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Innovation and wage effects of international outsourcing

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Abstract

We investigate the effects of increased outsourcing of production to a low wage country. Such international outsourcing lowers the marginal cost of production and thus increases profits, creating greater incentives for innovation. A reduction in the resource requirement in adapting technology relative to improving products or an expansion in the portion of production that can be outsourced generates a greater extent of international outsourcing, a lower relative wage and a faster rate of innovation. An increase in production taxes in the North, production subsidies in the South, or a subsidy to adapting technologies has similar effects. © 2001 Elsevier Science B.V. All rights reserved.

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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 much lower.

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Due to the increased extent of international outsourcing of production, the effect of international outsourcing on wages has become an important policy issue.

For example, in March 1996, General Motors employees (at an Ohio plant) went on strike to protest increased outsourcing of production to low wage countries. In October 1995, Boeing employees (in Kansas, Washington, and Oregon) went on strike to protest Boeing's commitment to outsource half of the value of the average jet aircraft, mostly to China. The negative impact of increased international outsourcing on U.S. wages has helped fuel the political campaigns of such candidates as Ross Perot and Pat Buchanan, backed by workers whose livelihoods are threatened.[1]

We construct a North–South product cycle model to help identify the forces that can lead to increased outsourcing as well as a lowering of the Northern relative wage. An important goal of this paper is to determine the effect of these forces on the rate at which the technology frontier progresses. Thus, our analysis brings a dynamic approach to an issue that previously has been analyzed in static models.

We develop a product cycle model with international outsourcing of basic production to low wage countries. Northern firms import basic components from the South, assemble the components into finished products using Northern labor and then sell the finished products on world markets. Cheaper Southern labor substitutes for Northern labor in basic production. International outsourcing of production is viewed as detrimental to the welfare of workers in industrialized countries due to the resulting negative impact on wages. We explore what forces lead to a greater extent of international outsourcing along with a relative decline in Northern wages.

However, the emphasis on the detrimental effect of international outsourcing on Northern wages ignores potential benefits. Increased access to the work force in low wage countries increases the profitability of Northern firms through cost savings. Since profits provide the incentive for firms to improve products through costly innovations, international outsourcing logically should encourage innovation. By increasing the rate of innovation, international outsourcing can potentially create gains sufficient to offset the decline in Northern wages. Thus, ignoring the dynamic aspects of the problem can lead to overly pessimistic conclusions.

In existing papers such as Jensen and Thursby (1987), Segerstrom et al. (1990), and Grossman and Helpman (1991), production shifts to the low cost country through imitation by firms located there.[2] In contrast, here production shifts

[1] Workers may also object to outsourcing within a country if they are not able to follow production shifts. The features and results of our model also apply to separate labor markets within the same country.

[2] In Helpman (1993) and Glass and Saggi (1999), production shifts to the South through foreign direct investment by Northern firms.

through the original innovator outsourcing part of its production to the low wage country. Once firms have successfully innovated, they then may adapt their basic production techniques for production in the low wage country. Due to differences in the technology involved in the two stages of production, Northern firms find international outsourcing of only the basic stage attractive. Since international outsourcing requires firms to adapt production technologies, newly developed designs remain produced in the high wage country while older designs have basic production shifted to the low wage country, similar to Vernon (1966).

While empirical analysis of the impact of international outsourcing on wages in the United States is prevalent, only Feenstra and Hanson (1996a) model the effects of international outsourcing. In their model, a single manufactured good is produced from a continuum of intermediate goods that differ in their relative use of skilled and unskilled workers. Intermediate goods that require a range of inputs up to some critical ratio of skilled to unskilled labor are produced by the South, whereas the remaining goods are produced in the North. An increase in the relative capital stock of the South results in the South producing a greater range of intermediate goods. Total payments to labor in the North decline as the South produces goods that require a higher ratio of skilled to unskilled labor. However, an increase in international outsourcing benefits Northern workers by lowering the prices of goods and, if the South is small enough, this effect outweighs the negative wage effects, leading to an overall welfare gain.

Our approach differs from that of Feenstra and Hanson in the fundamental model of international trade in which outsourcing occurs. Their model is driven by differences in factor endowments, while ours is driven by differences in technology. An increase in international outsourcing results from changes in the South's capital stock in their model, while the increase results from reduced costs of adapting technologies for Southern production or a wider span of production that can be outsourced in our model. We also demonstrate that increases in production taxes in the North, production subsidies in the South, or subsidies to adapting technologies for Southern production lead to increased international outsourcing. Furthermore, international outsourcing can provide a welfare gain for the North by lowering prices in their model, while a welfare gain can occur through faster innovation in our model. Thus our analysis complements Feenstra and Hanson's results by determining the impact of international outsourcing on the rate of innovation.

