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Abstract

TITLE: Growth and North-South Wage Gap

We study the sources of long-run growth and wage gap in a North-South (N-S) model with trade and foreign direct investment (FDI). Although R&D is the engine of global growth, increased share of R&D spending need not be accompanied by higher growth rate, and vice versa. Although investment is induced by productivity growth, investment-output ratio need not rise monotonically with productivity growth. Lower investment-output ratio may accompany higher productivity growth, so higher growth rate need not entail lower share of consumption. We argue that existing models may exaggerate or under-estimate the role of R&D in growth. We also show that higher growth rate is normally accompanied by greater N-S wage gap in the long run. The effect of country size on wage gap is generally ambiguous, depending on the direction and magnitude of scale effects in R&D. Both FDI and S-N migration may increase global growth rate and N-S wage gap.

JEL Classification: O41, O15, F21, F43

Key Words: endogenous growth, North-South wage gap, R&D, investment

1 Introduction

Economic growth and wage gap between countries have long engaged economists. What factors determine the growth rate of the global economy? How do these factors interact to affect the wage gap between developed countries (North) and developing countries (South)? In particular, does the relative wage of a country decrease or increase with its size as measured by its labor endowment? Recently, these issues have been studied from various perspectives in the endogenous growth literature.

Regarding the engine of growth, AK models focus on investment, and predict that higher investment-output ratio (henceforth investment share) yields higher growth rate.[1] In comparison, R&D models focus on total factor productivity (TFP) growth generated by innovation as the engine of growth.[2] They predict that higher R&D-output ratio (henceforth R&D share) yields higher growth rate, and that investment share rises monotonically with TFP growth rate. The latter prediction often leads to the view that investment only plays a supporting role in growth and can be ignored.[3] However, this view has been challenged by Young (1995) who documents a fundamental role for investment and factor accumulation in general in East Asia's rapid growth.

Regarding North-South (henceforth N-S) wage gap, a common view has long been that it stems from relative labor abundance in S, accentuated by productivity differences. This view finds support in Krugman's (1979) work on world income distribution. In a N-S trade model with exogenous rates of innovation in N and imitation in S, Krugman finds that the relative wage of a country decreases with its labor endowment (i.e. size). However, Krugman's result has been reversed by Grossman and Helpman (1991a) when the rates of innovation in N and imitation in S depend on their respective labor endowments.

Given the seemingly conflicting perspectives and results in the literature, we attempt a careful re-examination of the issues in this paper. To this end, we generalize an R&D-based endogenous growth model of the Grossman and Helpman (1991a, b) type with several features that we consider important. In this generalized framework, we relate growth rate, investment share, R&D share and N-S wage gap to structural characteristics of the global economy and government policies. We then derive a number of results

[1] See e.g. Romer (1986) and Rebelo (1991).

[2] See e.g. Romer (1990), Grossman and Helpman (1991b), and Aghion and Howitt (1992).

[3] See e.g. Grossman and Helpman (1991b:122).

that shed light on the existing literature.

First, higher growth rate stems from faster rate of innovation or more growth-conducive manufacturing technology. Such technology features greater returns to specialization or greater dependence on capital or innovated goods as inputs. Second, higher growth rate is accompanied by increased share of spending on either investment or R&D, but not necessarily both. In particular, higher growth rate need not be accompanied by increased share of R&D spending, and vice versa, although R&D is the engine of growth. Third, investment share need not rise monotonically with TFP growth rate, although investment is induced by TFP growth. Lower investment share may well accompany higher growth rate, so the latter need not entail lower consumption share.

The above results follow from incorporating capital into the production of intermediate inputs (as well as the final good), and from treating the effect of product differentiation on TFP growth generally. In comparison, existing R&D models implicitly assume that product differentiation always increases TFP growth. They also frequently (choose to) ignore capital in some or all manufacturing sectors, based on the perception that investment only plays a supporting role in growth. We show that the implicit assumption may lead to exaggerating the role of R&D in growth.[4] On the other hand, ignoring capital may lead to under-estimating the role of R&D in growth, because one ignores that investment may enhance the growth effect of any given R&D, as we show in the paper. Only by coincidence will these two opposing effects exactly cancel out. In general, therefore, existing R&D models may exaggerate or under-estimate the role of R&D in growth.

We also find that the wage gap between N and S depends on their sizes as well as wage shares (i.e. the shares of world income accruing to their workers as wages). Higher growth rate is normally accompanied by greater N-S wage gap in the long run, because determinants of the growth rate also affect wage shares. The overall effect of country size on relative wage depends on the direction and magnitude of scale effects (dynamic scale economies or dis-economies) in R&D, because these effects link wage share to country size through the rate of innovation. A country's relative wage increases with its size if and only if strongly positive scale effects prevail, i.e. more R&D input raises innovation

[4]This is consistent with the analysis of Benassy (1998). He observes that R&D-based growth models adopting this implicit assumption – in a more restrictive form to be specified later – all predict that insufficient resources are devoted to R&D as compared to a social optimum. Our analysis generalizes Benassy (1998) on this point.

and growth rates substantially. Otherwise no relationship or even an inverse one holds. These results follow from a general treatment of scale effects in R&D, motivated by current controversy over the empirical (ir)relevance of such effects in the literature.[5] By showing that variations in the direction and magnitude of scale effects may affect the link between country size and wage gap differently, we reconcile the seemingly conflicting results of Krugman (1979) and Grossman and Helpman (1991a) mentioned earlier.

