Outsourcing under imperfect protection of intellectual property

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Abstract

This paper models outsourcing decisions when intellectual property rights are imperfectly protected. Firms in the advanced North develop higher quality levels of existing products and then decide whether to shift a basic stage of production to the South, where production costs are lower. However, production of even the basic stage in the South entails a risk of imitation by Southern firms. The larger this risk of imitation, the lower the rate of innovation,and the higher the relative wage. The increased relative wage raises the cost savings from outsourcing, which offsets the reduction in the expected duration of profits due to imitation. Additionally, a larger world labor supply has the opposite effect – accelerating innovation while reducing the relative wage.

Keywords: Outsourcing, Fragmentation, Innovation, Intellectual Property Rights

JEL classification: F1; O3

1. Introduction

U.S. firms have increasingly been outsourcing their basic stages of production to countries such as Mexico and China, where production costs are lower. Glass and Saggi (2000) constructed a North-South product cycle model to help identify the 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

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that faster innovation could potentially create gains sufficient to offset the decline in Northern wages.

The Glass and Saggi (2000) model assumed away Southern imitation for simplicity. This paper adds imitation to address how increased exposure to imitation might affect the incentives to outsource basic production and to innovate, as well as relative wages. I find that an increase in the intensity of imitation decreases the rate of innovation, while increasing the Northern relative wage. The increase in the relative wage restores some of the incentive to shift basic production to the South, since a higher Northern relative wage implies larger cost savings. The extent of outsourcing falls if imitation is large enough.

Understanding the effects of imitation on the decision to outsource production internationally is important because higher risk of imitation is thought to limit the attractiveness of outsourcing. Firms may refrain from outsourcing all production for fear that sharing production secrets with outside firms may lead to future competition. Lower production costs provide an incentive to outsource by raising profits, but imitation risk may reduce the expected duration of profits. This trade-off between the size and duration of profits seems central to the outsourcing decision.

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 Glass and Saggi (2000) model, labor supplies did not affect the relative wage across countries. Here they do, 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 relative degree of discounting when outsourcing relative to when not: if innovation occurs frequently, the additional risk of imitation will be relatively less important.

Intuitively, labor supplies should affect relative wages. While adding imitation generates the intuitive effect that an increase in the Northern labor supply lowers the Northern wage (relative to the Southern wage), that an increase in the Southern labor supply has the same effect seems less obvious. In the model, an increase in either labor supply increases innovation. But it is only through innovation that the labor supplies affect the relative wage, and so an increase in either labor supply decreases the Northern relative wage. An expansion in the Southern labor supply may reduce the demand for Northern labor through increasing the extent of outsourcing.

Firms may choose to outsource only more basic stages of production to help protect their product designs from imitation. Another way firms may try to reduce the risk of opportunistic behavior is by keeping activities within the firm. An innovator may shift production to the South by forming a subsidiary for that purpose – foreign direct investment (FDI). There may nonetheless be some sort of demonstration effect that exposes the firm to a greater risk of imitation even

when production is kept within the firm. Lai (1998) has argued that an increase in the intensity of imitation of multinational's products causes a reduction in FDI and imitation. 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 a basic stage of production to the low cost South. However, by licensing a Southern firm to perform basic production, the Northern firm exposes itself to imitation. The degree that shifting basic production to the South lowers costs is determined endogenously through the relative wage across countries.

2.1. Consumers

Consumer preferences are as described in the quality ladders product cycle model of Grossman and Helpman (1991). 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 in country i has additively separable intertemporal preferences given by lifetime utility

$$U_i = \int_0^\infty e^{-\rho t} \log u_i(t) dt, \tag{1}$$

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

$$\log u_i(t) = \int_0^1 \log \left[\sum_m \lambda^m x_{im}(j,t) \right] dj, \tag{2}$$

λ^m is the assessment of quality level m and $x_{im}(j,t)$ is consumption by consumers in country i 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

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

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

$$Y(t) = \sum_i L_i w_i(t), \tag{4}$$

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 both measured in efficiency units. Aggregate spending is

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

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.

2.2. 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 (2000), in my model Northern firms can purchase basic stages of production from Southern firms. Production occurs in two stages: a basic stage followed by an advanced stage. Normalize the unit labor requirement in production to one. Of the one unit of labor needed to produce one unit of the final product, β is used in the basic stage and the remaining $(1-\beta)$ is combined with the output of the basic stage in the advanced stage to produce the final product. β corresponds to α in the Glass and Saggi (2000) model: the switch to β is to avoid confusion with the unit labor requirement in innovation a. The output of the basic stage is a tradeable intermediate component; the output of the advanced stage is the tradeable final product. Hence, the two stages of production can be located in different countries.

To outsource basic production, a firm must first adapt its production process for the Southern economic environment. For simplicity,

assume this adaptation process is costless (but uncertain). Undertaking outsourcing intensity ϕ for a time interval dt requires leads to success with probability ϕdt. If successful at its efforts, a firm outsources all of the basic stage of production since production costs for the basic stage are lower in the South.

