

Dynamic Effects of Outsourcing on Wage Inequality and Skill Formation^{*}

by

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Abstract

This paper investigates the effects of multinational firm activity on wage inequality in both the host and source economy. We develop a North-South product cycle model of endogenous growth without scale effects, where the rates of innovation, outsourcing, and skill acquisition are endogenously determined. We consider two sets of exogenous events that increase the extent of Foreign Direct Investment (FDI). The first refer to technological improvements in outsourcing, which increase the feasibility of shifting production to the South or reduce the resource requirement to explore the Southern market. The second refer to policy changes through taxes and subsidies, which alter the investment decisions of multinationals. When increased FDI is driven by technological change, the impact on the wage differential between skilled and unskilled labor in the North and the South is ambiguous. Whereas if FDI is driven by policy changes such as production subsidies by the South or production taxes by the North, the wage gap in both economies widens. The rise in wage inequality, in turn, induces a higher fraction of the population to upgrade their skills.

Keywords: FDI, wage inequality, outsourcing, endogenous growth

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1. Introduction

Over the past two decades, the relative position of less-skilled workers has deteriorated in both developed and developing countries. In the US, between the late 1970s and early 1990s, the college/high school wage premium has increased from 45% to 80% (Topel, 1997). In OECD Europe, there was a mild increase in the wage gap but a substantial surge in the unemployment rate. In the developing countries the evidence on wage inequality is mixed. In Mexico, between 1985 and 1989, the relative wage gap between skilled and unskilled labor increased by 15% (Feenstra and Hanson, 1997); in Chile, between 1980 and 1990, the college wage premium increased by 56.4 % (Robbins, 1996). However, in Singapore between 1966 and 1980 and in Mexico between 1978 and 1985, the skill premia have actually decreased (Wood, 1994; Feenstra and Hanson, 1997).

The literature on wage inequality predominantly focuses on advanced countries, offering two explanations for rising wage inequality: technological change (Lawrence and Slaughter, 1993, and Berman et al., 1994) and increased trade (Leamer, 1993, 1994; Borjas and Ramey, 1995). The debate so far has been centered around the empirical and theoretical relevance of these two arguments, paying relatively little attention to the possible role that foreign direct investment (FDI) and Multinational Firm (MNF) activity can play in explaining the labor market developments. Moreover, only a few attempts have been made to investigate the issue in a unified framework that incorporates both advanced countries (the North) and developing countries (the South). This is surprising when one considers the fact that developments in the labor markets across the globe have been synchronous with a drastic increase in capital flows from the North to the South.¹

Recently, a number of empirical studies have analyzed the relationship between MNF activity and wage inequality. Blonigen and Slaughter (1999) and Slaughter (2000), examining the wage effects of FDI flows in and out of the US, find little evidence for the contribution of FDI to relative labor demand shifts. In contrast to these findings, Feenstra and Hanson (1999) attribute 15% of the rise in US wage inequality to international outsourcing by US MNFs. On the other hand, Aitken, Harrison, and Lipsey (1996) provide evidence from Mexico and Venezuela,

showing that increased foreign ownership in the host country raises the wages of skilled workers more than those of unskilled workers.

Similar to empirical findings, theoretical studies also provide ambiguous results. Feenstra and Hanson (1997) construct a factor endowment model where one final good is produced by a continuum of intermediate inputs ranked by skill intensity. In this model, increased international outsourcing shifts the production of intermediate goods from the North to the South. From the North's standpoint, these are most unskilled-intensive activities; from the South's standpoint, these are most skilled-intensive activities. The resulting surge in the relative demand for skilled labor in both countries widens the wage gap in both regions. Extending the Feenstra and Hanson model, Xu (2000) considers an economy with two sectors, each producing a final good. In sharp contrast to Feenstra and Hanson (1997), Xu (2000) finds that international outsourcing does not necessarily generate skill-biased labor demand shifts in either the host or the source economy. He argues that sectoral differences in FDI barriers can be the key in determining the bias of the labor demand shift. In another factor endowment framework, Markusen and Venables (1996, 1998) study the impact of MNFs on real wages in both the host and the source economies. They find that the real wage implications of MNFs depend on the initial conditions and factor endowments of both economies.

Although the theoretical studies have exclusively focused on factor endowment models, the literature on FDI indicates that most MNF activity is caused by differences in technology between the host and the source countries. The eclectic paradigm developed by Dunning (1993) specifically outlines the ownership-location-internalization (OLI) framework, which extends the modeling of MNF activity to include technological differences between the host and source economies as well as factor endowment differences. In this framework MNFs emerge due to ownership advantages of the technologically advanced North, the location advantages of the South in the form of lower costs, and internalization advantages of MNFs in keeping the superior technology within themselves.

In this paper, we investigate the issue of FDI and wage inequality, using a dynamic North-South model that explicitly incorporates the mechanics of technological progress and

outsourcing. Our approach contributes to the theoretical modeling in three respects. First, our dynamic model adds a new dimension to the literature on FDI and wage inequality, which so far has focused on static factor-endowment models. Second, we model international outsourcing as an activity that stems from technological differences between the North and the South, which is more consistent with the OLI framework. Third, our model attempts to shed light on the different labor market experiences of developing countries in a unified North-South framework.

We construct a variation of the standard product cycle model that incorporates international outsourcing and endogenous skill acquisition.² In this model, the world economy is comprised of only two countries: the North and the South. In each country, there exists a continuum of households differentiated in terms of their ability. Household optimization consists of two problems: optimal allocation of expenditure across goods and over time, and optimal skill acquisition decisions given the ability levels.

The product market consists of a continuum of structurally identical industries. In each industry, Northern firms participate in stochastic and sequential R&D races aimed at discovering the next generation product. Conducting R&D requires Northern skilled labor. Innovative activity takes place exclusively in the North. Northern firms successful in their R&D efforts immediately start manufacturing the final good by hiring Northern unskilled workers. A leader firm maintains temporary monopoly power in the global market until further innovation takes place in its industry.

While manufacturing in the North, the Northern quality leaders continuously explore the Southern market in order to exploit low-cost manufacturing opportunities. This market exploration may involve searching for suitable production sites or licensees in the South or exploring the feasibility of technology transfer, which necessitates “services” provided by skilled workers such as consultants, financial experts, accountants, and engineers. Thus, conducting market exploration requires Southern skilled labor. We assume that manufacturing consists of two parts: standardized production and advanced production. Northern firms successful in their market exploration attempts can shift *only* the standardized portion of production to the South; advanced production must remain in the North. Outsourcing standardized production to the South

generates demand for Southern unskilled labor, while advanced production in the North requires Northern unskilled labor. The extent of MNF activity equals the fraction of outsourcing industries times the share of standardized production in the overall production.

In the model, we consider two sets of exogenous events that increase the extent of FDI: improvements in outsourcing technology and policy changes through taxes and subsidies. With regards to technological change, we consider the following shocks: an increase in the feasibility of shifting production to the South and a decline in the resource requirement to explore the Southern market. We find that if increased FDI is driven by either of the above shocks, the impact on the wage differential between skilled and unskilled labor is ambiguous in both the North and the South. The effects on the rate of innovations and intensity of market exploration also depend on the parameters of the model.

To see the intuition consider an increase in FDI generated by an increase in the feasibility of outsourcing production to the South. Such a change exerts three first-order effects on the steady-state equilibrium. The first two operate through labor market conditions: A higher level of outsourcing raises the demand for Southern unskilled labor and reduces the demand for Northern unskilled labor. As a result, there is downward pressure on the skill premium in the South and upward pressure on that in the North. These two effects are identical to the results from standard trade theory: as unskilled-labor-intensive manufacturing jobs move from the North to the South, the relative position of unskilled in the North deteriorates whereas that in the South improves. But, in addition, the present model identifies a third direct effect by assigning a role to the Southern skilled workers in the outsourcing process. More possibilities to outsource production to the South implies that firms can further exploit the low-cost manufacturing opportunities. As a result, profitability of exploring the Southern market increases. This, in turn, boosts the demand for Southern skilled labor, putting upward pressure on the skill premium in the South. Combining these first-order effects with the second-order general equilibrium effects, we find that the changes in the relative wages depend on the parameters of the model. To gain some further insight on the analytical results, we also run some simulations using an extensive set of parameter

values (see Section 3.1 for details). The simulation analysis shows that technology shocks reduce the skill premium in the South, but generate ambiguous results on the skill premium in the North.

With regards to policy changes, we consider four different parameters that can be influenced by governments: production subsidies by the South, production taxes by the North, innovation subsidies by the North, and outsourcing subsidies by the South. We find that if increased FDI is driven by changes in any of these policy parameters, the wage gap in both economies clearly widens. The higher wage inequality, in turn, induces a larger fraction of the population to upgrade their skills. The rise in the supply of skilled labor in both regions raises the arrival rate of innovations as well as the intensity of market exploration in the South.

These findings contribute to the debate on wages and FDI by emphasizing the differentiating roles that policy changes and technological shocks may play in explaining the observed wage patterns. Our model implies that policy-initiated FDI contributes positively to the wage gap between skilled and unskilled labor, whereas technology-driven FDI does not seem to generate strong results in this context. The intuitive basis for this argument is as follows. Policy changes that promote FDI alter the profitability of innovation and outsourcing and thereby affect the incentives to engage in such activities. On the other hand, technological changes—in addition to altering the profitability of innovation and outsourcing—alter the unit labor requirements and thereby affect the labor market equilibrium conditions. The results indicate that this labor market effect, in turn, may work to mitigate (or overturn) the increase in wage inequality.

The rest of the paper is organized as follows. Section 2 describes the features of the theoretical model and establishes the steady-state equilibrium. Section 3 provides an analysis of the comparative steady-state results. Section 4 concludes the paper.