Our paper also supplements the literature by explicitly addressing the roles of foreign direct investment (FDI) and migration – in addition to R&D and investment – in affecting growth. The roles of FDI and migration have rarely been addressed in the endogenous growth literature, although both have featured prominently in contemporary growth experience.[6] We show that FDI in S by N-firms may increase both growth rate and N-S wage gap. The effects of migration are ambiguous, depending on the direction and magnitude of scale effects in R&D. If scale effects are positive but weak, S-N migration may promote growth and reduce wage gap. If scale effects are strongly positive, S-N migration may increase both growth rate and N-S wage gap, exacerbating polarization in a faster-growing world.

The paper demonstrates a simple yet fundamental point: Because growth rate, investment share, R&D share and N-S wage gap are all endogenous in the long run, it may be misleading to study any causal relationship between any pair of these variables, as the literature frequently seems to suggest. A proper understanding of the long-run behavior of these endogenous variables requires careful analysis of the underlying structural characteristics of the economy (i.e. technology, endowments, preferences) and relevant government policies.

The rest of the paper is organized as follows. Section 2 presents the details of the model. Section 3 derives and discusses the main results. Section 4 concludes with some remarks on possible extensions of the model. Proofs of a more technical nature appear in the Appendix.

[5] Grossman and Helpman (1991a, b) and most early R&D models feature positive scale effects which has been questioned by Jones (1995) on empirical grounds. Recent work that re-examines the issue includes Backus et al. (1992), Aghion and Howitt (1998), Segerstrom (1998), Young (1998), Dinopoulos and Thompson (1999), and Jones (1999).

[6] By comparison, the role of trade in growth has been extensively studied, largely due to the seminal work of Grossman and Helpman (1991b).

2 The model

Consider an economy with two countries (or regions), N and S, with labor endowments (consumer populations) L_N and L_S, respectively. Labor is not mobile between countries unless otherwise specified. Capital is perfectly mobile. Firms own physical capital and finance investment by borrowing from consumers. FDI arises when a firm based in one country produces in the other.

There are two types of goods: a continuum of differentiated intermediate goods $\mathbf{x} := \{x(i) : i \in [0, \infty)\}$ and a final good Y. Production of an intermediate is based on a blueprint developed through R&D. The subset of $\mathbf{x}$ already developed and under production is denoted I with measure n. Production of Y uses $\mathbf{x}$ as intermediates. Y is used for consumption and investment in manufacturing.

We would like the model to approximate two facts. First, innovation is concentrated in developed countries (N), and developing countries (S) predominately engage in manufacturing. Second, production of innovated goods tends to be controlled by firms from the innovating countries, and (at least at some stage of the product life cycle) takes the form of FDI to reduce cost. To capture these facts as simply as possible, we restrict attention to equilibria where N innovates new varieties of $\mathbf{x}$ which are then produced in S through FDI, and S specializes in manufacturing (both $\mathbf{x}$ and Y) and exports Y to N for consumption there. This specialization pattern is admittedly extreme, but it simplifies the analysis substantially. More importantly, the main results of the paper will not be affected qualitatively if we generalize to less extreme specialization patterns, provided N continues to engage predominately in R&D and S predominately in manufacturing.

The assumed specialization pattern requires (i) sufficient productivity difference in R&D between regions so that it is not worth doing R&D in S; (ii) patents protection so that blueprints remain in the hands of N-firms; and (iii) sufficient cost difference in manufacturing so that it is not worth producing in N. We assume (i) and (ii) to hold, and derive the parameter restrictions ensuring (iii) in the appendix.

Final good. Y is produced in S by local firms (indexed by $j = S$) or FDI firms from N (indexed by $j = F$). Firms of type j produce output Y_j of the final good using all available intermediates $\{x_j(i) : i \in I\}$, labor L_{jy} and capital K_{jy}. Output is

$$Y_j = \xi_y B_j K_{jy}^{\theta_1} M_j^{\theta_2} L_{jy}^{1-\theta_1-\theta_2}, \quad j = S, F, \tag{1}$$

where

$$M_j = \left\{ n^{\sigma(\alpha) - \frac{1-\alpha}{\alpha}} \left(\int_0^n [x_j(i)]^\alpha \, di \right)^{\frac{1}{\alpha}} \right\} \tag{2}$$

is an index of intermediates. ξ_y is a scaling parameter, $\alpha, \theta_1, \theta_2, (\theta_1 + \theta_2) \in (0,1)$, $\sigma(\alpha) > 0$, and B_j is a productivity parameter. By assumption, FDI firms may be more productive so $B_F \geq B_S > 0$.

