result face a larger intensity of imitation M , and if M/β rises, the rate of innovation will fall. If β rises but M/β falls, the rate of innovation would rise.

Glass and Saggi (2001) found, in the absence of imitation, that an increase in β (which was called α) always increased innovation. So the addition of imitation risk

would seem to have introduced the possibility of reversing the prior result that more outsourcing (due to expanding the share of each product that is outsourced) leads to faster innovation. But the discussion of the condition (14) implied by the two valuation conditions holding implied that firms would pick β to minimize M/β as so doing would maximize the rate of return generated by outsourcing. Thus firms would never in equilibrium pick a β that increased M/β . So the GS result regarding an increase in β is robust to the addition of imitation risk when outsourcing.

Labor Supplies

However, the effect of the labor supplies turns out to be somewhat different with imitation than in Glass and Saggi (2001). One might think that one reason international outsourcing has been on the rise is an increase in the Southern labor supply since outsourcing is a way of shifting labor demand from the North to the South.

In the original model, the labor supplies had no effect on the relative wage. The point of the original model was to argue that faster innovation could offset lower relative wages and thus cause Northern workers to benefit from forces that increased outsourcing. Since increasing the Southern labor supply did not lower Northern wages (relative to the South), it did not fit the scenario being considered. Why was there no effect of labor supplies on the relative wage? Without imitation, the relative wage was determined exclusively by the two valuation conditions. Without imitation, the profit streams before and after outsourcing were discounted to the same degree (by $\rho + \iota$). Thus, the relative wage was all that was left to ensure that both valuation conditions held.

But with imitation, outsourcing profits are discounted by more than they were prior to outsourcing due to the increased risk that the profit stream will be terminated by imitation. Imitation adds a term involving the relative effective discount rates $(\rho + \iota + M)/(\rho + \iota) = 1 + M/(\rho + \iota)$. So now the partial solution for the relative wage (27) is a function of the rate of innovation. There is still no direct effect of labor supplies on the relative wage, but there is now an indirect effect that operates through the effect of the labor supplies on innovation.

An increase in the rate of innovation makes the risk of imitation less important. If there is almost no innovation, the expected duration of profits will be substantially shortened when outsourcing because imitation would almost surely occur prior to the next innovation. Therefore, the relative wage would need to be high to generate sufficient cost savings from outsourcing to justify the imitation risk. But if innovation is especially quick, the next innovation will almost always occur prior to imitation, so the expected duration of the profit stream will be essentially unchanged by outsourcing. In that case, the relative wage would fall to almost one as little cost savings are needed from outsourcing.

Since an increase in either labor supply increases the rate of innovation, it follows that the relative wage falls regardless of which labor supply increased. With imitation, it is now possible that an increase in the Southern labor supply can lead to an increase in the extent of outsourcing together with a reduction in the Northern relative wage and an increase in the rate of innovation.

PROPOSITION 2. *An increase in the Northern or Southern labor supply leads to a faster rate of innovation, a larger extent of outsourcing (if imitation is sufficiently large), a larger aggregate expenditure, and a lower relative wage.*

The rate of innovation rises as

$$\frac{dt}{dL_N} = \frac{a(\beta\delta t + M)^2 - L_S\beta\delta M(1-\delta)^2}{(1-\delta)(\beta\delta t + M)^2} > 0 \quad \text{if } \rho < \bar{\rho}, \tag{41}$$

$$\frac{dt}{dL_S} = \frac{a(\beta\delta t + M)^2 - L_S\beta\delta M(1-\delta)^2}{\delta(1-\delta)(\beta\delta t + M)(\beta t + M)} > 0 \quad \text{if } \rho < \bar{\rho}, \tag{42}$$

where the numerator in each is the same as the large term in the denominator of dt/dM that was shown to be positive if the discount rate is small enough. Expanding labor supplies increase innovation, so this economy exhibits scale effects. The expressions for the derivatives of the rate of innovation with respect to the labor supplies, however, suggests that the magnitude of the scale effect shrinks as the Southern labor supply expands. Segerstrom and Dinopoulos (2003) have recently constructed a North–South quality-ladders model without scale effects but no outsourcing.