2. The Model

The model is a variant of the standard North South product-cycle model. The household optimization closely follows the standard quality-ladders growth model (see, Grossman and Helpman, 1991). Endogenous skill formation is introduced along the lines of Dinopoulos and Segerstrom (1999) and Sener (2001). The scale effects are removed from the endogenous growth

model in the spirit of Dinopoulos and Thompson (2000). The mechanics of outsourcing is incorporated along the lines of Glass and Saggi (2001).

2.1. Household Behavior and Skill Formation

The world economy consists of two countries, the North and the South denoted as $i \in \{N, S\}$. Each economy consists of a continuum of households indexed by ability $q \in [0, 1]$. The ability parameter q is uniformly distributed across families. Members within a household have the same ability level. The size of each household grows at a rate of $n = b - d$, where b and d refer to birth and death rates, respectively. The size of population at time t is $N_i(t) = N_{0i}e^{nt}$ for $i = N, S$, where N_{0i} denotes the initial level of population. Each individual lives for an exogenously given time period $D > 0$.³

Each household takes goods prices, factor prices, and the interest rate as given and maximizes its utility over an infinite horizon

$$U_{qi} = \int_0^\infty N_{0i} e^{-(r-n)t} \log u_{qi}(t) dt, \quad \text{for } i = N, S, \quad (1)$$

where r is the subjective discount rate, and $\log u_{qi}(t)$ is the instantaneous utility of each household member defined as:

$$\log u_{qi}(t) = \int_0^I \log [S_j I^j x_{qi}(j, \mathbf{w}, t)] d\mathbf{w}, \quad \text{for } i = N, S, \quad (2)$$

where $x_{qi}(j, \mathbf{w}, t)$ is the quantity demanded of product with quality j in industry \mathbf{w} at time t . The size of quality improvements (the innovation size) is denoted by $I > 1$. Therefore, the total quality of a good after j innovations will be I^j .

Each household allocates per capita consumption expenditure $c_{qi}(t)$ to maximize $u_{qi}(t)$ given prices at time t . Note that all products within an industry are perfect substitutes; thus, households buy only the products with the lowest quality-adjusted prices. Products enter the utility function symmetrically; therefore, households spread their expenditure evenly across goods. The resulting per capita product demand in each industry is $x_{qi}(t) = c_{qi}(t)/p_m$, where p_m is the relevant market price for the product that has the lowest quality-adjusted price.

Given the static demand behavior, the household's problem is simplified to maximizing

$$\int_0^{\infty} N_{0i} e^{-(r-n)t} \log c_{qi}(t) dt, \quad \text{for } i = N, S,$$

subject to the budget constraint $\dot{A}_{qi}(t) = W_{qi}(t) + r(t)A_{qi}(t) - c_{qi}(t)N_{0i}(t)$, where $A_{qi}(t)$ denotes the financial assets owned by the household, $W_{qi}(t)$ is the family's expected wage income and $r(t)$ is the instantaneous rate of return.⁴ The solution to this optimization gives

$$\frac{\dot{c}_{qi}(t)}{c_{qi}(t)} = r(t) - \mathbf{r}, \quad \text{for } i = N, S.$$

At the steady-state equilibrium, c_{qi} remains fixed; thus, the market interest rate $r(t)$ is equal to the subjective discount rate \mathbf{r} . From this point on we will focus on the balanced-growth path behavior of the economy; hence, we drop the time index for the variables that remain constant.

Each family member must also decide on entering the labor force as skilled or unskilled. The level of ability is common knowledge to both the workers and the firms. Let w_{Li} represent unskilled wages and w_{Hi} denote skilled wages for $i = N, S$. An unskilled worker is an untrained individual who earns w_{Li} regardless of her ability. To become a skilled worker, the individual must undergo training for a time period of $T < D$. During training, the individual does not earn any wage income. Once the training is over, she starts earning a wage income of $q_i w_{Hi}$, which is positively related to her ability. An individual with ability θ decides to acquire skills if and only if the discounted lifetime wage earnings as a skilled worker is more than those earned as an unskilled worker:⁵

$$\int_t^{t+D} e^{-r(s-t)} w_{Li} ds < \int_{t+T}^{t+D} e^{-r(s-t)} q_i w_{Hi} ds, \quad \text{for } i = N, S. \quad (3)$$

Rewriting equation (3) as an equality gives the critical level of ability q_{0i} , which reflects the skill distribution of the population. All households with ability levels below q_{0i} remain unskilled, while all households with ability levels above q_{0i} undergo training and become skilled. The implied critical level of ability is

$$q_{0i} = \left[\frac{1 - e^{-rD}}{e^{-rT} - e^{-rD}} \right] \frac{w_{Li}}{w_{Hi}} = \mathbf{s} \frac{w_{Li}}{w_{Hi}}, \quad \text{for } i = N, S, \quad (4)$$

where \mathbf{s} can be viewed as a measure of the relative discount factor of unskilled labor earnings with respect to skilled labor earnings. With $\mathbf{s} > 1$ and $\mathbf{q}_{0i} < 1$ (which must hold in equilibrium), the wage of a skilled worker per efficiency unit is higher than the wage of a skilled worker ($w_{Hi} > w_{Li}$).

The uniform distribution of the ability level across families implies that the supply of unskilled labor in each country is given by

$$L_i(t) = \mathbf{q}_{0i}N_i(t), \quad \text{for } i = N, S, \quad (5)$$

where \mathbf{q}_{0i} now represents the share of unskilled labor in the population. The remaining share of the population ($1 - \mathbf{q}_{0i}$) decides to become skilled. At each point in time a certain portion of this subpopulation is under training and a certain portion is endowed with the skills necessary to perform skilled labor jobs. The group with acquired skills consists of workers who were born between time $(T - D)$ and $(t - T)$, which is given by

$$\int_{t-D}^{t-T} \mathbf{b}(1 - \mathbf{q}_{0i})N_i(s)ds = (1 - \mathbf{q}_{0i})\mathbf{h}N_i(t), \quad \text{for } i = N, S,$$

where $\mathbf{h} = [e^{n(D-T)} - 1]/[e^{nD} - 1] < 1$ captures the fraction of skilled workers who have completed their training. The average skill level of those workers is $(1 + \mathbf{q}_{0i})/2$. Multiplying the average skill level by $(1 - \mathbf{q}_{0i})\mathbf{h}N_i(t)$ yields the supply of skilled labor in terms of efficiency units

$$H_i(t) = \frac{(1 - (\mathbf{q}_{0i})^2)}{2} \mathbf{h}N_i(t), \quad \text{for } i = N, S. \quad (6)$$

Equations (4), (5), and (6) establish the supply side of the labor market for each region.⁶ The steady-state growth rates of factor endowments are equal to n given the constant level of \mathbf{q}_{0i} :

$$\frac{\dot{H}_i(t)}{H_i(t)} = \frac{\dot{L}_i(t)}{L_i(t)} = \frac{\dot{N}_i(t)}{N_i(t)} = n, \quad \text{for } i = N, S.$$

2.2. Producers

We first provide an overview of the mechanics of innovation and outsourcing with the help of Figure 1. The global economy consists of a continuum of structurally identical industries indexed by $\mathbf{w} \hat{\mathbf{I}} [0, 1]$. In each industry, Northern firms participate in stochastic and sequential R&D races aimed at discovering the next generation product. Conducting R&D requires Northern

skilled labor. Observe that engaging in R&D is costly and involves uncertainty. Innovative activity takes place exclusively in the North. Northern firms successful in their R&D efforts immediately start manufacturing the final good by hiring Northern unskilled workers. The leader firm maintains temporary monopoly power in the global market until further innovation takes place in its industry.

While manufacturing in the North, the Northern quality leaders continuously explore the Southern market in order to exploit low-cost manufacturing opportunities. This market exploration may involve searching for suitable production sites or licensees in the South and/or exploring the feasibility of technology transfer for final goods production, which necessitates “services” provided by skilled workers such as consultants, financial experts, accountants, and engineers. Performing such services require Southern skilled labor.^{7 8} Like R&D, exploring the Southern market is costly and involves uncertainty.

We assume that manufacturing of a final good consists of two parts: standardized production and advanced production. We denote the share of standardized production in total production as \mathbf{a} and the share of advanced production as $(1 - \mathbf{a})$. Following Glass and Saggi (2001), we assume that Northern firms successful in their market exploration attempts can shift *only* the standardized portion of production to the South; advanced production must remain in the North. Standardized production utilizes Southern unskilled labor, while advanced production utilizes Northern unskilled labor. This production scheme can also be visualized as a fragmented production scheme, where advanced intermediate goods are produced in the North and final goods are assembled in the South.

2.1. R&D Races and Outsourcing

In this model, the world economy consists of a continuum of structurally identical industries; thus we will omit the index \mathbf{w} for the industry variables and use the time index t only for those variables that change over time. As noted above, Northern firms must engage in innovative activity to participate in R&D races. There is free entry into R&D races. The arrival of innovations follows a Poisson process whose intensity equals \mathbf{i} . A Northern firm j which undertakes R&D intensity \mathbf{i}_j for a time period dt innovates the next generation product with

probability $\mathbf{i}dt$. We assume that returns to R&D activity are distributed independently across firms and industries; thus, industry level R&D intensity is $\mathbf{i} = \mathbf{S}_j \mathbf{i}_j$.

Let \mathbf{u}_N represent the value of a successful innovator (i.e., the expected discounted profits of a successful innovator). A typical firm j enjoys \mathbf{u}_N with probability $\mathbf{i}_j dt$ and incurs a cost equal to $w_{HN} a_i X_j(t) dt$, where $a_i X_j(t)$ represents the labor requirement per R&D intensity. Free entry into R&D races drives expected profits down to zero and results in the following zero profit condition:

$$\mathbf{u}_N(t) = w_{HN} a_i X_j(t). \quad (7)$$

The term $X_j(t)$ is a measure for the difficulty of conducting R&D, which is introduced to remove the scale effects from the model. We specify $X_j(t)$ as

$$X_j(t) = k_i N_N(t), \quad (8)$$

where k_i is a positive constant.⁹ This specification reflects the difficulty of introducing new products and replacing old ones in larger markets.