According to (1) and (2), output exhibits constant returns to scale (CRS) for given n, and TFP increases with n.[7] (2) is a CES function where smaller α indicates more differentiation (less substitutability) among intermediates. It introduces a new feature: We allow $\sigma'(\alpha) \gtreqless 0$, so differentiation of intermediates may have negative, zero or positive effect on the returns to specialization indexed by σ.[8] As noted by Benassy (1998), most authors implicitly assume $\sigma(\alpha) = \frac{1-\alpha}{\alpha}$ implying $\sigma'(\alpha) < 0$, i.e. returns to specialization increase with differentiation of intermediates in a specific way. This originates from the consumption index proposed by Dixit and Stiglitz (1977) to model preference for increasing diversity (i.e. larger number of differentiated goods) in consumption. In that context $\sigma'(\alpha) < 0$ seems plausible: More differentiation among consumption goods is better, provided $n > 1$. Re-interpreting the Dixit-Stiglitz consumption index as a production index, however, it is not obvious why $\sigma'(\alpha) < 0$ should continue to hold. As Ethier (1982) and Benassy (1998) both suggest, one can think of σ as being independent of α [i.e. $\sigma'(\alpha) = 0$]. In principle, one can also think of technologies where returns to specialization decrease with differentiation of intermediates [i.e. $\sigma'(\alpha) > 0$].

Labor market in each country is competitive. However, for reasons not addressed here, FDI firms may pay a premium above the locally competitive wage rate:[9]

$$w_F = \beta w_S, \quad \beta \geq 1.$$

We discuss how the magnitude of β affects employment structure and wage gap in S later.

Assuming perfect competition and negligible transport costs, the CRS technology (1) implies Y will be priced at its minimum unit cost on the world market:

$$p_y = \min_j \{p_{jy}\}, \tag{3}$$

[7] These properties can be verified most simply if we let $x_j(i) = x_j$ (which holds in equilibrium) and $X_j \equiv n x_j$ so $M_j = n^{\sigma(\alpha)} X_j$.

[8] The term "returns to specialization" was coined by Ethier (1982).

[9] FDI firms often pay higher wages than local firms, especially in developing countries. They may do so to overcome local operational barriers or out of efficiency-wage consideration, among other things.

where with ξ_y properly chosen,

$$p_{jy} = \frac{1}{B_j n^{\theta_2\left(\sigma - \frac{1-\alpha}{\alpha}\right)}} q^{\theta_1} \left(\int_0^n [p(i)]^{1-\varepsilon} di \right)^{\frac{\theta_2}{1-\varepsilon}} w_j^{1-\theta_1-\theta_2} \tag{4}$$

is the unit cost of type j firms, q is the interest rate firms pay on capital loans, and $p(i)$ is the price of $x(i)$. For the remainder of the paper we normalize prices so

$$p_y \equiv 1.$$

Cost minimization by producers of Y_j yields the following demand for inputs:

$$K_{jy} = \frac{1}{q}\theta_1 Y_j, \tag{5a}$$

$$L_{jy} = \frac{1}{w_j}(1-\theta_1-\theta_2) Y_j, \tag{5b}$$

$$x_j(i) = \frac{[p(i)]^{-\varepsilon}}{\int_0^n [p(i')]^{1-\varepsilon} di'} \theta_2 Y_j, \quad \forall i \in I. \tag{5c}$$

Aggregate input demands are $K_y = \sum_j K_{jy}$, $L_y = \sum_j L_{jy}$ and $x(i) = \sum_j x_j(i)$. Aggregate output is $Y = \sum_j Y_j$.

Intermediate goods. By assumption, these are innovated in N and then produced in S through FDI. Economy-wide innovation output is

$$\dot{n} = A(n, \delta n) f(L_N), \tag{6}$$

where $f\ (L_N) > 0$ for $L_N > 0$. $A(n, \delta n)$ is the aggregate knowledge index affecting productivity in R&D. Following much of the endogenous-growth literature, we assume A increases with cumulative innovation experience, approximated by the total number of innovations n. We also observe that producing in foreign markets where the products are sold often helps firms develop new products (or improve existing ones). This *learning effect* of FDI is captured by the assumption that A increases with cumulative FDI experience, approximated by δn, where n is the total number of FDI projects (since all n intermediates are produced through FDI) and δ parameterizes the learning effect of FDI relative to innovation.[10] Let $A(\cdot,\cdot)$ be linear-homogeneous and $\psi(\delta) \equiv A(1,\delta)$,

[10] Firms frequently cite the learning effect as one major motivation for undertaking FDI, see e.g. examples and reports on multinational operations in UNCTAD (1995). Another reflection of the learning effect of FDI is that multinationals often locate some of their R&D facilities (often with expatriate staff) near their overseas production facilities, see e.g. reports on such practice of Japanese multinationals in the *Financial Times,* October 17, 1994.

then $A(n, \delta n) = n\psi(\delta)$. Let $\widehat{z}$ denote the growth rate of any variable z so that $\widehat{z} \equiv \frac{\dot{z}}{z}$. Then (6) can be re-written as

$$\widehat{n} = \psi(\delta) f(L_N) \tag{7}$$

where by assumption, $\psi(0) = 1, \psi(\infty) = \overline{\psi} < \infty, \psi' > 0$ and $\psi'' < 0$.