Section 2 constructs the model and determines the equilibrium. Section 3 examines how the rate of innovation, extent of international outsourcing (fraction of all production that occurs in the South) and relative wage respond to outsourcing opportunities, labor supplies, production taxes or subsidies, and R&D subsidies. Section 4 concludes.

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 attempt to outsource production by adapting its basic production technology for the low cost country. If the firm is successful in adapting its technology, it then licenses a Southern firm to perform basic production at cost.

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

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

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.[3] Thus $L_i w_i(t)$ is total labor income in country i at time t. Aggregate spending is

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

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 (Northern) firm must first design it. However, due to assumed differences in technological knowledge across countries, only Northern firms innovate. 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, so $w \equiv w_N/w_S = w_N$ is the Northern wage relative to the Southern wage. Assume undertaking innovation intensity $\imath$ for a time interval $\mathrm{d}t$ requires $a_\imath \imath \, \mathrm{d}t$ units of labor at a cost of $w a_\imath \imath \, \mathrm{d}t$ and leads to success with probability $\imath \mathrm{d}t$.

We part from Grossman and Helpman's model by allowing Northern firms to purchase basic stages of production from Southern firms: outsourcing takes the place of imitation in shifting production to the South. 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, α is used in the basic stage and the remaining $(1-\alpha)$ is combined with the output of the basic stage in the advanced stage to produce the final product. 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.

[3] Throughout the paper, wages refer to wages per efficiency unit of labor.

To outsource basic production, a firm must first expend resources to adapt its production process for the Southern economic environment.[4] Like innovation, outsourcing involves certain costs with uncertain rewards: a firm might never find a feasible adaptation of its production process. Undertaking outsourcing intensity ϕ for a time interval dt requires $a_\phi \phi \mathrm{d}t$ units of labor at a cost of $wa_\phi \phi \mathrm{d}t$ and leads to success with probability $\phi \mathrm{d}t$. If successful at its efforts, a firm outsources all basic production.

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:

$$v_{\mathrm{N}} \leq wa_\iota, \quad \iota > 0 \Leftrightarrow v_{\mathrm{N}} = wa_\iota, \tag{6}$$

where v_{N} is the value a firm gains from successful innovation. Similarly, expected gains from international outsourcing must not exceed cost, with equality when outsourcing occurs with positive intensity

$$v_{\mathrm{O}} - v_{\mathrm{N}} \leq wa_\phi, \quad \phi > 0 \Leftrightarrow v_{\mathrm{O}} - v_{\mathrm{N}} = wa_\phi, \tag{7}$$

where $v_{\mathrm{O}} - v_{\mathrm{N}}$ is the capital gain from outsourcing basic production.[5] We focus on equilibria with both innovation and outsourcing, so both of these conditions hold with equality.

A Northern firm that successfully innovates earns the reward

$$v_{\mathrm{N}} = \frac{\pi_{\mathrm{N}} + \phi(v_{\mathrm{O}} - wa_\phi)}{\rho + \phi + \iota}, \tag{8}$$

where upon successfully adapting its technology for Southern production the firm's value becomes

$$v_{\mathrm{O}} = \frac{\pi_{\mathrm{O}}}{\rho + \iota} \tag{9}$$

until rival innovation terminates its value. The reward to innovation is the discounted stream of profits from production.

[4] An alternative interpretation of the adaptation process is that Northern firms must spend resources locating a suitable licensee.

[5] Subscripts denote the type of market: N for Northern production and O for outsourcing basic production.

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. While Southern firms are never able to produce the advanced stage of production (of state-of-the-art technologies), once technologies no longer yield profits in equilibrium, these old technologies become fully available to Southern firms.[6] This assumption provides a common marginal cost of production of one for all technologies no longer produced in equilibrium.

Thus each producing firm charges price $p = \lambda$ and makes sales $x = E/\lambda$ regardless of whether the firm outsources basic production.[7] International outsourcing does affect costs and thus profits. Let $\delta = 1/\lambda$. Firms that do not outsource basic production have marginal cost w, yielding instantaneous profits

$$\pi_{\mathrm{N}} = E(1 - w\delta). \tag{10}$$

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

$$\pi_{\mathrm{O}} = E(1 - c\delta) = E[1 - w\delta + \alpha\delta(w - 1)]. \tag{11}$$

The cost savings of outsourcing increase profits, which provide an incentive for firms to endure the cost of adapting technologies.

Inserting profits (10), (11) 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

$$E(1 - w\delta) = wa_{\iota}(\rho + \iota), \tag{12}$$

$$\alpha E\delta(w - 1) = wa_{\phi}(\rho + \iota), \tag{13}$$

which must hold for any 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

[6] Free access to old technologies may arise because the potential for opportunistic behavior keeps Northern firms from providing the knowledge of advanced stage production to Southern firms. Once a technology becomes obsolete, Northern firms have no incentive to protect knowledge of their technology (see also Glass, 1997).