Similar to the process of innovation, the arrival of successful outsourcing follows a Poisson process, whose intensity equals \mathbf{f} . Observe that only successful Northern innovators can consider options of outsourcing. A Northern quality leader exploring the Southern market with intensity \mathbf{f} for a time period dt successfully shifts production abroad with probability $\mathbf{f}dt$.

Let $\mathbf{u}_O(t)$ represent the value of a Northern firm successfully outsourcing (i.e., the expected discounted profits of such a firm). A Northern quality leader exploring the Southern market realizes a change in its value from $\mathbf{u}_N(t)$ to $\mathbf{u}_O(t)$ with probability $\mathbf{f}dt$ and incurs a cost equal to $w_{HS} a_f X_f(t) \mathbf{f}dt$, where $a_f X_f(t)$ represents the labor requirement per outsourcing intensity. A finite intensity of \mathbf{f} requires the following zero profit condition:

$$\mathbf{u}_O(t) - \mathbf{u}_N(t) = w_{HS} a_f X_f(t). \quad (9)$$

The term $X_f(t)$ is a measure for the difficulty of exploring the Southern market, which is, in the same spirit as above, introduced to remove the scale effects from the model. We specify $X_f(t)$ as

$$X_f(t) = k_f N_S(t), \quad (10)$$

where k_f is a positive constant. This specification reflects the difficulty of searching for a suitable partner, licensee, or production site in larger markets.

The next step is to derive the value functions for $\mathbf{u}_O(t)$ and $\mathbf{u}_N(t)$ at the steady-state equilibrium. The household savings are channeled to firms engaged in R&D races through a global stock market. To find $\mathbf{u}_N(t)$ we start by calculating the expected return generated by a quality leader. With probability $\mathbf{i}dt$, the leader firm loses its monopoly position and observes a reduction in its value from $\mathbf{u}_N(t)$ to 0. With probability $(1 - \mathbf{i}dt)$, the firm continues serving the market and realizes a gain/loss in its value given by $\dot{\mathbf{u}}_N(t)$. At each point in time, the quality leader considers the options of outsourcing by exploring the Southern market. With probability $\mathbf{f}dt$, the firm becomes successful in its outsourcing attempts, realizing a change in its value from $\mathbf{u}_N(t)$ to $\mathbf{u}_O(t)$. The cost of conducting market exploration in the South is $w_{HS}a_fX_f(t)\mathbf{f}dt$. Finally, the Northern leader firm producing in the North earns a profit flow of $\mathbf{p}_N(t)dt$. Stock market efficiency condition requires that the expected rate of return generated by a successful innovator must be equal to the risk-free interest rate $r = \mathbf{r}$:

$$\begin{aligned} \mathbf{i} \frac{(0 - \mathbf{u}_N(t))}{\mathbf{u}_N(t)} dt + (1 - \mathbf{i}dt) \frac{\dot{\mathbf{u}}_N(t)}{\mathbf{u}_N(t)} dt - \frac{\mathbf{f}w_{HS}a_fX_f(t)}{\mathbf{u}_N(t)} dt \\ + \mathbf{f} \frac{(\mathbf{u}_O(t) - \mathbf{u}_N(t))}{\mathbf{u}_N(t)} dt + \frac{\mathbf{p}_N(t)}{\mathbf{u}_N(t)} dt = rdt. \end{aligned}$$

Taking limits as $dt \rightarrow 0$, and noting that $\dot{\mathbf{u}}_N/\mathbf{u}_N = n$ at the steady-state equilibrium we derive:

$$\mathbf{u}_N(t) = \frac{\mathbf{p}_N(t) + \mathbf{f}(\mathbf{u}_O(t) - w_{HS}a_fX_f(t))}{\mathbf{r} + \mathbf{i} + \mathbf{f} - n}. \quad (11)$$

We apply a similar analysis to calculate the return generated by a Northern firm that has successfully outsourced. With probability $\mathbf{i}dt$, the outsourcing firm is replaced by an innovator and subject to a fall in its value from $\mathbf{u}_O(t)$ to 0. With probability $(1 - \mathbf{i}dt)$, no further innovation takes place, and the firm realizes a gain/loss in its value given by $\dot{\mathbf{u}}_O(t)$. Finally, the Northern firm outsourcing to the South earns a profit flow of $\mathbf{p}_O(t)dt$. The stock market efficiency condition requires that

$$\mathbf{i} \frac{(0 - \mathbf{u}_o(t))}{\mathbf{u}_o(t)} dt + (1 - \mathbf{i} dt) \frac{\dot{\mathbf{u}}_o(t)}{\mathbf{u}_o(t)} dt + \frac{\mathbf{p}_o(t)}{\mathbf{u}_o(t)} dt = r dt.$$

Taking limits as $dt \rightarrow 0$, and noting that $\dot{\mathbf{u}}_o / \mathbf{u}_o = n$ at the steady-state equilibrium, we obtain:

$$\mathbf{u}_o(t) = \frac{\mathbf{p}_o(t)}{\mathbf{r} + \mathbf{i} - n}. \quad (12)$$

2.2.2 Product Markets

In the global market, successful Northern innovators engage in price competition with followers that are one step down in the quality ladder. Once a new innovation occurs, the old technology becomes accessible to both the Northern and the Southern firms. Production of one unit of final good requires one unit of unskilled labor in either North or South. We focus on a steady-state equilibrium, where $w_{LN} > w_{LS}$; thus, production in the South is cheaper relative to the North. This implies that the Northern followers cannot effectively compete in the global market. Hence, in each industry, competition takes place between the Northern innovators and the Southern followers. The Northern leader can charge a price that is I times as high as the Southern followers' marginal cost. Southern followers charge a price equal to marginal cost and cannot do better than break even. By engaging in limit pricing, the Northern leader can drive the followers out of the market.

We normalize the Southern unskilled wage w_{LS} to one; thus, the leader can charge a product price of I . The demand for each product line can be denoted as $E(t)/I$, where $E(t)$ represents worldwide spending. From here on we define $\mathbf{d} = I/I$. Thus, we can express the instantaneous profits of a Northern firm that produces only in the North as:

$$\mathbf{p}_N(t) = E(t)(I - \mathbf{d}w_{LN}). \quad (13)$$

Similarly, we can derive $\mathbf{p}_o(t)$, the instantaneous profits of an outsourcing firm. Note that outsourcing firms shift standardized portion of production to the South \mathbf{a} and continue advanced portion in the North $(I - \mathbf{a})$. Thus, the marginal cost of production under successful outsourcing is $\mathbf{a}w_{LS} + (I - \mathbf{a})w_{LN}$. Since in equilibrium $w_{LN} > w_{LS}$, shifting standardized production reduces overall manufacturing costs and increases profit margins, giving the firm an incentive to incur the

cost of technology transfer. With w_{LS} normalized to one and product price equal to I , \mathbf{p}_O can be written as:

$$\mathbf{p}_O(t) = E(t)(I - \mathbf{ad}(I - w_{LN}) - w_{LN}\mathbf{d}). \quad (14)$$

Substituting for $v_O(t)$ from (9) and for $v_N(t)$ from (7) into (11) using (13), we simplify the zero-profit in R&D condition as

$$w_{HN}a_i k_i N_N(t) = \frac{E(t)(I - w_{LN}\mathbf{d})}{(\mathbf{r} + \mathbf{i} - n)}. \quad (15)$$

Substituting for $v_O(t)$ from (9), for $v_N(t)$ from (7), and for w_{HN} from (15) into (12), using (14) we also simplify the zero profit in market exploration as

$$w_{HS}a_f k_f N_S(t) = \frac{E(t)\mathbf{ad}(w_{LN} - I)}{(\mathbf{r} + \mathbf{i} - n)}. \quad (16)$$

2.3 Labor Markets

The fraction of industries successfully engaged in outsourcing activity is denoted as n_O . The fraction of industries that manufacture only in the North is denoted as n_N . Since the measure of industries equals one, it follows that:

$$n_O + n_N = I. \quad (17)$$

In the steady-state equilibrium, the flow of industries into the outsourcing industries pool is given by the intensity of market exploration for outsourcing \mathbf{f} , times the fraction of industries engaged in such activities, n_N . The flow of industries out of this pool is given by the intensity of innovation, \mathbf{i} , times the fraction of industries targeted by R&D firms, n_O . For the share of industries to remain constant in equilibrium, we require

$$\mathbf{f}n_N = \mathbf{i}n_O. \quad (18)$$

The labor market equilibrium in each country is achieved when the demand for each type of labor is equal to its supply. The skilled labor in the North is solely employed in innovative activity. The demand for skilled labor equals $a_i X_i(t)\mathbf{i}$, the difficulty-adjusted unit labor requirement of R&D activity multiplied by the aggregate R&D intensity. Note that in the continuum, all industries are targeted by R&D firms; thus, \mathbf{i} represents the arrival rate of innovations in the world economy. Using the supply of skilled labor in the North implied by

equation (6) along with equations (4) and (8), equilibrium in the Northern skilled labor market is determined by:

$$k_i N_N(t) i a_i = \frac{h}{2} \left[1 - \left(\frac{s w_{LN}}{w_{HN}} \right)^2 \right] N_N(t). \quad (19)$$