(7) has two novel features. First, innovation rate $\widehat{n}$ increases with the relative learning effect of FDI, δ, via the multiplier $\psi(\cdot)$. This captures the role of FDI in knowledge accumulation and innovation, which has largely been ignored in the literature. Second, without any a priori restriction on the sign of $f'(L_N)$, increased R&D input may affect innovation rate differently. Scale effects are positive if $f'(L_N) > 0$, absent if $f'(L_N) = 0$, and negative if $f'(L_N) < 0$. Moreover, the magnitude of any scale effects may vary with L_N. This general specification is motivated by the common view that as R&D input increases, innovation may become more difficult. Hence, it is generally unclear whether innovation increases or decreases with R&D input. Our specification encompasses those in Grossman and Helpman (1991a, b) and early R&D models where positive scale effects prevail and take the special form of $\widehat{n}$ being linear in R&D input [i.e. $f'(L_N) = 1$]. It also encompasses the specifications in Segerstrom (1998), Young (1998) and recent models where scale effects are intentionally absent. The general treatment of scale effects allows us to shed light on the relationship between relative wage and country size in general, as will be seen later.

An intermediate firm from N may develop the blueprint of its intermediate product through its own R&D, or it may buy the blueprint at a price. In either case the firm finances the cost of the blueprint by issuing shares, and pays out subsequent profits as dividends. With patent protection, each intermediate $i \in I$ is produced in S by the N-firm which owns the blueprint exclusively. Production employs labor $l_x(i)$ and capital $k_x(i)$. Output is

$$x(i) = \xi_x B_F [k_x(i)]^{\theta_3} [l_x(i)]^{1-\theta_3}, \tag{8}$$

where ξ_x is a scaling parameter and $\theta_3 \in (0, 1)$. With ξ_x properly chosen, (8) implies a unit cost

$$c = \frac{q^{\theta_3} w_F^{1-\theta_3}}{B_F}. \tag{9}$$

Given (5c), optimization by each producer yields the following price, output and profit for all $i \in I$:

$$p(i) = \frac{c}{\alpha} = p, \tag{10a}$$

$$x(i) = \frac{1}{p}\frac{\theta_2 Y}{n} = x, \tag{10b}$$

$$\pi(i) = (1-\alpha)\, px = \pi, \tag{10c}$$

and the following demand for $k_x(i)$ and $l_x(i)$ for all $i \in I$:

$$k_x(i) = \frac{\theta_3 cx}{q} = k_x, \tag{11a}$$

$$l_x(i) = \frac{(1-\theta_3)\, cx}{w_F} = l_x. \tag{11b}$$

Aggregate input demands are $K_x = nk_x$ and $L_x = nl_x$. Noting (10a) and (10b), we find from (11a) and (11b), respectively,

$$K_x = nk_x = \frac{\theta_3 \alpha \theta_2 Y}{q}, \tag{12a}$$

$$L_x = nl_x = \frac{(1-\theta_3)\, \alpha\theta_2 Y}{w_F}. \tag{12b}$$

Consumption and saving. A consumer can lend to other consumers at interest rate r. She can also lend to firms which buy capital at unit price $p_y \equiv 1$ and pay her interest rate q. Finally, she can invest in the shares of intermediate firms. Each of these firms has market value v and earns instant profit π which is paid out to share-holders as dividends. With perfect capital mobility, arbitrage ensures that the rate of return on each asset adjusted for capital gains or losses must equal the world interest rate at any time:

$$\frac{\pi}{v} + \widehat{v} = r(t), \tag{13a}$$

$$q = r(t). \tag{13b}$$

A consumer h (in N or S) chooses consumption $C_h(t)$ of the final good to maximize discounted utility

$$U_h = \int_0^\infty e^{-\rho t} \ln\left[C_h(t)\right] dt$$

subject to intertemporal budget constraint

$$\int_0^\infty e^{-R(t)} C_h(t)\, dt \leq w_h(0) + W_h(0),$$

where $\rho > 0$ is subjective discount rate, $R(t) \equiv \int_0^t r(s)\, ds$, $w_h(0)$ is wage income discounted to $t = 0$, and $W_h(0)$ is initial asset endowment. The solution to this standard intertemporal optimization problem implies $\widehat{C}_h = r(t) - \rho, \forall t$. Aggregating over h, global consumption C evolves as follows:

$$\widehat{C} = r(t) - \rho, \quad \forall t. \tag{14}$$

Market clearing. Labor market equilibrium requires R&D employment to equal labor endowment in N, which is embedded in (6). It also requires manufacturing employment to equal labor endowment in S :