[7] We purposely develop a model that keeps price independent of outsourcing so that innovation provides the sole positive consequence of outsourcing on Northern welfare. This isolation helps us better contrast with Feenstra and Hanson (1996a) the root of additional outsourcing benefits here.

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. Based on the expression for the equilibrium wage (to follow), this condition is satisfied if the size of the quality increment is not too large.[8]

Alternatively, suppose the cost of adapting the advanced stage for Southern production A_ϕ is larger than the cost of adapting the basic stage for Southern production a_ϕ relative to the share of production transferred:

$$\frac{A_\phi}{1-\alpha} > \frac{a_\phi}{\alpha} \rightarrow A_\phi > a_\phi\left(\frac{1-\alpha}{\alpha}\right). \tag{14}$$

The expected gain from adapting the advanced stage then would be less than the cost of adapting the advanced stage for Southern production:

$$E\delta(1-\alpha)(w-1) < wA_\phi(\rho+\iota), \tag{15}$$

even though the expected gains from adapting the basic stage cover costs, as indicated in (13). The lower level of development in the South ensures that adapting advanced stages of production is more difficult than adapting basic stages.

Finally, the limitation on how much of production can be shifted to the South could stem from concerns over opportunistic behavior. Northern firms possess an advantage due to their innovation success. International outsourcing involves purchasing some stages of production from outsiders. If a firm were to purchase all stages of production from outside the firm, its full knowledge advantage would be shared with outsiders. These outsiders could then exclude the innovator since the innovator no longer serves any necessary function. Keeping at least a small step of production (broadly defined) within the firm ensures that outsiders cannot fully replicate the production process.[9]

2.3. Market measures and resources

A product has basic production outsourced when adaptation occurs and reverts to Northern production with each new quality improvement. In a steady

[8] See Deardorff (1997) and Jones and Kierkowski (1997) for static models of fragmentation (also known as segmentation) of the production process.

[9] How the desire to minimize technology diffusion and associated opportunistic behavior affects a firm's choice of mode for serving a foreign market is discussed in Ethier and Markusen (1996) and Saggi (1996).

state, the flows in must equal flows out of basic outsourcing so that the fraction of products outsourced n_O remains constant. Let n_N similarly denote the fraction of products not outsourced (all production occurs in the North). The flows into outsourcing are ϕn_N while the flows out are ιn_O; therefore, $\phi n_N = \iota n_O$. Additionally, the product measures must sum to one: $n_N = 1 - n_O$.

The fixed supply of labor is allocated between innovation, adaptation and production in the North and to production in the South.[10]

$$a_\iota \iota + a_\phi \phi n_N + [n_N + (1 - \alpha) n_O] E\delta = L_N \,, \tag{16}$$

$$\alpha n_O E\delta = L_S \,. \tag{17}$$

The North produces only the advanced stage in markets with outsourcing and both stages otherwise; the South produces only the basic stage in markets with outsourcing.[11]

Define the extent of international outsourcing as the fraction of all production outsourced to the South, $\chi \equiv \alpha n_O$, the fraction of products outsourced times the fraction of production outsourced for each product. Also, define the resource requirement in adaptation relative to innovation $a_R \equiv a_\phi / a_\iota$. The market measures and intensity of adaptation can be eliminated from the resource constraints, leaving

$$\left(1 + \frac{a_R \chi}{\alpha}\right) a_\iota \iota + (1 - \chi) E\delta = L_N \,, \tag{18}$$

$$\chi E\delta = L_S \tag{19}$$

These two resource constraints (18), (19) combined with the two valuation conditions (12), (13) comprise the system.[12] The system of four equations (12), (13), (18) and (19) determines aggregate spending E, the relative wage w, the rate of innovation ι, and the extent of international outsourcing χ.

[10] Adaptation could be conducted in the South, which would resemble imitation except that only basic production would be imitated so ownership would remain exclusively with Northern firms.

[11] If adaptation instead occurs in the South, the labor demand for adaptation enters into the Southern rather than the Northern labor constraint. This modification only strengthens our results since more labor demand (both basic production and adaptation) is shifted to the South.

[12] The Northern resource constraint clearly indicates that less labor is involved in production in the North as the extent of international outsourcing increases. If unions organize only production workers, not workers employed in laboratories doing innovation and adaptation, this reduction in production employment reinforces their wage concerns.