In each industry Ed represents the amount of unskilled labor required to satisfy demand. The unskilled labor in the North is employed in two types of industries. In a fraction n_N of the industries, where all manufacturing occurs in the North, the demand for Northern unskilled labor is $Ed n_N$. In a fraction n_O of the industries, where standardized production has shifted to the South, the demand for Northern unskilled labor is $Ed(1 - a)n_O$. Using the supply of unskilled labor in the North, derived in equation (4), the equilibrium in the Northern unskilled labor market is given by:

$$dE(t) [n_N + (1 - a)n_O] = \frac{s w_{LN}}{w_{HN}} N_N(t). \quad (20)$$

Next, we turn to the Southern labor markets. Firms that explore the Southern market prior to shifting production require services provided by Southern skilled labor. The fraction of industries engaged in such activities is n_N . Thus, the demand for Southern skilled labor is $a_f X_f f n_N$, the difficulty-adjusted unit labor requirement of market exploration activity multiplied by the aggregate intensity of such activity. As above, using the supply of skilled labor in the South implied by equation (6) along with equations (4) and (10), the Southern skilled labor market equilibrium is stated as

$$k_f N_s(t) a_f f n_N = \frac{h}{2} \left[1 - \left(\frac{s}{w_{HS}} \right)^2 \right] N_s(t). \quad (21)$$

In a fraction n_O of the industries, firms that outsource the standardized portion of production a to the South generate demand for Southern unskilled labor $a n_O dE$. Using the supply of unskilled labor in the South, derived in equation (4), the equilibrium in the Southern unskilled labor market is given by:

$$dE(t) a n_O = \frac{s}{w_{SH}} N_s(t). \quad (22)$$

2.4 Steady-State Equilibrium

The labor market equilibrium conditions (equations (19), (20), (21), (22)), together with the zero profit condition for innovation and market exploration (equations (15), (16)), the industry continuum measure and the flow condition (equations (17), (18)) constitute a system of eight equations with eight unknowns ($E, n_O, n_N, \mathbf{i}, \mathbf{f}, w_{LN}, w_{HN}, w_{HS}$).

To simplify notation, we denote the extent of outsourcing as the fraction of *all* production outsourced to the South as $\mathbf{c} = \mathbf{a}n_O$, the difficulty of outsourcing relative to innovation as $k_R = k_f/k_i$, the resource requirement in outsourcing relative to innovation as $a_R = a_f/a_i$ and the relative population as $n_R = N_S/N_N$. Using these and manipulating the equations, the steady-state equilibrium can be characterized by a system of two equations with two unknowns \mathbf{c} and w_{LN} (see Appendix A for details):

$$\frac{\mathbf{c}}{(1-\mathbf{c})k_R a_R n_R^2} = \frac{(1-\mathbf{d}w_{LN})}{\mathbf{a}d w_{LN} (w_{LN} - 1)} \quad (\text{S1})$$

$$\frac{(w_{LN} - 1)}{\mathbf{s}} = \frac{\left[1 - a_R k_R n_R^2 \frac{(1-\mathbf{c})^2}{\mathbf{c}\mathbf{a}} \right]}{\left[1 - a_R k_R \frac{\mathbf{c}}{\mathbf{a}} \right]} \left[(\mathbf{r} - n) k_R a_R k_i a_i \frac{\mathbf{c}}{\mathbf{a}} + \frac{\mathbf{h}}{2} \right] - \frac{\mathbf{h}}{2}. \quad (\text{S2})$$

Proposition 1: *Under the assumptions below there exists a unique steady-state equilibrium in which the wage rates for skilled and unskilled labor in both North and South w_{HN}, w_{HS}, w_{LN} and 1 , respectively, the arrival rate of innovations \mathbf{i} , the aggregate intensity of market exploration $\mathbf{f}n_N$ attain strictly positive values, the proportion of industries outsourcing n_O lies between zero and 1, and the North is skilled-abundant relative to South (i.e., $\mathbf{q}_{0S} > \mathbf{q}_{0N}$).*

Proof. See Appendix A

Assumptions:

1. $k_R a_R < 1$.

2. $0 < \frac{n_R^2(1-\mathbf{a})}{\mathbf{a}U} \left[\frac{1}{1+U} - \mathbf{d} \right] < \frac{\mathbf{a}d}{k_R a_R} < \frac{1}{\mathbf{Z}} \left[\frac{1}{1+\mathbf{Z}} - \mathbf{d} \right]$,

$$\text{where } U = \frac{s \left(1 - \frac{a_R k_R n_R^2 (1-a)^2}{a^2} \right)}{(1 - a_R k_R)} \left((r-n) k_f a_f + \frac{h}{2} \right) - \frac{hs}{2} \text{ and } Z = \frac{s (r-n) k_f a_f n_R}{(1+n_R) a}.$$

Assumption 1 states a sufficient condition for $q_{OS} > q_{ON}$. Assumption 2 assures that in Figure 2 $(w_{LN})^1 > (w_{LN})^0$ and $(w_{LN})^3 > (w_{LN})^2$ (see Appendix A for details). The unique steady-state equilibrium of the model is illustrated in Figure 2 by the intersection of (S1) and (S2) curves. These two curves determine the equilibrium levels of w_{LN} and c . The equilibrium levels for the remaining endogenous variables are then calculated by substituting w_{LN} and c into the relevant equations.

3. Comparative Steady-State Analysis

Having established the steady-state equilibrium, we now turn to investigating the effects of exogenous changes in our two-country world economy. We classify the sources of changes into two categories: technology-driven and policy-driven.

3.1. Technology-driven changes in outsourcing

Technological improvements in the past two decades have positively affected the cost structure of multinationals. More specifically, the availability of new technologies in transmitting information coupled with lower transportation and communication costs have provided additional incentives for MNCs to spread production across the globe and chase low-cost manufacturing opportunities.¹⁰ The implications of these changes can materialize via two specific channels. First, positive technology shocks can raise the feasibility of shifting standardized production or outsourcing unskilled intensive intermediate goods to the low-cost South. Second, such shocks can facilitate the exploration of international outsourcing opportunities.

In the context of the present paper, the former channel can be captured by an increase in a (i.e., the portion of the manufacturing process that is outsourced), whereas the latter can be captured by a decline in a_R (i.e., the resource requirement of market exploration activity relative to innovation). Observe that the two parameters enter the steady-state equations symmetrically; thus, the impact of an increase in a is exactly the same as that of a decrease in a_R .

Proposition 2: *An increase in the share of production shifted to the South α or a decrease in the resource requirement of market exploration activity a_R :*

- a. increases the extent of outsourcing c ,*
- b. generates an ambiguous effect on the relative wage of skilled labor in both North and South w_{HN}/w_{LN} and w_{HS} , respectively,*
- c. exerts an ambiguous impact on the aggregate intensity of outsourcing \bar{f}_N ,*
- d. exerts an ambiguous impact the arrival rate of innovations \dot{i} .*

Proof. See Appendix B for proofs of all propositions on comparative steady-state analysis.

To uncover the intuition, we will focus on the case of an increase in α . Holding others constant, an increase in α exerts three first-order effects on the steady-state equilibrium. The first two are through equations (20) and (22). An increase in production shifted to South raises the demand for Southern unskilled labor and reduces the demand for Northern unskilled labor. As a result, there is downward pressure on the skill premium in the South and upward pressure on that in the North. These two effects are identical to the results from standard trade theory: as unskilled-labor-intensive manufacturing jobs move from the North to the South, the relative position of unskilled in the North deteriorates whereas that in the South improves.

In addition, the model identifies a third direct effect by assigning a role to the Southern skilled workers in the outsourcing process. This effect enters through the free-entry condition in market exploration activity (see equation (16)). A higher α implies that firms can further exploit the low-cost manufacturing opportunities in the South. As a result, profitability of exploring the Southern market increases. This, in turn, boosts the demand for Southern skilled labor, putting upward pressure on the skill premium in the South.

Summing up the first-order effects, we observe that an increase in α exerts two conflicting effects on the skill premium in the South and a positive effect on the skill premium in the North. To find the changes in the equilibrium levels, we take into account the second-order effects generated by the changes in the other endogenous variables of the system.

The results from the comparative steady-state analysis are as follows: In the new equilibrium, the extent of outsourcing c increases despite the mitigating effect of a decrease in the

fraction of industries engaged in outsourcing n_0 . In the Appendix, we show that the relative wage in the South increases if and only if the elasticity of outsourcing with respect to the share of standardized production $\frac{d\mathbf{c}\mathbf{a}}{d\mathbf{a}\mathbf{c}}$ is sufficiently large. Thus, the qualitative change in w_{HS} depends on the parameters of the model. However, computer simulations using an extensive set of values for each parameter has led us to the conclusion that $dw_{HS}/d\mathbf{a}$ is more likely to be negative.¹¹ If that is indeed the case, then the incentives to become skilled decreases, motivating a smaller fraction of the Southern population to enter the labor force as skilled labor.

To analyze the change in the equilibrium level of Northern skill premium, we use equations (20) and (22):

$$\frac{w_{HN}}{w_{LN}} = \frac{\mathbf{c}}{(1-\mathbf{c})n_R} \frac{w_{HS}}{w_{LN}}. \quad (23)$$

The above equation implies that if $dw_{HS}/d\mathbf{a} < 0$, then an increase in α has two opposing effects on the equilibrium value of w_{HN}/w_{LN} . The first is through the *outsourcing channel*, whereby a larger extent of outsourcing \mathbf{c} reduces the demand for unskilled in the North relative to South and contributes positively to the Northern skill premium. The second is through the *skill formation channel*, whereby an decrease in the share of skilled labor in the South relative to the North (generated by the lower w_{HS}) mitigates the rise in the Northern skill premium.

Using computer simulations, we find that for an extensive set of parameter values $dw_{HN}/d\mathbf{a}$ is positive, while there are ranges of parameters, where it becomes negative.¹² If the skill premium in the North increases, then the incentives to become skilled increases, inducing a larger fraction of the population to undertake training and become skilled.