$$L_{Sy} + L_{Fy} + L_x = L_S. \tag{15}$$

Product market equilibrium requires demand for x as input to equal its output, which is embedded in (10b). It also requires demand for Y as consumption and investment goods to equal its output:

$$\dot{K}_x + \dot{K}_{Sy} + \dot{K}_{Fy} + C = Y. \tag{16}$$

Finally, the cost of developing a new intermediate in N is $\frac{w_N L_N}{\dot{n}}$, where w_N is the wage rate in N. This cost is eventually borne by the intermediate firm which owns the blueprint (either directly or through purchase) by issuing shares. In a free-entry equilibrium with ongoing innovation $\left(\dot{n} > 0\right)$, the market value of an intermediate firm, v, must equal the product development cost:

$$v = \frac{w_N L_N}{\dot{n}}. \tag{17}$$

3 Balanced-growth equilibria

In the remainder of the paper we study balanced growth equilibria of the global economy where N specializes in innovating intermediates which are produced in S through FDI, and S specializes in manufacturing.

Definition 1 *A balanced growth equilibrium (BGE) is characterized by:*
(i) fixed sectoral labor allocation in S (constant L_{Sy}, L_{Fy} and L_x);
(ii) fixed share of consumption in final output (constant $\gamma_C \equiv \frac{C}{Y}$);
(iii) fixed share of Y produced by local S-firms (constant $\gamma_{Sy} \equiv \frac{Y_S}{Y}$);
(iv) $\widehat{n}, \widehat{k}_x, \widehat{K}_{jy}, \widehat{x}, \widehat{Y}, \widehat{C}, \widehat{p}, \widehat{q}, \widehat{w}_j$ all being constant (not necessarily equal).

3.1 Growth rate

In a BGE, final output, consumption, capital stocks in manufacturing, and wages all grow at the common rate (see appendix)

$$\widehat{Y} = \widehat{C} = \widehat{K}_x = \widehat{K}_{Sy} = \widehat{K}_{Fy} = \widehat{w}_N = \widehat{w}_S = \frac{\theta_2 \sigma (\alpha) \widehat{n}}{1 - \theta_1 - \theta_2 \theta_3}, \tag{18}$$

which we will henceforth refer to as the growth rate and denote as $\widehat{Y}$.[11] Clearly, growth is driven by innovation-induced TFP growth ($\theta_2 \sigma \widehat{n} > 0$). If either $\widehat{n} \to 0$ (no innovation) or $\theta_2 \sigma \to 0$ (innovation has no effect on TFP), growth rate would approach zero. Higher growth rate stems from faster rate of innovation (larger $\widehat{n}$) or more growth-conducive manufacturing technology. Such technology features greater returns to specialization or greater dependence on capital or innovated intermediates as inputs (larger σ, θ_1, θ_3 or θ_2).

According to (18), capital in manufacturing is not necessary for sustained growth ($\widehat{Y} > 0$ even if $\theta_1 = \theta_3 = 0$),[12] but it magnifies the growth effect of R&D in two ways. First, increased dependence on capital in manufacturing stimulates investment and, through the multiplier $\frac{1}{1-\theta_1-\theta_2\theta_3} > 1$, magnifies the growth effect of any positive rate of TFP growth. Without capital the multiplier would equal 1 and the growth effect of any TFP growth would be smaller. Second, as a special type of investment, FDI in intermediates sector carries a learning effect which may enhance $\widehat{n}$ and $\widehat{Y}$ through the multiplier $\psi(\delta)$ in (7). Hence, we note the following:

Remark 1 *When existing R&D growth models (choose to) ignore capital in general and FDI in particular, they may under-estimate the role of R&D in growth.*

From (7) and (18) we also note the following:

Remark 2 *Policies that enhance the relative learning effect of FDI, δ, will increase $\widehat{n}$ and $\widehat{Y}$ regardless of any scale effects, although positive (negative) scale effects will amplify (mitigate) the increases in $\widehat{n}$ and $\widehat{Y}$.*

[11] Output of each intermediate good grows in a BGE at the rate $\widehat{x} = \theta_3 \widehat{Y} - \widehat{n}$ (see appendix), so $\widehat{x} > 0 \Leftrightarrow \sigma > \frac{1-\theta_1-\theta_2\theta_3}{\theta_2\theta_3}$, i.e. output of each intermediate grows in a BGE iff the returns to specialization are large enough. Similarly, $\widehat{Y} > \widehat{n}$ iff $\sigma > \frac{1-\theta_1-\theta_2\theta_3}{\theta_2}$.

[12] Employing capital in R&D would render it necessary for sustained growth, as shown by Aghion and Howitt (1998).