Aggregate expenditure rises as there is no direct effect and it rises with the rate of innovation. Similarly, the relative wage falls as there is no direct effect and it falls with the rate of innovation. Recall that the extent of outsourcing increases with the rate of innovation $\partial\chi/\partial t > 0$ if $M(M + \beta\delta\rho) > \beta^2\delta^2t^2$. The Southern labor supply has a direct effect of increasing the extent of outsourcing

$$\frac{\partial\chi}{\partial L_S} = \frac{\beta^2\delta t(1-\delta)}{a(\beta\delta t + M)^2 [M + \beta\delta(t + \rho)]^2} > 0. \tag{43}$$

Applying the chain rule, an increase in the Southern labor supply should increase the extent of outsourcing if the intensity of imitation is sufficiently high:

$$\frac{d\chi}{dL_S} = \underbrace{\frac{\partial\chi}{\partial L_S}}_+ + \underbrace{\frac{\partial\chi}{\partial t}}_? \underbrace{\frac{dt}{dL_S}}_+. \tag{44}$$

There is no direct effect of the Northern labor supply, so if outsourcing increases with innovation, then an increase in the Northern labor supply should increase the extent of outsourcing:

$$\frac{d\chi}{dL_N} = \underbrace{\frac{\partial\chi}{\partial t}}_? \underbrace{\frac{dt}{dL_N}}_+. \tag{45}$$

Because there is a direct positive effect for the Southern labor supply, if imitation is low so that outsourcing falls with innovation, outsourcing could rise with the Southern labor supply and fall with the Northern labor supply.

Table 3 summarizes the analytical results for the effects of increases in the imitation intensity, the Southern labor supply, and the Northern labor supply on the Northern relative wage, aggregate expenditure, the rate of innovation, and the extent of outsourcing.

Welfare Effects and Numerical Examples

Is the North hurt by outsourcing due to the reduction in its relative wage reducing income and thus consumption? Do the effects of outsourcing on Northern (or Southern) welfare depend on why outsourcing expanded? Is the South hurt if it adopts

Table 3. Signs of Effects of Imitation and Labor Supplies

	<i>M</i>	<i>L_S</i>	<i>L_N</i>
<i>w</i>	+	-	-
<i>E</i>	+	+	+
<i>t</i>	-	+	+
<i>χ</i>	-	±	±

policies such as stronger protection of intellectual property that decrease imitation? Or if Northern or Southern labor supplies expand?

To address these questions, return to the expressions for utility and examine them for a steady-state equilibrium. By the law of large numbers, the expected number of innovations arriving in time period *t* is $\bar{m} = \iota t$. The average price paid by consumers is

$$\bar{p} = (1 - n_s)\lambda + n_s = \lambda - n_s(\lambda - 1) \tag{46}$$

since they pay price λ for all but imitated products, which have a price of one. Instantaneous utility (2) is

$$\log u(t) = \log E - \log \bar{p} + \bar{m} \log \lambda. \tag{47}$$

Lifetime utility (1) is

$$U = \frac{\log E + \left(\frac{\iota}{\rho} - 1\right) \log \lambda - \log[\lambda - n_s(\lambda - 1)]}{\rho}. \tag{48}$$

The first term indicates that utility rises with expenditure, the second term that utility rises with innovation due to higher average quality of products consumed, and the third term that utility declines with the average price level. The average price level declines if the measure of pure Southern production rises so that a larger fraction of products have had their highest available quality level imitated.

A larger extent of outsourcing can be caused by a reduction in imitation or an expansion in labor supplies. Whichever the source, innovation will rise and generate a positive growth effect on welfare due to the higher average quality of products. However, the Northern relative wage always falls, so the amount of expenditure by Northern consumers will fall, a negative level effect on their welfare. So the North can benefit if it is patient enough. A series of numerical examples will help illustrate the conflict between growth and level effects for both countries.

The numerical examples will also check that the condition for the imitation intensity to be large enough, $M(M + \beta\delta\rho) > \beta^2\delta^2t^2$, can be true in equilibrium, so increases in labor supplies can expand outsourcing. And the examples will illustrate possible ways in which the average price level might adjust. Set the quality increment to $\lambda = 3$ (so $\delta = 1/3$), the share of each unit of production that can be outsourced to $\beta = 1/2$, the unit labor requirement in innovation to $a = 1$, and the discount rate to $\rho = 1/12$. The base case parameters will be imitation intensity $M = 1/2$, Southern labor supply $L_S = 1$, and Northern labor supply $L_N = 2$. Then consider increasing the imitation intensity $M' = 2/3$, Southern labor supply $L'_S = 3/2$, and Northern labor supply $L'_N = 3$, each in turn. The outcomes are presented in Table 4.

Table 4. Numerical Examples

	Base	$M' = 2/3$	$L'_S = 3/2$	$L'_N = 3$
w	2.19	2.63	2.08	1.82
E	5.53	6.45	5.79	6.62
ι	0.602	0.217	0.776	1.33
χ	0.091	0.024	0.160	0.139
n_O	18.1%	4.8%	31.9%	27.8%
n_N	66.8%	80.5%	47.5%	62.0%
n_S	15.1%	14.7%	20.6%	10.2%

Table 5. Welfare Effects for Numerical Examples

	M'	L'_S	L'_N
$\Delta \log E$	+0.19, +0.001	-0.06, -0.004	-0.19, -0.002
$\left(\frac{\Delta \iota}{\rho} - 1\right) \log \lambda$	-5.07	+2.29	+9.61
$\Delta \log \bar{p}$	+0.003	-0.04	+0.03
Total effect	-4.89, -5.07	+2.19, +2.24	+9.46, +9.64

Increases in either the Northern or the Southern labor supply do increase the extent of outsourcing in this numerical example. The measure of pure Southern production increases with the Southern labor supply but decreases with increases in imitation or the Northern labor supply. Therefore, increases in the Southern labor supply or decreases in imitation may reduce the average price level, but increases in the Northern labor supply may increase the average price level.