To investigate the changes in the arrival rate of innovations \mathbf{i} and the aggregate intensity of market exploration activity $\mathbf{f}n_N$, we focus on the skilled labor market equilibrium conditions (19) and (21). Observe that \mathbf{i} increases with the Northern skill premium, and $\mathbf{f}n_N$ increases with the Southern skill premium.

The above comparative steady-state analysis does not attribute a strong role to technology-driven shocks in explaining rising wage inequality. Even though such shocks clearly raise the extent of outsourcing, the effects on relative wages remain ambiguous. These analytical findings,

along with the simulation results, have led us to conclude the following: increased outsourcing driven by improvements in outsourcing technology is less likely to widen the wage gap in both North and South. This conclusion provides the basis for the second comparative steady-state analysis. Can there be a role for outsourcing if it is driven by policy changes?

3.2. Policy-driven changes in outsourcing

We next consider the economic impacts of changes in the policy parameters controlled by governments and investigate their possible role in explaining wage inequality.

Taxes and subsidies on production

Following several economic crisis in the recent two decades, emphasis among policy makers has shifted to attracting relatively stable capital flows, which includes FDI.¹³ Additional benefits accrue due to improved use of resources made possible by foreign investment, introduction of new processes to the domestic market, and technological spillovers made possible by learning-by-observing or training of the labor force.¹⁴ Due to these numerous benefits that MNF activity seems to convey, developing countries have implemented production subsidies that benefit domestic firms catering to multinational firms.¹⁵ In the present model, with $I > z > 0$ denoting the subsidy rate, such subsidies reduce the unit cost of production in the South from I to $(I - z)$. On the other hand, due to concerns over environmental issues and maintenance of higher labor standards, developed countries have implemented policies that have led to increased production taxes. With $t > 0$ denoting the tax rate, such taxes raise the unit cost of production in the North from w_{LN} to $w_{LN}(I + t)$.

The Southern production subsidy and the Northern production tax enter the model through the profit flow equations p_0 and p_N , respectively:

$$p_0 = Ead \left[w_{LN} \frac{(I + t)}{(I - z)} - I \right],$$

$$p_N = E \left[I - d w_{LN} \frac{(I + t)}{(I - z)} \right].$$

Observe that t and z enter the model symmetrically; thus, the effects of a higher Northern production tax are identical to those of a higher Southern production subsidy.

Proposition 3: *A higher production subsidy in the South \mathbf{z} or a higher production tax in the North \mathbf{t}*

- a. increases the extent of outsourcing \mathbf{c} ,*
- b. increases the relative wage of skilled labor in both North and South w_{HN}/w_{LN} and w_{HS} , respectively,*
- c. increases the aggregate intensity of outsourcing \mathbf{fn}_N ,*
- d. increases the arrival rate of innovations \mathbf{I} .*

To uncover the intuition, we will focus on the case of an increase in \mathbf{z} . Holding all else constant, a higher ζ exerts two first-order effects on the steady-state equations. The first is through the zero profit in R&D condition (15). A higher Southern subsidy reduces the unit cost of production in the South. As a result, Northern firms competing with Southern followers must reduce the mark-up price. Recall that innovators charge a price that is \mathbf{I} times more than the follower's unit cost. The decline in the profit margin negatively affects R&D profitability. This reduces the demand for Northern skilled labor and puts downward pressure on the skill premium in the North. The second effect is through the zero-profit condition in market exploration activity (16). A higher \mathbf{z} increases the profitability of outsourcing. This raises the demand for Southern skilled labor and puts upward pressure on the skill premium in the South.

Summing up the first-order effects, we observe that an increase in \mathbf{z} exerts a negative influence on the Northern skill premium and a positive influence on the Southern skill premium.

The results from the comparative steady-state analysis are as follows. In the new equilibrium, the extent of outsourcing \mathbf{c} increases. Observe that with \mathbf{a} constant, this is due to an increase in the fraction of industries successfully engaged in outsourcing n_o . The skill premium in the South w_{HS} also increases, inducing a larger fraction of the Southern population to become skilled.¹⁶ On the other hand, the Northern skill premium is subject to the effects generated through the outsourcing and skill formation channels (Eq. (23)). Observe that with both \mathbf{c} and w_{HS} increasing, the effects work to increase w_{HN}/w_{LN} . Thus, the share of skilled labor in the North increases. With the skill premia rising in both regions, \mathbf{fn}_N and \mathbf{i} also attain higher levels in the new equilibrium.

Subsidies to R&D and market exploration activity

Next, we move on to analyzing the economic impact of subsidies that promote skilled labor requiring activities, market exploration and innovation. Southern governments may subsidize the market exploration efforts of Northern firms in order to stimulate the flow of FDI into the country. Northern governments may subsidize innovative activity in order to increase their living standards through faster innovation.

Let $s_i > 0$ denote the subsidy rate for innovation and $s_f > 0$ the subsidy rate for market exploration activity. The subsidies enter the system through the zero-profit conditions (15) and (16):

$$(1 - s_i)w_{HN}a_i k_i N_N = \frac{E(1 - w_{LN}d)}{(\mathbf{r} + \mathbf{i} - n)}, \quad (24)$$

$$(1 - s_f)w_{HS}a_f k_f N_S = \frac{Ead(w_{LN} - 1)}{(\mathbf{r} + \mathbf{i} - n)}. \quad (25)$$

First, we consider the case of a larger subsidy for market exploration activity by the Southern government.

Proposition 4: *A larger subsidy for market exploration activity in the South s_f*

- a. has an ambiguous impact on the extent of outsourcing \mathbf{c}*
- b. increases the relative wage of skilled labor in both North and South (i.e., w_{HN}/w_{LN} and w_{HS} respectively) iff \mathbf{c} increases,*
- c. increases the aggregate intensity of outsourcing \mathbf{fn}_N iff \mathbf{c} increases,*
- d. increases the aggregate intensity of innovations \mathbf{i} iff \mathbf{c} increases.*

The intuition is as follows. Holding others constant, an increase in s_f exerts a first-order effect on the system through equation (25). A larger s_f renders market exploration more profitable and motivates more Northern firms to explore outsourcing opportunities abroad. This raises the demand for Southern skilled workers, putting upward pressure on the skill premium in the South.

The results of the comparative steady-state analysis are as follows. The change in the equilibrium level of \mathbf{c} depends on the parameters of the model. The skill premium in the South moves in the direction of \mathbf{c} . Thus, w_{HS} increases if and only if the extent of outsourcing increases.

Equation (23) implies that this is also the necessary and sufficient condition for an increase in the Northern skill premium.

Finally, we investigate the case of a larger subsidy for R&D activity by Northern governments.

Proposition 5: *A higher subsidy for innovative activity in the North s_i*

- a. increases the extent of outsourcing \mathbf{c} ,*
- b. increases the relative wage of skilled labor in both North and South, w_{HN}/w_{LN} and w_{HS} , respectively,*
- c. increases the aggregate intensity of outsourcing $\mathbf{f}n_N$,*
- d. increases the arrival rate of innovations I .*

The intuition is as follows. Holding others constant, an increase in s_i exerts a first-order effect on the model through equation (24). A larger s_i renders R&D more profitable and induces more firms to engage in R&D. This, in turn, raises the demand for skilled workers, putting upward pressure on the Northern skill premium.

The comparative steady-state results imply that in the new equilibrium the extent of outsourcing \mathbf{c} increases. Since w_{HS} moves in the direction of \mathbf{c} , the skill premium in the South also increases. Equation (23) implies that, with \mathbf{c} and w_{HS} both increasing, the Northern skill premium increases as well.

4. Conclusion

Over the past two decades, unskilled workers in most developed and developing countries have experienced a decline in their relative position in the society. The literature on this issue has focused heavily on the role of international trade and skill-biased technological change, paying relatively little attention to the possible effects of FDI on labor markets. In addition, a disproportionately large number of studies have concentrated on the developments in advanced countries, ignoring the ongoing changes in developing countries.

In this paper, we have attempted to bridge this gap by considering a unified North-South framework, where FDI takes the form of outsourcing production to South. We have exclusively focused on parameter changes that influence FDI, and investigated their effects on wage

inequality, skill endowments, technological change, and outsourcing intensity. Our main finding is that identifying the factors that stimulate FDI can play a crucial role on in explaining the wage patterns. More specifically, technology-driven FDI and policy-initiated FDI may have different effects on the wage gap between skilled and unskilled labor. We find that if increased FDI is driven by improvements in the technology of international outsourcing, the effects on relative wages in both host and source countries depend on the parameters of the model. To shed further light on the analytical results, we have run some simulations using an extensive set of parameter values. The simulation results show that technology shocks reduce the skill premium in the South, but generate ambiguous results on the skill premium in the North. On the other hand, using only analytics we are able to show that if increased FDI is initiated by changes in policy parameters such as taxes and subsidies, the relative wage of skilled labor clearly increase in both regions.

These findings suggest that the role of policy choices may outweigh the role of exogenous technological changes in explaining the widening wage gap via increased MNC activity. The analytical results present an empirically testable hypothesis and can stimulate further econometric research on the issue of wages and FDI. The theoretical model in this paper can also be extended in various directions. For instance, one can use the present framework to investigate FDI and labor markets in a North-North setting, where investment flows takes place between two advanced countries. Alternatively, one can enrich the existing structure by explicitly incorporating the spillover effects generated by FDI and study its labor market implications.

Endnotes

¹ Between 1980-98, the amount of net FDI received by developing countries has increased from 4.4 billion dollars to 170.9 billion dollars, almost a forty times increase (World Bank, 2000, p. 188).

² See Feenstra (1998) for an excellent discussion of empirical and stylized evidence on the increasing importance of international outsourcing.