Examples of policies and other factors that enhance δ include improved infrastructure and investment climate, better market access, and government promotion of FDI in general. The above result supplements recent work which emphasizes that policies can affect long-run growth rate even when scale effects are eliminated.[13]

3.2 Investment share

The global investment share in a BGE is (see appendix)

$$\iota \equiv \frac{\dot{K}}{Y} = \left[\frac{\theta_1 + \alpha\theta_2\theta_3}{\rho + \widehat{Y}}\right]\widehat{Y}, \tag{19}$$

where $K = K_x + K_{Sy} + K_{Fy}$ and the term in square brackets is the equilibrium capital-output ratio, $\frac{K}{Y}$. Hence, investment is also induced by innovation-based TFP growth. Without this we would obtain $\widehat{Y} = 0$ and $\iota = 0$. Global investment share rises with innovation rate ($\widehat{n}$) and the cost shares of capital (θ_1 and θ_3) and of intermediates (θ_2).[14] However, contrary to what existing R&D models suggest, ι need not rise monotonically with $\widehat{Y}$. To see this, we first define the elasticity $\eta \equiv \frac{\alpha}{\sigma(\alpha)}\sigma'(\alpha)$ and state the following lemma which is derived in the appendix.

Lemma 1 $\frac{\partial\iota}{\partial\alpha} > 0$ *iff* $\widehat{n} > \widehat{n}^* \equiv -\frac{\rho(1-\theta_1-\theta_2\theta_3)[\alpha\theta_2\theta_3(1+\eta)+\theta_1\eta]}{\sigma\theta_2^2\theta_3\alpha}$.

That is, investment share decreases with differentiation of intermediates (i.e. increases with α) if and only if innovation is fast enough. Notice that the critical value $\widehat{n}^*$ depends on η. Define $\eta^* \equiv -\frac{\alpha\theta_2\theta_3}{\alpha\theta_2\theta_3+\theta_1}$ and note $\eta^* \in (-1, 0)$. If $\eta \geq \eta^* \Leftrightarrow \widehat{n}^* \leq 0$, condition $\widehat{n} > \widehat{n}^*$ is satisfied with any positive $\widehat{n}$ and $\frac{\partial\iota}{\partial\alpha} > 0$ always obtains. Only if $\eta < \eta^*$ do we need the condition $\widehat{n} > \widehat{n}^* > 0$ to ensure $\frac{\partial\iota}{\partial\alpha} > 0$.

To understand Lemma 1, we note from (19) that α may affect ι both directly and indirectly via $\widehat{Y}$:

$$\frac{\partial\iota}{\partial\alpha} = \underbrace{\theta_2\theta_3\frac{\widehat{Y}}{\rho + \widehat{Y}}}_{\text{monopoly effect}} + \underbrace{(\theta_1 + \alpha\theta_2\theta_3)\frac{\partial}{\partial\alpha}\left(\frac{\widehat{Y}}{\rho + \widehat{Y}}\right)}_{\text{growth effect}}. \tag{20}$$

[13] See Jones (1999) for a discussion.

[14] Intuitively, larger $\widehat{n}$ accelerates (capital) growth rate $\widehat{Y}$, pushes up the rental price of capital (equal to interest rate), $\left(\rho + \widehat{Y}\right)$, and reduces the equilibrium capital-output ratio. With discounting, $\left(\rho + \widehat{Y}\right)$ increases proportionately more slowly than $\widehat{Y}$. Hence, ι rises with $\widehat{n}$. Larger θ_1, θ_3 or θ_2 implies greater share of spending on capital (see (5a) and (12a)) and faster growth of capital stock (see (18)). Both effects raise ι in the long-run.

Dircetly, α affects the monopoly power of intermediate producers, the share of spending on intermediates and the share of spending on capital thereof. We call this the *monopoly effect*, captured by the first term in (20). It is positive, so ι rises with α (i.e. decreases with product differentiation), given $\widehat{Y}$. However, α may also affect $\widehat{Y}$ and thereby ι if $\sigma'(\alpha) \neq 0$, cfr. (18). We call this the *growth effect*, captured by the second term in (20). If $\eta \geq \eta^*$, $\widehat{Y}$ decreases with α by not much (if at all), since $\eta^* \in (-1, 0)$. So the growth effect is not strongly negative (if at all) and the monopoly effect dominates. If $\eta < \eta^* < 0$, the growth effect is negative but diminishes in magnitude with $\widehat{n}$,[15] while the monopoly effect increases in magnitude with $\widehat{n}$. At sufficiently high innovation rate ($\widehat{n} > \widehat{n}^* > 0$), the positive monopoly effect will therefore dominate so that ι always rises with α.

The following result follows from Lemma 1 and (18).

Proposition 1 *If* $\widehat{n} > \widehat{n}^*$ *and* $\sigma'(\alpha) < 0$, *then* $\frac{\partial \widehat{Y}}{\partial \alpha} < 0$ *and* $\frac{\partial \iota}{\partial \alpha} > 0$.