2.4. Steady-state equilibrium with outsourcing

The valuation conditions (12), (13) exclusively determine the relative wage consistent with innovation and outsourcing both occurring in equilibrium:

$$w = \frac{\alpha + a_R\lambda}{\alpha + a_R} > 1. \tag{20}$$

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). The solution for the relative wage narrows the potential forces behind a reduced relative wage down to the labor share in basic production α, the resource requirement in adaptation relative to innovation a_R or the quality increment λ since only these parameters affect the relative wage.[13]

For various extents of international outsourcing $\chi \in (0, \alpha)$, Fig. 1 traces the rate of innovation ι that equates labor demand and labor supply in each country.[14] The innovation condition (12) is solved for real expenditure and substituted into the two resource constraints. The Northern resource constraint is represented by LN:

$$\left(1 + \frac{a_R\chi}{\alpha}\right) a_\iota \iota + (1 - \chi)\left[\frac{(\alpha + a_R\lambda)}{\alpha(\lambda - 1)}\, a_\iota(\rho + \iota)\right] = L_N \tag{21}$$

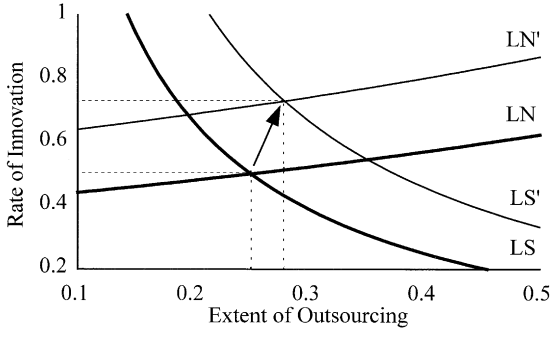

Fig. 1. Outsourcing and innovation.

[13] The labor supplies do not affect the relative wage due to constant returns in innovation and adaptation (recall that the relative wage is determined by the innovation and adaptation conditions).

[14] Figures are drawn for $\rho = \frac{1}{6}$, $\lambda = 2$, $a_\iota = 2$, $a_R = \frac{1}{2}$, $a'_R = \frac{1}{4}$, $\alpha = \frac{1}{2}$, $L_S = 1$, and $L_N = \frac{17}{4}$. The steady-state equilibrium is $E = 8$, $w = \frac{3}{2}$, $\iota = \frac{1}{2}$, and $\chi = \frac{1}{4}$.

and the Southern resource constraint by LS:

$$\chi\left[\frac{(\alpha + a_R\lambda)}{\alpha(\lambda - 1)}\, a_l(\rho + \iota)\right] = L_S. \tag{22}$$

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

3. Outsourcing causes and effects

Recently, most industrialized countries have experienced an increased extent of international outsourcing χ with a decreased relative wage w. Feenstra and Hanson (1996b) document that international outsourcing by U.S. firms has expanded from 5.34% of material purchases in 1972 to 11.61% in 1990 (doubling over less than 20 years).

Meanwhile, wages in countries where basic production is shifted from have fallen relative to the wages of countries where basic production is shifted to. From 1970 to 1980, manufacturing earnings per employee rose by an average annual rate of 4.0% in the East Asian NICs (Korea, Singapore, Malaysia, Indonesia, Thailand) but only an average annual rate of 2.0% in the leading developed countries (Germany, U.S., Japan, U.K. and Canada) as reported in the World Bank's *World Development Report* (World Bank, 1975–1995, various issues). Similarly, from 1980 to 1991, these earnings rose by 5.3% for the NICs but only 1.3% for the DCs.[15] What forces could explain these trends? What effect do these forces have on the rate of innovation?

3.1. Outsourcing opportunities

The range of activities that can be undertaken in the South is a function of many factors. These many factors, in one way or another, represent an increased ability to outsource: Northern firms face a lower cost of adapting technologies or can outsource a greater share of production activities.

Therefore, an increased ability to outsource can be represented by two parameters in our model: a fall in the resource requirement in international outsourcing relative to innovation a_R or an increase in the share of production activities that can be outsourced for each product α. The first approach implies that the costs of international outsourcing fall as adapting production for the South becomes easier. The second approach implies that the benefits of

[15] The data does not control for other forces affecting wages. Data limitations make the wage coverage 1970–1991 slightly wider than the outsourcing coverage 1972–1990.

international outsourcing rise as production becomes cheaper due to outsourcing a larger proportion of production to the South. We show both these forces increase the extent of international outsourcing and reduce the relative wage. Additionally, both these forces increase the rate of innovation.

First consider the role of a_R. A smaller labor requirement in adaptation relative to innovation means fewer resources must be spent to achieve cost reduction. Fig. 1 shows that the Northern resource constraint LN′ supports a faster rate of innovation for any given extent of outsourcing, and similarly for the Southern resource constraint LS′ as a_R falls. Hence, the rate of innovation and extent of international outsourcing rise. However, the relative wage must fall to maintain the incentives for innovation in the presence of higher opportunity cost of innovation in terms of adaptation.