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

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

where v_N is the value a firm gains from successful innovation. Similarly, expected gains from international outsourcing must not exceed the cost of zero, with equality when outsourcing occurs with positive intensity

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

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

For equilibria with both innovation and outsourcing, both of these conditions must hold with equality and thus $v_N = v_O = wa$.

A Northern firm that successfully innovates earns the reward

$$v_N = \frac{\pi_N + \phi v_O}{\rho + \phi + \iota} = \frac{\pi_N}{\rho + \iota}, \tag{8}$$

where 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. The reward to innovation is the discounted stream of profits from production. 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 Glass and Saggi (2000), outsourcing profits had to be larger to offset costs of adapting the technology for producing the basic stage of production in the South. Even if technologies do not need to be adapted, increased risk of imitation may be a downside of outsourcing. 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 $M > \underline{M}$.

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 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 basic 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 basic production have marginal cost w, yielding instantaneous profits

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

Firms that outsource basic production have marginal cost $c \equiv \beta + (1 - \beta)w$, where $0 < \beta < 1$ represents the labor share in basic production, yielding instantaneous profits

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

The advanced stage costs w and the basic stage costs 1 to produce. I assume that there are sufficiently many potential suppliers of the

basic stage of production in the South that Northern firms are able to purchase it at cost. Comparing the profit expressions, profits rise with outsourcing in proportion to how much of production is basic enough to be outsourced, how large the cost savings are, 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.

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

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 the advanced stage of 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. The lower level of development in the South ensures that adapting advanced stages of production is more difficult than adapting basic stages.

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

$$\frac{\overline{M}}{\rho + \iota} >> \frac{\delta (w - 1)}{1 - w\delta} \tag{17}$$

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

$$E (1 - \delta) < wa \left(\rho + \iota + \overline{M}\right). \tag{18}$$

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.

2.3. Market Measures and Resources

A quality level of a product is produced entirely in the North following innovation, partially in the North (advanced stage) and partially in the South (basic stage) 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 in must equal flows out of basic 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,

$$\phi n_N = (\iota + M)\, n_O. \tag{19}$$

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

$$Mn_O = \iota n_S. \tag{20}$$

These product measures must sum to one:

$$n_N = 1 - n_O - n_S. \tag{21}$$

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 $a\iota$. Sales 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 the advanced stage 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:

$$a\iota + [n_N + (1-\beta)n_O]E\delta = L_N. \tag{22}$$

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 the basic stage in markets with outsourcing and both stages for products that have been imitated. Labor demand for production of basic stages of outsourced products is $\beta n_O E\delta$. I assume that following imitation, all Southern firms become able to produce the entire product (both basic and advanced stages) and thus set the price of the product at 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 a product that arises from the basic stage of 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 $n_S = Mn_O/\iota$ 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 $n_N + (1-\beta)n_O = 1 - (\chi/\beta)\,(1 + M/\iota) + (1-\beta)(\chi/\beta) = 1 - \chi[1 + M/(\beta\iota)]$, and the Southern resource constraint

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

as $\beta n_O\delta + n_S = \chi\delta + M\chi/(\beta\iota) = \chi[\delta + M/(\beta\iota)]$.

These two resource constraints (24, 25) combined with the two valuation conditions (15, 16) comprise the system. This system of four equations determines aggregate spending E, the 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 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 the aggregate expenditure

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

and the relative wage

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

(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 One traces the rate of innovation ι that equates labor demand and

labor supply in each country. The Northern resource constraint is represented by $\mathbf{L}_N$

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

and the Southern resource constraint by $\mathbf{L}_S$.

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

The intersection of the two resource constraints indicates the equilibrium extent of outsourcing and rate of innovation. Both resource constraints are upward sloping: a larger extent of outsourcing permits a faster rate of innovation. The Northern resource constraint is more steeply upward sloping than the Southern resource constraint.

3.1. Imitation Intensity

An increase in the intensity of imitation M clearly shifts the Southern resource constraint down: for any given rate if innovation ι, the extent of outsourcing χ must fall. More imitation raises the measure of Southern production $n_S = (\chi M)/(\beta\iota)$, holding ι 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 basic production in the South.

The shift of in the Northern resource constraint due to an increase in M is less clear. More imitation reduces the measure of Northern pro-

duction $n_N = 1 - \chi\,(1 + M/\beta\iota)$ 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 ι more formally, solve the Southern resource constraint (25) for the extent of outsourcing

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

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 basic 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 ι and so solving for ι is not convenient) to find

$$\frac{d\iota}{dM} = -\frac{\beta\left[a\,(\beta\delta\iota + M)^2 - L_S\beta\delta M\,(1-\delta)^2\right]}{a\,(\beta\delta\iota + M)^2 + L_S\beta^2\delta\iota\,(1-\delta)^2} < 0 \tag{31}$$

if $\rho < (L_S/a)\,(1-\delta)\,(\iota + M\delta)\,/\,(M + \iota\beta\delta) \equiv \overline{\rho}$, which should be true since the discount rate should be quite small. So indeed an increase in the intensity of imitation decreases the rate of innovation. The condition on the discount rate ρ is found by inserting the partial solution for χ (30) into $n_N = 1 - (\chi/\beta)(1 + M/\iota) > 0$. The discount rate being small enough $\rho < \overline{\rho}$, together with some products being produced

entirely in the North $n_N > 0$, ensures that the numerator of $d\iota/dM$ is positive. 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