³ Using the fact that the number of births at time t has to be equal to the number of deaths at time $t + D$, we can express the birth and death rates as $\mathbf{b} = (ne^{nD}/e^{nD} - 1)$ and $\mathbf{d} = n / (e^{nD} - 1)$.

⁴ It is assumed that each unit of household is infinitely large, and transfers among family members allow each member to realize the same level of consumption regardless of ability. This assumption together with the law of large numbers eliminate aggregate effective uncertainty in household income.

⁵ Wages refer to wages per efficiency unit of labor throughout the paper.

⁶ To simplify notation, we used the same skill acquisition parameters for both the North and the South. However, it is straightforward to extend the model by allowing for differences in D and T . Conceivably, this can capture some of the differences between the North and the South in terms of quality of education, durability of human capital and credit market imperfections. The main results of the paper are robust to such extensions.

⁷ The industrial organization approach to FDI suggest that MNFs have an advantage in foreign markets because of intangible productive assets such as technological know-how, marketing and managing skills, export contracts, coordinated relationships with suppliers and consumers, and reputation. (See Caves 1996, and Dunning 1993). Despite the listed intangible assets, though, the MNFs still require a level of understanding of the host economy prior to investing in the economy. The recent surge in cross-border mergers and acquisitions provides evidence that most multinationals are seeking investment that will provide them strategic assets, including know-how of the host economy and production techniques compatible with the host economy as well as semi-skilled labor (See World Investment Report, 2000).

⁸ Based on empirical studies, Fosfuri et al. (2001) argue that, in the early stages of establishing entities abroad, MNFs rely heavily on skilled labor from the source country and subsequently replace them with local workers. It is reasonable to assume that during this stage, the skilled workers from the source country interact with the skilled workers in the host country. Note that in our model, to keep the analysis tractable, we have undermined the role of Northern skilled labor in exploring the Southern market.

⁹ Equation (8) removes the scale-effects feature of the early endogenous growth models, which predicted explosive growth in the presence of positive population growth. The R&D difficulty specification originally proposed by Dinopoulos and Thompson (1996) has now been used in a number of studies including Dinopoulos and Segerstrom (1999) and Sener (2001). Evaluating the empirical relevance of equation (8) using cross-country data, Dinopoulos and Thompson (2000) argue that this R&D specification provides “a useful template on which to begin building more sophisticated models of long-run growth.”

¹⁰ Using bilateral trade data from OECD countries, Baier and Bergstrand (2001) attribute one-third of the increase in world trade to the combined effects of falling tariffs and transportation costs. However, they report that the impact of the tariff reduction on world trade is three times larger than that of transport costs. On the other hand, Feenstra (1998, p.41) emphasizes the role of improved communication in explaining the increased level of outsourcing activity in the 1980s. In particular he argues that “improvements in communication technology and the speed with which product quality and design can be monitored, which was in turn related to the use of computers” have made it more feasible to outsource unskilled intensive production to low-cost countries. It is reasonable to infer that the introduction of new technologies such as the internet, e-mail and cellular phones have propped up this upward trend in outsourcing in the 1990s as well.

¹¹ The benchmark case is where we set $a_R = 0.5$, $\mathbf{a} = 0.5$ (following Glass and Saggi, 2001), $\mathbf{s} = 1.19$, $\mathbf{r} = 0.03$, $n = 0.025$, $\mathbf{h} = 0.88$, $\mathbf{l} = 1.35$ (following Dinopoulos and Segerstrom, 1999), $k_R = 0.25$, and $n_R = 0.45$.

¹² The Northern relative wage patterns alter as we change n_R , the ratio of Southern population to Northern population. For small values of n_R (i.e., $n_R < 0.45$), we find that w_{HN}/w_{LN} declines, and for large values of n_R (i.e., $n_R > 0.45$) we find that w_{HN}/w_{LN} increases for all ranges of \mathbf{a}

¹³ Fernandez-Arias et al. (2000) and Soto (2000) have shown that FDI, which is driven by longer-term decision making, was much less volatile compared to commercial bank loans and foreign portfolio flows during the period 1992-97.

¹⁴ See Grossman and Helpman (1991) for technology diffusion models. See Blomstrom and Kokko (1998) for a comprehensive survey of FDI spillovers.

¹⁵ According to UNCTAD (1999, p. 115) roughly 94 percent of regulatory changes in the 1990s have been more favorable to FDI. These changes include adjustments in the degree of control in market functioning as well as explicit incentives to MNFs.

¹⁶ To see this, take the ratio of equations (21) and (19) and substitute for (w_{HN}/w_{LN}) from equation (23). The resulting expression defines w_{HS} as a function of χ and the parameters of the model. Totally differentiating this expression yields $dw_{HS}/d\mathbf{c} > 0$ (see Appendix A, equation A.2).

Figure 1: Mechanics of Innovation and Outsourcing

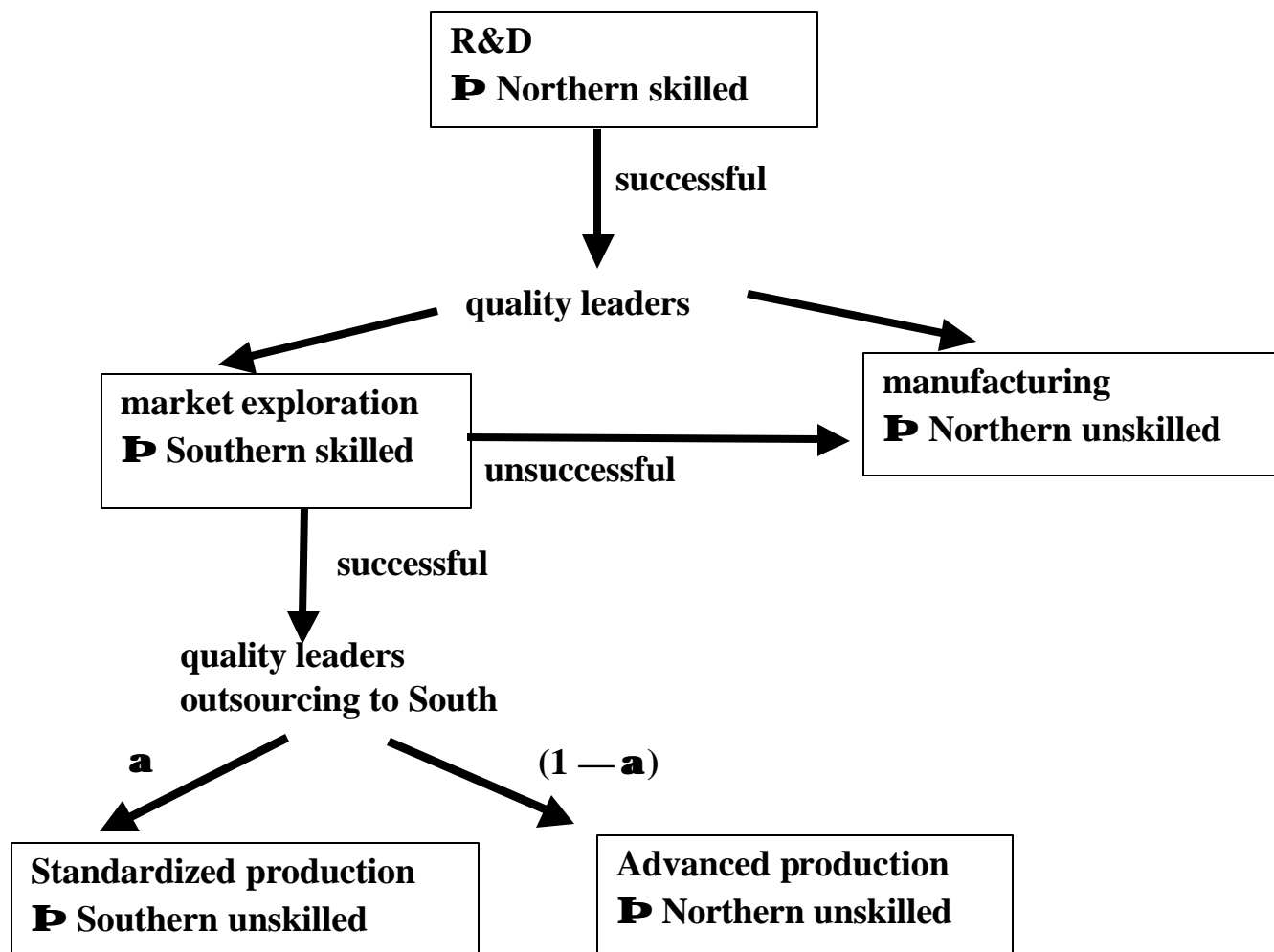
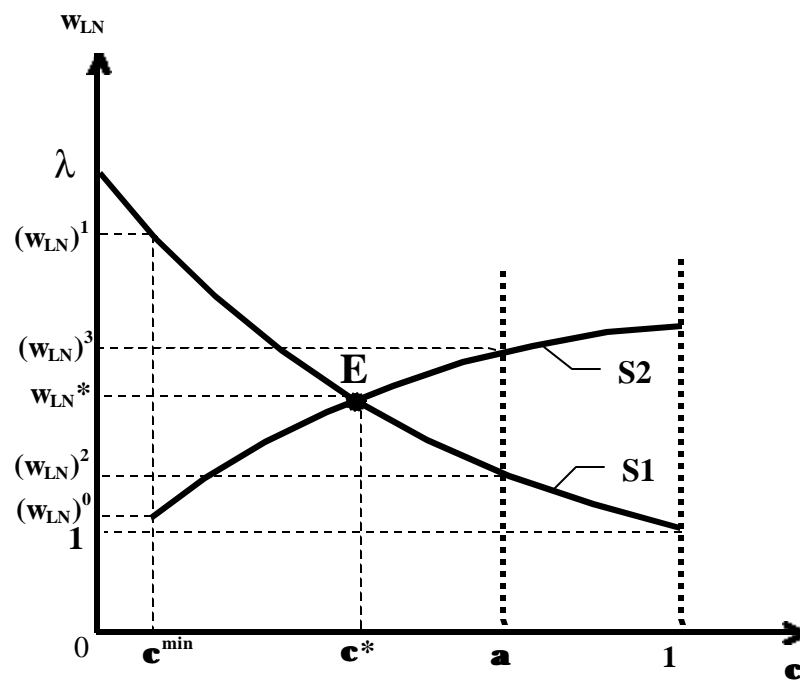


Figure 2: The steady-state equilibrium

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Appendix A

A.1 Proof of Proposition1: Existence and Uniqueness of Steady State Equilibrium

Step 1:

We first derive the steady-state equations (S1) and (S2). Taking the ratio of (15) to (16) and substituting for (w_{HN}/w_{HS}) from (23) yields:

$$\frac{\mathbf{c}}{(1-\mathbf{c})k_R a_R n_R^2} = \frac{(1-dw_{LN})}{\mathbf{a}dw_{LN}(w_{LN}-1)}. \quad (\text{S1})$$

To find (S2), we start by taking the ratio of (19) to (21) and substitute for (w_{HN}/w_{LN}) from (23).