Next consider the role of α. An increase in the fraction of production outsourced leads to a direct decrease in costs of production when outsourcing occurs. Furthermore, an increase in α also has an indirect effect on costs of production: the relative wage decreases according to (20). This decrease in the relative wage reinforces the direct decline in costs of production. As with a fall in a_R, a rise in α requires the relative wage to fall to preserve the incentives for innovation.

Proposition 1. The smaller the resource requirement in adaptation relative to innovation or the larger the share of production activities that can be outsourced, the greater the extent of international outsourcing, the faster the rate of innovation and the lower the relative wage.

Both of these forces may occur as a natural consequence of development in the South. As the South develops, the Southern economic environment becomes more similar to the North. Thus, adapting technologies is not as difficult and more advanced production stages can be outsourced.

3.2. Labor supplies

Much attention has been drawn to the phenomenal rate of factor accumulation by the East Asian Tigers, which would be represented here by an increase in Southern resources. An increase in the Southern labor supply leads to a greater extent of international outsourcing of production and a faster rate of innovation, as international outsourcing relies on abundant Southern labor. While Southern resources affect the capacity of the South for hosting production, the Southern labor supply does not directly affect the incentives for innovation and international outsourcing, so the relative wage does not change. Thus, an increase in Southern resources does not appear to be (exclusively) behind the increased extent of international outsourcing since the relative wage is unaffected. Similarly, while a smaller Northern labor supply does lead to a greater

extent of outsourcing, it does not affect the relative wage. Thus, a decrease in Northern resources does not appear to be (exclusively) behind the increased extent of international outsourcing.

Proposition 2. The smaller the Northern labor supply, the greater the extent of international outsourcing, and the slower the rate of innovation, with no effect on the relative wage. The larger the Southern labor supply, the greater the extent of international outsourcing, and the faster the rate of innovation, with no effect on the relative wage.

An increase in Southern resources could be encouraging outsourcing in the presence of other forces generating the reduction in the relative wage. If so, then the dynamic benefits of outsourcing would be more pronounced.[16]

3.3. Production taxes and subsidies

Having found two probable natural economic forces behind an increased extent of international outsourcing and a decline in the relative wage, we now explore the potential for government policies to induce similar effects. Discussions surrounding trade and investment agreements often center around not only lower wages attracting basic production but also lower taxes. How do differences in tax rates across countries affect international outsourcing?

Industrialized countries that provide the source of international outsourcing generally have stricter environmental protection regulations, labor safety, unemployment and social security provisions and higher overall tax rates that raise the cost of production in the North relative to the South beyond the level indicated by wages alone. Suppose the marginal cost of production in the North is $w(1+\tau)$, the relative wage elevated by the tax rate τ.[17]

Not only do Northern governments tend to impose environmental and other regulations that raise production costs, but Southern governments adopt policies that lower production costs there. Southern governments may enforce wage ceilings, tolerate harsh work conditions, permit depletion of natural resources or directly subsidize exports.[18] Suppose the marginal cost of production in the

[16] An increase in the quality increment (or similar forces increasing product prices) leads to a greater extent of outsourcing and a faster rate of innovation, but causes the relative wage to rise. Thus, an increase in the quality increment does not appear to be (exclusively) behind the increase in the extent of outsourcing because the effect on the relative wage occurs in the wrong direction.

[17] We consider a production tax that applies to workers employed in producing output, not to workers employed in innovation or adaptation, since only production can be outsourced.

[18] Southern countries may also have poorly defined property rights, political risk, corruption or other factors that raise production costs. The effects for an increase in a Southern subsidy also apply to a reduction in a Southern tax (for a production tax, $\sigma < 0$).

South is $(1-\sigma)$, the Southern wage (normalized to one) depressed by the subsidy rate σ. Recall $\delta \equiv 1/\lambda$.

The valuation condition for innovation then becomes

$$E[1 - w(1+\tau)\delta] = wa_{\iota}(\rho + \iota) \tag{23}$$

and the valuation condition for adaptation becomes

$$E\alpha[w(1+\tau) - (1-\sigma)]\delta = wa_{\phi}(\rho + \iota). \tag{24}$$

These new valuation conditions determine the new relative wage

$$w = \frac{\alpha(1-\sigma) + a_{\mathrm{R}}\lambda}{(1+\tau)(\alpha + a_{\mathrm{R}})}. \tag{25}$$

The solution for the relative wage indicates that a reduction in the relative wage could stem from an increase in production taxes in the North or an increase in production subsidies in the South.