Hence, if innovation rate is sufficiently high (it suffices with $\widehat{n} > 0$ if $\eta \geq \eta^*$) and product differentiation is good for TFP growth, then growth rate will rise with product differentiation (decrease with α) and investment share will decrease with it. The key to this result is the monopoly effect which arises when intermediates production also uses capital ($\theta_3 > 0$).[16] At sufficiently fast innovation rate, the TFP effect of product differentiation becomes negligible for capital growth. Therefore it stimulates growth without reversing the monopoly effect that suppresses investment share.

When $\sigma'(\alpha) \geq 0$, note from (19) that ι increases with α and σ.

3.3 R&D share

Since all N workers engage in R&D, with free entry the share of their wage in global income (wage share) equals the share of global income spent on R&D. In a BGE we find (see appendix)

$$R \equiv \frac{w_N L_N}{Y} = \left[\frac{\theta_2 (1-\alpha)}{\rho + \widehat{n}}\right] \widehat{n}, \tag{21}$$

where the term in square brackets is the global innovation-output ratio, $\left(\frac{vn}{Y}\right)$. Hence, global R&D share R rises with innovation rate ($\widehat{n}$) and the cost share of intermediates

[15] The growth effect diminishes in magnitude with $\widehat{n}$ because $\widehat{Y}$ increases with both $\widehat{n}$ and $\sigma(\alpha)$ [cfr. (18)], but it increases ι at a diminishing rate due to discounting [cfr. (19)].

[16] In Grossman and Helpman (1991b, ch.5) $\theta_3 = 0$ so the monopoly effect vanishes.

in final output (θ_2), and decreases with α.[17] Further, R&D spending is driven by the profitability of innovation. If either $\widehat{n} \to 0$ (no innovation) or $\theta_2 (1-\alpha) \to 0$ (no profits),[18] there would be no R&D spending.

3.4 N-S wage gap

Recall $\gamma_{Sy} \equiv \frac{Y_S}{Y}$ is S-firms' share of final-goods output, so $\left(1-\gamma_{Sy}\right) \equiv \frac{Y_F}{Y}$ is FDI firms' share. From (5b) and (12b) we find the following wage shares for S workers in local and FDI firms:

$$\frac{w_S L_{Sy}}{Y} = (1-\theta_1-\theta_2)\gamma_{Sy}, \tag{22a}$$

$$\frac{w_F L_{Fy}}{Y} = (1-\theta_1-\theta_2)\left(1-\gamma_{Sy}\right), \tag{22b}$$

$$\frac{w_F L_x}{Y} = (1-\theta_3)\alpha\theta_2. \tag{22c}$$

Let $w_S^* \equiv \left(\frac{L_{Sy}}{L_S}\right) w_S + \left(\frac{L_{Fy}+L_x}{L_S}\right) w_F$ be the employment-weighted average wage in S, where L_{Sy} and $(L_{Fy}+L_x)$ are employment in local and FDI firms, respectively. Then adding up (22a), (22b) and (22c) on both sides yields the aggregate wage share of S workers:

$$\frac{w_S^* L_S}{Y} = (1-\theta_1-\theta_2) + (1-\theta_3)\alpha\theta_2. \tag{23}$$

Dividing (21) by (23) yields the wage gap between N and S:

$$\omega \equiv \frac{w_N}{w_S^*} = \frac{\theta_2(1-\alpha)}{(1-\theta_1-\theta_2)+(1-\theta_3)\alpha\theta_2}\left(\frac{\widehat{n}}{\rho+\widehat{n}}\right)\left(\frac{L_S}{L_N}\right). \tag{24}$$

Hence, N-S wage gap may arise from (i) different sizes: $L_S \neq L_N$; or (ii) different wage shares accruing to N and S workers: $\theta_2(1-\alpha)\widehat{n}/(\rho+\widehat{n}) \neq (1-\theta_1-\theta_2)+(1-\theta_3)\alpha\theta_2$. Ceteris paribus, the relative wage of a country decreases with its own size (*country-size effect*) and rises with the wage share accruing to its workers (*wage-share effect*).

[17] Intuitively, larger θ_2 implies increased share of spending on intermediate goods, and smaller α implies higher price mark-up on these goods. Both effects raise the share of world income accruing to intermediate-goods producers as profits. As such they raise the innovation-output ratio and the global R&D share. Through knowledge spillovers, larger $\widehat{n}$ reduces the future development cost of new products. This raises the rate of return on R&D, $(\rho+\widehat{n})$, and reduces the equilibrium innovation-output ratio. With discounting, $(\rho+\widehat{n})$ increases proportionately more slowly than innovation rate $\widehat{n}$. Hence, global R&D share rises with $\widehat{n}$.

[18] Innovation would generate no profits if either $\theta_2 = 0$ (innovated inputs were not used in manufacturing) or $(1-\alpha)=0$ (innovated inputs were perfect substitutes so their prices were equal to marginal costs).