These numerical examples can then illustrate possible welfare effects. Table 5 calculates the three components of the overall welfare effect for each of the three parameter changes. In the row for $\Delta \log E$, the first number is for the North and the second is for the South.

Reducing imitation would mean reversing the signs on the column for M' : negative level effects though expenditures net of the price level effect and positive growth effect through imitation. Increases in the labor supplies have similar consequences, although increases in the Northern labor supply elevate the price level slightly. The total effect is $\log E + (\iota/\rho - 1)\log \lambda - \log \bar{p}$ (subtract the third row from the sum of the first two rows) and change in lifetime utility ΔU is this total effect divided by the discount rate. For these numerical examples, the discount rate is sufficiently slight that both countries gain from increased outsourcing, regardless of its cause.

4. Conclusion

This paper has developed a quality ladders model with both outsourcing and imitation. Glass and Saggi (2001) is extended to capture the possibility that outsourcing stages of production to the South, while lowering costs, may expose the firm to a greater risk of imitation. This extension is useful for discovering what the effects of imitation

risk are on the rate of innovation, the extent of outsourcing, the North-to-South relative wage, and aggregate expenditure. The new model is also useful for examining whether the effects of increases in the Northern or Southern labor supplies on these endogenous variables are altered by the addition of imitation risk.

The first result is that an increase in the intensity of imitation reduces the rate of innovation and the extent of outsourcing, and increases the relative wage and aggregate expenditure. The main point of GS, that the decline in the relative wage due to outsourcing can be offset by faster innovation, is shown to be robust, even if the increased outsourcing stemmed from reduced imitation risk.

The second result is that increases in either labor supply lead to a decline in the relative wage, along with a faster rate of innovation. There was no effect of labor supplies on the relative wage in the original model without imitation. However, the addition of imitation generates an indirect effect of labor supplies on relative wages that occurs through the rate of innovation. Increases in innovation make the imitation risk less important, and so the relative wage falls as cost savings from outsourcing do not need to be as large to compensate for the shorter expected duration of profits. Provided imitation is large enough, increased labor supplies increase the extent of outsourcing. So increased Northern or Southern labor supplies can be added to the list of forces that could be behind the trend toward greater outsourcing.

Appendix

Signing $dt/dM < 0$

The expression for the extent of outsourcing (30) is inserted into the Northern labor constraint (28), which is then solved for the Northern labor supply. That value for L_N is then used to simplify the derivative of the rate of innovation with respect to the imitation intensity (31) since starting from an equilibrium. The condition on the discount rate ρ is found by inserting the partial solution for χ (30) into $n_N = 1 - (\chi/\beta)(1 + M/t) > 0$. The discount rate being small enough, $\rho < \bar{\rho}$, together with some products being produced entirely in the North, $n_N > 0$, ensures that the denominator of dt/dM is positive. The value of the Southern labor supply needed for the denominator to be negative, $a(\beta\delta t + M)^2/[\beta\delta M(1 - \delta)^2]$, exceeds the maximum L_S allowed for $n_N > 0$.

Signing $d\chi/dM < 0$

Plug the corresponding expressions for the partials to find

$$L_S < \tilde{L}_S \equiv \frac{\bar{L}_S + a\left(\frac{2M}{\beta\delta} + 2t + \rho\right)}{1 - \delta} \rightarrow \frac{d\chi}{dM} < 0, \tag{49}$$

where

$$\bar{L}_S \equiv \frac{a\left(\frac{M}{\beta} + \delta(t + \rho)\right)}{\delta(1 - \delta)} \left(\delta + \frac{M}{\beta t}\right) \tag{50}$$

is an upper bound on the supply of Southern labor such that $L_S < \bar{L}_S$ is required for the extent of outsourcing to remain complete, $\chi < \beta$ (that is $n_O < 1$). Since $\tilde{L}_S > \bar{L}_S$

as $a[2M/(\beta\delta) + 2t + \rho] > 0$ and $1/(1 - \delta) > 1$ due to $\delta < 1$, the upper bound $L_S < \bar{L}_S$ implies that the condition $L_S < \tilde{L}_S$ is satisfied.

Signing $dE/dM > 0$

The level of Southern labor supply required to make the derivative negative exceeds the maximum allowed for the measure of Northern production to be positive.

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