Higher production taxes in the North increase the incentives for international outsourcing (to escape the taxes), which in turn permits a faster rate of innovation due to the resources freed from production in the North. Similarly, higher production subsidies in the South increase the incentives for international outsourcing (to obtain the subsidy), which in turn permits a faster rate of innovation due to the resources freed from production in the North. In both cases, the relative wage must decline to maintain the incentive for innovation.

Proposition 3. The larger the Northern production tax or the larger the Southern production subsidy, the greater the extent of international outsourcing, the faster the rate of innovation and the lower the relative wage.

Thus increases in Northern production taxes and Southern production subsidies can also provide an explanation for the observed increase in the extent of international outsourcing and decline in the relative wage. Like the natural economic forces examined, these government interventions share the trait that the rate of innovation rises.

3.4. R&D subsidies

Governments distort not only production decisions, but investment decisions as well. Suppose the government offers a subsidy s_{ι} to innovation, so a potential innovator bears only an innovation expense of $1 - s_{\iota}$ of the true cost of innovation. Suppose also that the government offers a subsidy s_{ϕ}

to adaptation, so a firm bears only the share $1 - s_\phi$ of the true cost of adaptation.[19]

The valuation condition for innovation then becomes

$$E[1 - w\delta] = wa_\iota(1 - s_\iota)(\rho + \iota) \tag{26}$$

and the valuation condition for adaptation then becomes

$$E[\alpha(w - 1)\delta] = wa_\phi(1 - s_\phi)(\rho + \iota) \tag{27}$$

These valuation conditions determine the new relative wage

$$w = \frac{\alpha(1 - s_\iota) + a_{\mathbf{R}}\lambda(1 - s_\phi)}{\alpha(1 - s_\iota) + a_{\mathbf{R}}(1 - s_\phi)}. \tag{28}$$

The solution for the relative wage indicates that a tax on innovation would depress the relative wage. However, a subsidy to innovation (not a tax) yields a greater extent of outsourcing. Thus, a policy of either taxing or subsidizing innovation does not seem to be behind the greater extent of outsourcing with a lower relative wage.

The solution for the relative wage does indicate that a reduction in the relative wage could stem from an increase in the subsidy to adaptation. We confirm that subsidizing adaptation does indeed lead to a greater extent of outsourcing.

Proposition 4. The larger the innovation subsidy, the greater the extent of international outsourcing, the faster the rate of innovation and the higher the relative wage. The larger the adaptation subsidy, the greater the extent of international outsourcing, the faster the rate of innovation and the lower the relative wage.

The relative wage falls when adaptation is subsidized but rises when innovation is subsidized. When adaptation is encouraged by a subsidy, the relative wage must fall to ensure the same return to innovation (through lower costs of innovation and lower production costs). On the other hand, when innovation is encouraged by a subsidy, the relative wage must rise to ensure the same return to adaptation (through greater cost savings from outsourcing).

Similar to Northern production taxes or Southern production subsidies, subsidizing adaptation increases the incentives for firms to outsource basic production to the South.[20] Subsidizing investments in adapting technologies for

[19] Subsidies could be paid by a Southern government keen to attract Northern production to its market.

[20] Thus our model is well-behaved: it does not exhibit the peculiar features that concern Cheng and Tao (1999) and Davidson and Segerstrom (1998) in the closed economy quality ladder model (with innovation and imitation) by Segerstrom (1991). In particular, a subsidy targeted at a form of R&D succeeds in stimulating that form of R&D, while the effects on the other form of R&D follow economic intuition.

Southern production results in encouraging innovation as well. In addition to the incentive effect already described, the increased outsourcing frees Northern resources for innovation.

4. Conclusion

This paper examines the sources and impact of increased international outsourcing of production. As for sources, we find five forces with the potential to explain an increased extent of international outsourcing along with a decline in the relative wage. A reduction in the costs of adapting technologies for production in low wage countries or an increase in the portion of production sufficiently basic to be outsourced could play a role. An increase in production taxes in high wage countries, an increase in production subsidies (reduction in production tax) in low wage countries, or a subsidy to adapting technologies for the South could also play a role. Each of these forces, along with raising the extent of international outsourcing and lowering the relative wage, also leads to a faster rate of innovation. Product market profits provide the reward to costly improvements in products, and international outsourcing increases product market profits. Also, shifting production to the South frees Northern resources for innovation. Thus, forces that increase international outsourcing accelerate the progression of the technology frontier.

As for impact, increased international outsourcing affects the welfare of Northern citizens in two conflicting directions. First, increased international outsourcing fuels the rate of innovation leading to a faster arrival of product improvements, a positive growth effect. Second, increased international outsourcing lowers the relative wage (and aggregate spending), a negative level effect. Evaluating Northern welfare requires weighing the innovation benefits of international outsourcing against sacrificed purchasing power due to reduced wage earnings. Restricting attention to the wage damage from international outsourcing is overly pessimistic, since this negative effect can be offset by the positive effect from faster innovation.[21]

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[21] Details of welfare analysis can be found in an earlier version of this paper.