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

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

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

An increase in the intensity of imitation therefore decreases the extent of outsourcing

$$\frac{d\chi}{dM} = \underbrace{\frac{\partial \chi}{\partial M}}_{-} + \underbrace{\frac{\partial \chi}{\partial \iota}}_{?} \underbrace{\frac{d\iota}{dM}}_{-} \tag{34}$$

The relative wage decreases with the rate of innovation

$$\frac{\partial w}{\partial \iota} = -\frac{\beta M (1-\delta)}{\delta \left(M + \beta (\iota + \rho) \right)^2} < 0 \tag{35}$$

and increases with the intensity of imitation

$$\frac{\partial w}{\partial M} = \frac{\beta (1-\delta) (\iota + \rho)}{\delta \left(M + \beta (\iota + \rho) \right)^2} > 0 \tag{36}$$

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

$$\frac{dw}{dM} = \underbrace{\frac{\partial w}{\partial M}}_{+} + \underbrace{\frac{\partial w}{\partial \iota}}_{-} \underbrace{\frac{d\iota}{dM}}_{-} > 0 \tag{37}$$

Aggregate expenditure increases with the rate of innovation

$$\frac{\partial E}{\partial \iota} = \frac{a}{1-\delta} > 0 \tag{38}$$

and increases with the intensity of imitation

$$\frac{\partial E}{\partial M} = \frac{a}{\beta\delta\left(1-\delta\right)} > 0 \tag{39}$$

but 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.

$$\frac{dE}{dM} = \underbrace{\frac{\partial E}{\partial M}}_{+} + \underbrace{\underbrace{\frac{\partial E}{\partial \iota}}_{+}\underbrace{\frac{d\iota}{dM}}_{-}}_{} \tag{40}$$

Proposition 1 *An increase in the intensity of imitation reduces the rate of innovation and increases the relative wage. The extent of international outsourcing falls (provided the imitation intensity is sufficiently large). Aggregate expenditure may rise or fall.*

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 trade-off 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 (2000) found, in the absence of innovation, and 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 Glass and Saggi (2000) result is robust to the addition of imitation risk when outsourcing.

3.2. Labor Supplies

However, the effect of the labor supplies turns out to be somewhat different with imitation than in Glass and Saggi (2000). One might think that one reason international outsourcing has been on the rise is an increase in the Southern labor supply, especially relative to the Northern 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 the expected effect on

the extent of outsourcing; however, they 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 relative to the North 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 for 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 were almost no innovation, the expected duration of profits would 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 can fall to almost one as little cost savings are needed from outsourcing.

However, 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. Intuition would suggest that an increase in the Southern labor supply would raise the North-to-South relative wage due to standard supply and demand reasoning. So the effect for the Southern labor supply might not seem intuitive. But if an increase in the Southern labor supply increases the extent of outsourcing, which shifts labor demand from the North to the South, the reduction in labor demand in the North should lead to a reduction in the Northern wage relative to the South. So in the presence of outsourcing, the simple logic may be too simple. So 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

$$\frac{d\iota}{dL_N} = \frac{a\left(\beta\delta\iota + M\right)^2 - L_S\beta\delta M\left(1-\delta\right)^2}{\left(1-\delta\right)\left(\beta\delta\iota + M\right)^2} > 0 \tag{41}$$

$$\frac{d\iota}{dL_S} = \frac{a\left(\beta\delta\iota + M\right)^2 - L_S\beta\delta M\left(1-\delta\right)^2}{\delta\left(1-\delta\right)\left(\beta\delta\iota + M\right)\left(\beta\iota + M\right)} > 0 \tag{42}$$

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 $\partial\chi/\partial\iota > 0$ if $M\left(M + \beta\delta\rho\right) > \beta^2\delta^2\iota^2$. The Southern labor supply has a direct effect of increasing the extent of outsourcing

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

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

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

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.

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

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

4. Conclusion

This paper has developed a quality ladders model with both outsourcing and imitation. Glass and Saggi (2000) is extended to capture the possibility that outsourcing production to the South, while lowering costs, may expose the firm to a greater risk of imitation. When a Southern firm knows how to produce some key components of the final product, it may be more likely that the entire product is imitated. 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 increases the relative wage. The extent of outsourcing falls if imitation is large enough, while aggregate expenditure may rise or fall. The main point of Glass and Saggi (2000), that the decline in the relative wage can be offset by faster innovation seems robust, even if a larger share of a product being outsourced leads to a greater imitation risk.

The second result is that increases in either labor supply leads 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 can fall as cost savings from outsourcing do not need to be as large to compensate for the shorter expected duration of profits.

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Figure One. Effect of Imitation on Outsourcing and Innovation