This gives

$$\frac{k_R a_R \mathbf{c}}{\mathbf{a}} = \frac{I - \left(\frac{\mathbf{s}}{w_{HS}}\right)^2}{I - \left(\frac{\mathbf{s}}{w_{HS}}\right)^2 \left(\frac{(1-\mathbf{c})n_R}{\mathbf{c}}\right)^2}. \quad (\text{A1})$$

Rearranging terms yields

$$w_{HS}^2 = \frac{\mathbf{s}^2 \left[I - a_R k_R n_R^2 \frac{(1-\mathbf{c})^2}{\mathbf{c}\mathbf{a}} \right]}{\left[I - a_R k_R \frac{\mathbf{c}}{\mathbf{a}} \right]}. \quad (\text{A2})$$

Thus, through (A.2), w_{HS} is defined as a function of the parameters of \mathbf{c} and the parameters of the model as $w_{HS}(\mathbf{c}; \cdot)$. Next, we substitute for I from (19) into (16) and obtain an expression for E in terms of w_{HS} , \mathbf{c} , w_{LN} and parameters of the model as $E(w_{HS}, \mathbf{c}, w_{LN}; \cdot)$. Substituting for $E(w_{HS}, \mathbf{c}, w_{LN}; \cdot)$ into (22) and using w_{HS}^2 from (A.2) yields

$$\frac{(w_{LN}-1)}{\mathbf{s}} = \frac{\left[I - a_R k_R n_R^2 \frac{(1-\mathbf{c})^2}{\mathbf{c}\mathbf{a}} \right]}{\left[I - a_R k_R \frac{\mathbf{c}}{\mathbf{a}} \right]} \left[(r-n)k_R a_R k_i a_i \frac{\mathbf{c}}{\mathbf{a}} + \frac{\mathbf{h}}{2} \right] - \frac{\mathbf{h}}{2}. \quad (\text{S2})$$

Step 2:

We focus on a steady-state equilibrium in which all the endogenous variables attain strictly positive values. This interior solution imposes some restrictions on w_{LN} and \mathbf{c} . First, for $n_0 \hat{\mathbf{I}}(0, 1)$, we need $n_0 = \mathbf{c}/\mathbf{a} < 1$, which in turn entails $\mathbf{c} < \mathbf{a}$. Second, we consider a steady-state equilibrium in which the share of skilled in the Northern population is greater than the share of skilled in the Southern population. This implies that the RHS of (A.1) is less than 1, which in turn requires $k_R a_R \mathbf{c}/\mathbf{a} < 1$. A sufficient condition that satisfies this restriction is that $1 - k_R a_R > 0$ (i.e., the inequality when $\mathbf{c} = \mathbf{a}$). Third, for the share of skilled labor in the South to be positive, we need $1 - (\mathbf{s}/w_{HS})^2 > 0$ by (21), which in turn requires $\mathbf{c} > n_R/(1 + n_R)$ by (A.2) given $k_R a_R \mathbf{c}/\mathbf{a} < 1$. Fourth, equation (S1) implies that for $\mathbf{c} \hat{\mathbf{I}}(0, 1)$, we require $1 < w_{LN} < 1/\mathbf{d}$.

Step 3:

To plot the (S1) and (S2) curves, we focus on the range where $\mathbf{c} \hat{\mathbf{I}}(n_R/(1 + n_R), \mathbf{a})$ and $w_{LN} \hat{\mathbf{I}}(1, 1/\mathbf{d})$. For equation (S1) note that $\left. \frac{dw_{LN}}{dc} \right|_{S1} < 0$. On the (S1) curve as $\mathbf{c} \textcircled{R} n_R/(1 + n_R)$, $w_{LN} \textcircled{R} (w_{LN})^1$, where $(w_{LN})^1$ is implicitly defined by $\frac{\mathbf{a}\mathbf{d}}{k_R a_R n_R} = \frac{(1 - \mathbf{d}w_{LN})}{w_{LN}(w_{LN} - 1)}$; as $\mathbf{c} \textcircled{R} \mathbf{a}$, $w_{LN} \textcircled{R} (w_{LN})^2$, where $(w_{LN})^2$ is implicitly defined by $\frac{\mathbf{a}^2 \mathbf{d}}{k_R a_R n_R^2 (1 - \mathbf{a})} = \frac{(1 - \mathbf{d}w_{LN})}{w_{LN}(w_{LN} - 1)}$.

For equation (S2) note that $\left. \frac{dw_{LN}}{dc} \right|_{S2} > 0$. On the (S2) curve, as $\mathbf{c} \textcircled{R} n_R/(1 + n_R)$, $w_{LN} \textcircled{R} (w_{LN})^0$, where $(w_{LN})^0 = 1 + \frac{\mathbf{s}(\mathbf{r} - n)k_F a_F}{(1 + n_R)\mathbf{a}}$; as $\mathbf{c} \textcircled{R} \mathbf{a}$, $w_{LN} \textcircled{R} (w_{LN})^3$, where

$$(w_{LN})^3 = 1 + \frac{\mathbf{s} \left(1 - a_R k_R n_R^2 \frac{(1 - \mathbf{a})^2}{\mathbf{a}} \right) \left((\mathbf{r} - n)k_F a_F + \frac{\mathbf{h}}{2} \right)}{(1 - a_R k_R)} - \frac{\mathbf{h}\mathbf{s}}{2}.$$

Figure 2 illustrates the curves corresponding to (S1) and (S2) on (c, w_{LN}) space. The existence and uniqueness of a steady-state equilibrium requires that $(w_{LN})^1 > (w_{LN})^0$ and $(w_{LN})^3 > (w_{LN})^2$. For these inequalities to hold simultaneously, we need the following restriction:

$$0 < \frac{n_R^2(1-a)}{aU} \left[\frac{1}{1+U} - d \right] < \frac{ad}{k_R a_R} < \frac{1}{Z} \left[\frac{1}{1+Z} - d \right],$$

$$\text{where } U = \frac{s \left(1 - \frac{a_R k_R n_R^2 (1-a)^2}{a^2} \right)}{(1-a_R k_R)} \left((r-n) k_f a_f + \frac{h}{2} \right) - \frac{hs}{2} \text{ and } Z = \frac{s(r-n) k_f a_f n_R}{(1+n_R) a}.$$

APPENDIX B

B.2 Comparative Steady State Results

B.2.1 Proof of Proposition 2: An increase in \mathbf{a}

Let equations (S1) and (S2) define the following implicit functions:

$$S1(w_{LN}, \mathbf{c}; \cdot) = \frac{\mathbf{c}}{(1-\mathbf{c})k_R a_R n_R^2} - \frac{(1-dw_{LN})}{adw_{LN}(w_{LN}-1)} = 0, \quad (\text{S1})$$

$$S2(w_{LN}, \mathbf{c}; \cdot) = \frac{(w_{LN}-1)}{\mathbf{s}} - T - \frac{\mathbf{h}}{2} = 0, \quad (\text{S2})$$

where $T = \begin{bmatrix} 1-\frac{F}{\mathbf{a}} \\ 1-\frac{G}{\mathbf{a}} \end{bmatrix} \begin{bmatrix} H \\ \mathbf{a} + \frac{\mathbf{h}}{2} \end{bmatrix}$ with $F = a_R k_R n_R^2 (1-\mathbf{c})^2 / \mathbf{c}$, $G = a_R k_R \mathbf{c}$, and $H = (\mathbf{r}-n)k_f a_f \mathbf{c}$. Note

that since $\mathbf{c} > n_R / (1 + n_R)$ in equilibrium, $F - G < 0$. Totally differentiating the above system yields

$$\begin{bmatrix} (S1)_c & (S1)_{w_{LN}} \\ (S2)_c & (S2)_{w_{LN}} \end{bmatrix} \begin{bmatrix} d\mathbf{c} \\ dw_{LN} \end{bmatrix} = \begin{bmatrix} (-S1)_a \\ (-S2)_a \end{bmatrix} [d\mathbf{a}],$$

where $(S1)_c = \frac{1}{k_R a_R n_R^2 (1-\mathbf{c})^2} > 0$,

$$(S1)_{w_{LN}} = \frac{(w_{LN}-1) + (1-dw_{LN})w_{LN}}{ad(w_{LN}-1)^2(w_{LN})^2} > 0,$$

$$(S1)_a = \frac{(1-dw_{LN})}{\mathbf{a}^2 d(w_{LN}-1)w_{LN}} > 0,$$

$$(S2)_c = -\frac{T}{\mathbf{a}} \left[\frac{a_R k_R n_R^2 (1-\mathbf{c})^2}{\left(1-\frac{F}{\mathbf{a}}\right)\mathbf{c}^2} + \frac{a_R k_R}{\left(1-\frac{G}{\mathbf{a}}\right)} + \frac{(\mathbf{r}-n)k_f a_f}{\left(1-\frac{H}{\mathbf{a}}\right)} \right] < 0,$$

$$(S2)_{w_{LN}} = \frac{1}{\mathbf{s}} > 0,$$

$$(S2)_a = -\frac{dT}{da} = -\frac{1}{a^2 \left(1 - \frac{G}{a}\right)} \left[(F-G) \left(\frac{H}{a} + \frac{h}{2} \right) - H \left(1 - \frac{F}{a} \right) \left(1 - \frac{G}{a} \right) \right] > 0.$$