Appendix A

A.1. Proof of Proposition 1

Derivatives with respect to each parameter are generated by

$$\underbrace{\begin{bmatrix} (\alpha + a_R)(\lambda - \chi) & -[\alpha(\rho + \iota) + a_R(\lambda\rho + \iota)] \\ \chi(\alpha + a_R\lambda) & (\alpha + a_R\lambda)(\rho + \iota) \end{bmatrix}}_{B} \begin{bmatrix} \mathrm{d}\iota \\ \mathrm{d}\chi \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix},$$

where the determinant is clearly positive $|B| \equiv b_{11}b_{22} - b_{21}b_{12} > 0$, since $\lambda > 1$ and $\chi \equiv \alpha n_O < 1$ as $\alpha < 1$ and $n_O < 1$ so $\lambda > \chi$. The values of L_S and L_N that solve the resource constraints are applied in these derivatives to simplify the expressions. An increase in the resources required in adaptation relative to the resources required in innovation a_R decreases the rate of innovation, decreases the extent of international outsourcing and increases the relative wage:

$$\frac{\partial \iota}{\partial a_R} = -\frac{(\rho + \iota)\,[\alpha\iota\chi(\lambda - 1) + \lambda(\alpha + \lambda a_R)(\rho + \iota)]}{|B|} < 0,$$

$$\frac{\partial \chi}{\partial a_R} = -\frac{\chi(\lambda - 1)\,[\alpha\iota(\lambda - \chi) + \lambda\rho(\alpha + \chi a_R)]}{|B|} < 0,$$

$$\frac{\partial w}{\partial a_R} = \frac{\alpha(\lambda - 1)}{(\alpha + a_R)^2} > 0.$$

An increase in the basic share of production α increases the rate of innovation, increases the extent of international outsourcing, and decreases the relative wage:

$$\frac{\partial \iota}{\partial \alpha} = \frac{a_R}{\alpha}\frac{(\rho + \iota)\,[\alpha\iota\chi(\lambda - 1) + \lambda(\alpha + \lambda a_R)(\rho + \iota)]}{|B|} = -\frac{a_R}{\alpha}\frac{\partial \iota}{\partial a_R} > 0,$$

$$\frac{\partial \chi}{\partial \alpha} = \frac{a_R}{\alpha}\frac{\chi(\lambda - 1)\,[\alpha\iota(\lambda - \chi) + \lambda\rho(\alpha + \chi a_R)]}{|B|} = -\frac{a_R}{\alpha}\frac{\partial \chi}{\partial a_R} > 0,$$

$$\frac{\partial w}{\partial \alpha} = -\frac{a_R(\lambda - 1)}{(\alpha + a_R)^2} = -\frac{a_R}{\alpha}\frac{\partial w}{\partial a_R} < 0.$$

The link between the effects of a_R and α suggests that what matters is the share of production that can be outsourced once adaptation is successful per unit of labor devoted to adaptation.

A.2. Proof of Proposition 2

An increase in Northern L_N increases the rate of innovation, decreases the extent of international outsourcing and does not affect the relative wage:

$$\frac{\partial \iota}{\partial L_N} = \frac{\alpha(\lambda - 1)(\rho + \iota)(\alpha + \lambda a_R)}{a_N|B|} > 0,$$

$$\frac{\partial \chi}{\partial L_N} = -\frac{\alpha\chi(\lambda - 1)(\alpha + \lambda a_R)}{a_N|B|} < 0.$$

An increase in Southern resources L_S increases the rate of innovation, increases the extent of international outsourcing and does not affect the relative wage:

$$\frac{\partial \iota}{\partial L_S} = \frac{\alpha(\lambda - 1)[(\rho + \iota)\alpha + \rho\lambda a_R + \iota a_R]}{a_N|B|} > 0,$$

$$\frac{\partial \chi}{\partial L_S} = -\frac{\alpha(\lambda - \chi)(\lambda - 1)(\alpha + a_R)}{a_N|B|} > 0$$

A.3. Proof of Proposition 3

The condensed system with production taxes and subsidies is

$$\left(1 + \frac{a_R\chi}{\alpha}\right)a_\iota\iota + (1 - \chi)\left[\frac{\alpha(1 - \sigma) + a_R\lambda}{\alpha[\lambda - (1 - \sigma)](1 + \tau)}a_\iota(\rho + \iota)\right] = L_N,$$

$$\chi\left[\frac{\alpha(1 - \sigma) + a_R\lambda}{\alpha[\lambda - (1 - \sigma)](1 + \tau)}a_\iota(\rho + \iota)\right] = L_S.$$

An increase in the Northern production tax τ increases the rate of innovation, increases the extent of international outsourcing, and decreases the relative wage (evaluated at $\tau = 0$ and $\sigma = 0$):

$$\frac{\partial \iota}{\partial \tau} = \frac{a_\iota^2(\rho + \iota)(\alpha + \lambda a_R)[\alpha(\rho + \iota) + [\lambda\rho + \iota\chi + \iota\lambda(1 - \chi)]a_R]}{|B|} > 0,$$

$$\frac{\partial \chi}{\partial \tau} = \frac{\chi a_\iota^2(\lambda - 1)(\alpha + \lambda a_R)(\rho + \iota)(\alpha + \chi a_R)}{|B|} > 0,$$

$$\frac{\partial w}{\partial \tau} = -\frac{\alpha + a_R\lambda}{\alpha + a_R} < 0.$$

An increase in the Southern production subsidy σ increases the rate of innovation, increases the extent of international outsourcing, and decreases the relative

wage (evaluated at $\tau = 0$ and $\sigma = 0$):

$$\frac{\partial \imath}{\partial \sigma} = \frac{\lambda a_i^2(\rho + \imath)(\alpha + a_R)[\alpha(\rho + \imath) + [\lambda\rho + \imath\chi + \imath\lambda(1 - \chi)]a_R]}{(\lambda - 1)|B|} > 0,$$

$$\frac{\partial \chi}{\partial \sigma} = \frac{\chi\lambda a_i^2(\alpha + a_R)(\rho + \imath)(\alpha + \chi a_R)}{|B|} = \left(\frac{\lambda}{\lambda - 1}\right)\left(\frac{\alpha + a_R}{\alpha + a_R\lambda}\right)\frac{\partial \chi}{\partial \tau} > 0,$$

$$\frac{\partial w}{\partial \sigma} = -\frac{\alpha}{(\alpha + a_R)} < 0.$$

A.4. Proof of Proposition 4

The condensed system with innovation and adaptation subsidies is

$$\left(1 - s_\imath + \frac{a_R\chi(1 - s_\phi)}{\alpha}\right)a_\imath\imath + (1 - \chi)\left[\frac{\alpha(1 - s_\imath) + a_R\lambda(1 - s_\phi)}{\alpha(\lambda - 1)}a_\imath(\rho + \imath)\right] = L_N,$$

$$\chi\left[\frac{\alpha(1 - s_\imath) + a_R\lambda(1 - s_\phi)}{\alpha(\lambda - 1)}a_\imath(\rho + \imath)\right] = L_S.$$

An increase in the innovation subsidy $s_\imath$ increases the rate of innovation, increases the extent of international outsourcing, and increases the relative wage (evaluated at $s_\imath = 0$ and $s_\phi = 0$):

$$\frac{\partial \imath}{\partial s_\imath} = \frac{\alpha a_i^2(\rho + \imath)[\alpha(\rho + \imath) + [\lambda\rho + \imath\chi + \imath\lambda(1 - \chi)]a_R]}{|B|} > 0,$$

$$\frac{\partial \chi}{\partial s_\imath} = \frac{\chi\alpha a_i^2(\lambda - 1)(\alpha + \chi a_R)(\rho + \imath)}{|B|} > 0,$$

$$\frac{\partial w}{\partial s_\imath} = \frac{\alpha a_R(\lambda - 1)}{(\alpha + a_R)^2} > 0.$$

An increase in the adaptation subsidy s_ϕ increases the rate of innovation, increases the extent of international outsourcing, and decreases the relative wage (evaluated at $s_2 = 0$ and $s_\phi = 0$):

$$\frac{\partial \imath}{\partial s_\phi} = \frac{\lambda a_R a_i^2(\rho + \imath)[\alpha(\rho + \imath) + [\lambda\rho + \imath\chi + \imath\lambda(1 - \chi)]a_R]}{|B|} = \frac{a_R\lambda}{\alpha}\frac{\partial \imath}{\partial s_\imath} > 0,$$

$$\frac{\partial \chi}{\partial s_\phi} = \frac{\chi\lambda a_R a_i^2(\lambda - 1)(\alpha + \chi a_R)(\rho + \iota)}{|B|} = \frac{a_R \lambda}{\alpha}\frac{\partial \chi}{\partial s_\iota} > 0,$$

$$\frac{\partial w}{\partial s_\phi} = -\frac{\alpha a_R(\lambda - 1)}{(\alpha + a_R)^2} = -\frac{\partial w}{\partial s_\iota} < 0.$$

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