The determinant of the system is $\mathbf{D} = (SI)_c(S2)_{w_{LN}} - (SI)_{w_{LN}}(S2)_c > 0$. Using Cramer's rule, we derive

$$\frac{dc}{da} = \frac{(-SI)_a(S2)_{w_{LN}} - (SI)_{w_{LN}}(-S2)_a}{\mathbf{D}} < 0.$$

Substituting for the expressions in the numerator and simplifying, one can show that

$$\text{sign} \frac{dc}{da} \equiv \text{sign} \left[(1 - dw_{LN}) \left(-\frac{1}{sa} - \frac{1}{(w_{LN} - 1)} \frac{dT}{da} \right) - \frac{1}{w_{LN}} \frac{dT}{da} \right].$$

Focusing on the second expression in parenthesis on the RHS and substituting for w_{LN} from (S2)

and dT/da from (S2)_a, one can show that $\left(-\frac{1}{sa} - \frac{1}{(w_{LN} - 1)} \frac{dT}{da} \right) > 0$ iff $F - G < 0$. Since $F - G$

< 0 by assumption, it follows that $\frac{dc}{da} > 0$.

Using Cramer's rule one can also obtain

$$\frac{dw_{LN}}{da} = \frac{(SI)_c(-S2)_a - (-SI)_a(S2)_c}{\mathbf{D}} < 0.$$

To find $\frac{dn_0}{da}$, we rewrite (S2) as

$$\frac{(w_{LN} - 1)}{s \left[1 - a_R k_R n_R^2 \frac{(1-c)^2}{ca} \right]} = \frac{\left[(r-n) k_f a_f \frac{c}{a} + \frac{h}{2} \right]}{\left[1 - a_R k_R \frac{c}{a} \right]} - \frac{h}{2 \left[1 - a_R k_R n_R^2 \frac{(1-c)^2}{ca} \right]}.$$

Note that totally differentiating the above expression holding $n_0 = c/a$ constant implies that

$\frac{dLHS}{da} < 0$ and $\frac{dRHS}{da} > 0$. Thus, if a increases, to maintain equilibrium the RHS must fall

through a decline in n_0 . Hence it follows that $\frac{dn_0}{da} < 0$.

To sign $\frac{dw_{HS}}{da}$, we differentiate (A.2) with respect to \mathbf{a} :

$$\begin{aligned} \frac{dw_{HS}}{da} &= \frac{\partial w_{HS}}{\partial \mathbf{a}} + \frac{\partial w_{HS}}{\partial \mathbf{c}} \frac{d\mathbf{c}}{da} \\ &= \frac{w_{HS}}{2} \frac{1}{\left(1 - \frac{F}{\mathbf{a}}\right)\left(1 - \frac{G}{\mathbf{a}}\right)\mathbf{a}^2} \left[\frac{d\mathbf{c}}{da} \frac{\mathbf{a}}{\mathbf{c}} \left(\frac{F(1+\mathbf{c})}{(1-\mathbf{c})} + G + \frac{2}{(1-\mathbf{c})} \frac{GF}{\mathbf{a}} \right) + F - G \right] \ll 0. \end{aligned}$$

Thus, $\frac{dw_{HS}}{da} > 0$ iff $\frac{d\mathbf{c}}{da} \frac{\mathbf{a}}{\mathbf{c}} > \frac{G-F}{\frac{F(1+\mathbf{c})}{(1-\mathbf{c})} + G - \frac{2GF}{\mathbf{a}(1-\mathbf{c})}}$. However, note that this condition is

defined in terms of the endogenous variables of the system; thus, one should exercise caution in interpreting this finding. Our simulation analysis discussed in the text suggests that for an extensive set of parameter values that satisfies an interior equilibrium, this necessary condition does not hold. Hence, we conclude that $\frac{dw_{HS}}{da}$ is more likely to be negative. With these comparative steady state findings, it is straightforward to find the qualitative changes for the rest of the variables w_{HN}/w_{LN} , I and f_{N_s} , using (23), (19), and (21), respectively.

B.2.2 Proof of Proposition 3: Production Taxes and Subsidies

Note that production taxes by the North \mathbf{t} and production subsidies by the South \mathbf{z} enter the model symmetrically. Therefore, we only examine the case of a larger \mathbf{t} and note that the same analysis and results apply for the case of a larger ζ . The modified steady-state equations with the Northern production tax are:

$$S1(w_{LN}, \mathbf{c}; \cdot) = \frac{\mathbf{c}}{(1-\mathbf{c})k_R a_R n_R^2} - \frac{(1-d_{w_{LN}}(1+\mathbf{t}))}{\mathbf{a} d_{w_{LN}}((1+\mathbf{t})w_{LN} - 1)} = 0, \quad (\mathbf{S1})$$

$$S2(w_{LN}, \mathbf{c}; \cdot) = \frac{((1+\mathbf{t})w_{LN} - 1)}{\mathbf{s}} - \mathbf{T} - \frac{\mathbf{h}}{2} = 0. \quad (\mathbf{S2})$$

A larger t shifts both (S1) and (S2) curves down in Figure 2. Thus, $\frac{dw_{LN}}{dt} < 0$ and $\frac{dc}{dt}$ appears ambiguous. To further investigate the sign of $\frac{dc}{dt}$, we totally differentiate the above

system and use Cramer's rule. This yields

$$\text{sign} \frac{dc}{dt} \equiv \text{sign} \left[(-S1)_t (S2)_{w_{LN}} - (S1)_{w_{LN}} (-S2)_t \right],$$

$$\text{where } (S1)_t = \frac{(1-d)}{ad((1+t)w_{LN}-1)^2} > 0, \quad (S2)_t = \frac{w_{LN}}{s} > 0,$$

$$(S1)_{w_{LN}} = \frac{((1+t)w_{LN}-1) + (1+t)w_{LN}(1-dw_{LN}(1+t))}{ad((1+t)w_{LN}-1)^2(w_{LN})^2} > 0, \quad (S2)_{w_{LN}} = \frac{(1+t)}{s} > 0.$$

Substituting these expressions into above and simplifying yields

$$\text{sign} \frac{dc}{dt} \equiv \text{sign} \frac{((1+t)w_{LN}-1)(1-(1+t)w_{LN}d)}{ad((1+t)w_{LN}-1)^2 s w_{LN}} > 0.$$

Note that $((1+t)w_{LN}-1)$ and $(1-(1+t)w_{LN}d)$ must be positive to guarantee positive profit

flows; thus, $\frac{dc}{da} > 0$. Since $\frac{\partial w_{HS}}{\partial c} > 0$ by (S.3), it follows that $\frac{dw_{HS}}{dt} > 0$. Moreover, by (23)

$\frac{d(w_{HN}/w_{LN})}{dt} > 0$. With these findings, the qualitative changes for I and f_{n_N} can be obtained by

using (19) and (21), respectively.

B.2.3. Proofs of Propositions 4 and 5: Subsidies to Outsourcing and Innovation

The modified steady-state equations with outsourcing subsidy s_f and innovation subsidy s_i are:

$$S1(w_{LN}, c; \cdot) = \frac{(1-s_i)c}{(1-s_f)k_R a_R n_R^2 (1-c)} - \frac{(1-dw_{LN})}{adw_{LN}(w_{LN}-1)} = 0, \quad (\text{S1})$$

$$S2(w_{LN}, c; \cdot) = \frac{(w_{LN}-1)}{s} - \frac{\left[\frac{1-a_R k_R n_R^2 (1-c)^2}{ca} \right]}{\left[1-a_R k_R \frac{c}{a} \right]} \left[(1-s_f)(r-n)k_f a_f \frac{c}{a} + \frac{h}{2} \right] - \frac{h}{2}. \quad (\text{S2})$$

A larger s_f shifts both (S1) and (S2) curves down in Figure 2; thus, $\frac{dw_{LN}}{ds_f} < 0$ and

$\frac{dc}{ds_f}$ appears ambiguous. Finding a parametric restriction for $\frac{dc}{ds_f}$ appears to be analytically

infeasible. Thus, using (A.2) one can conclude that $\frac{dw_{HS}}{ds_f} > 0$ iff $\frac{dc}{ds_f} > 0$. Moreover, equation

(23) implies that $\frac{d(w_{HN} / w_{LN})}{ds_f} > 0$ iff $\frac{dc}{ds_f} > 0$. With these findings, one can determine the

qualitative changes in I and $f n_N$, using (19) and (21), respectively.

A larger s_i shifts the (S1) curve up. It follows that $\frac{dw_{LN}}{ds_i} > 0$ and $\frac{dc}{ds_i} > 0$. Using equations

(A.2) and (23), we also derive $\frac{dw_{HS}}{ds_i} > 0$ and $\frac{d(w_{HN} / w_{LN})}{ds_i} > 0$. The changes in the rest of the

variables can be analyzed as above.