Country size and wage gap. According to (23), the size of S does not affect its workers' wage share which only depends on technology parameters. However, due to scale effects, country size and wage share are linked for N : With positive scale effects, a larger L_N will increase $\widehat{n}$ (see (7)) and N-workers' wage share (see (21)). If this positive link between country size and wage share is strong enough, the relative wage of N may increase with its size. This is confirmed by the following result derived in the appendix. $\mu(L_N) = \frac{L_N}{f(L_N)} f'(L_N)$ is an elasticity function such that a positive and large value of μ indicates strong positive scale effects.

Proposition 2 $\frac{\partial \omega}{\partial L_N} \gtreqless 0$ *if and only if* $\mu(L_N) \gtreqless 1 + \frac{\widehat{n}}{\rho}$.

Hence, the relative wage of N increases (decreases) with its size if and only if there are (not) strong enough positive scale effects in innovation. Proposition 2 reconciles some seemingly contradictory results in the literature. The relative wage of N increases with its size as in Grossman and Helpman (1991a) if and only if scale effects are strongly positive $\left(\mu > 1 + \frac{\widehat{n}}{\rho}\right)$, so the wage-share effect of L_N dominates its country-size effect.[19] In the opposite case $\left(\mu < 1 + \frac{\widehat{n}}{\rho}\right)$ an inverse relationship à la Krugman (1979) obtains.[20] In the knife-edge case where $\mu = 1 + \frac{\widehat{n}}{\rho}$, relative wage in N is independent of its size.

Migration, FDI and wage gap. One source of increase in the size of N is immigration from S. To illustrate the effects of migration on wage gap most simply, we consider some exogenously determined migration taking place so that $m \in [0, L_S)$ workers move from S to N.[21] The size of S becomes $(L_S - m)$ and that of N becomes $(L_N + m)$. Innovation rate becomes $\widehat{n}^m \equiv \psi(\delta) f(L_N + m)$. Replacing $\widehat{n}$, L_S and L_N in (24) with $\widehat{n}^m$, $(L_S - m)$ and $(L_N + m)$, respectively, the wage gap with migration becomes[22]

$$\omega^m = \frac{\theta_2 (1-\alpha)}{(1-\theta_1-\theta_2) + (1-\theta_3)\alpha\theta_2} \left(\frac{\widehat{n}^m}{\rho + \widehat{n}^m}\right) \left(\frac{L_S - m}{L_N + m}\right). \tag{25}$$

The following result is derived in the appendix and illustrates how (exogenous) migration affects ω^m.

[19] Grossman and Helpman (1991b:305) also note that their result reflects the presence of "dynamic scale economies" in R&D. However, they do not explicitly establish that the scale economies have to be *sufficiently strong* for their result to hold. This is hidden in their specification that innovation output is linear in labor input.

[20] Krugman's (1979) model features an exogenous rate of innovation and thus no scale effects at all.

[21] m is assumed to be limited to ensure that all manufacturing still takes place in S.

[22] Note that $\widehat{n}^m = \widehat{n}$ and $\omega^m = \omega$ if $m = 0$.

Proposition 3 $\frac{\partial \omega^m}{\partial m} \gtreqless 0$ *if and only if* $\mu(L_N + m) \gtreqless \left(1 + \frac{\widehat{n}^m}{\rho}\right)\left(\frac{L_S + L_N}{L_S - m}\right)$.

Hence, N-S wage gap increases (decreases) with S-N migration if and only if there are (not) strong enough positive scale effects in innovation in N.

Proposition 3 sheds light on the common view which attributes N-S wage gap to relative labor abundance in S. This view implies that S-N migration may eventually reduce N-S wage gap, because it reduces downward wage pressure in S and increases that in N. This static view ignores R&D and innovation as the engine of growth, thus ignoring the link between country size and wage share through $\widehat{n}^m$. It holds only if scale effects in R&D are not strongly positive. If scale effects are strongly positive, S-N migration may raise $\widehat{n}^m$ and generate a strong wage-share effect that dominates the country-size effect, eventually increasing N-S wage gap. We may then experience migration-driven higher growth rate accompanied by a wider wage gap. The opposite occurs if negative scale effects prevail. Then S-N migration will retard growth and reduce N-S wage gap. Finally, with positive but weak scale effects, S-N migration will also reduce N-S wage gap but increase growth rate.

The next result follows directly from (24), (25) and (7).

Proposition 4 $\frac{\partial \omega}{\partial \delta} > 0$ *and* $\frac{\partial \omega^m}{\partial \delta} > 0$.

Hence, policies that enhance the relative learning effect of FDI will increase N-S wage gap unambiguously, regardless of migration and despite that FDI firms may pay higher wages than local firms in S. The reason is that such policies enhance innovation rate through the multiplier $\psi(\delta)$, thus enhancing the wage share of R&D workers in N. This contrasts with the ambiguous effects of migration on growth and N-S wage gap.

3.5 Comparative statics

Table 1 summarizes comparative statics results regarding growth rate, investment share, R&D share and N-S wage gap, among others. The results are based on (7), (18), (19), (21), (23), (24), (25), Lemma 1 and Propositions 2 and 3.

Table 1. Comparative Statics Results

Variables $\longrightarrow$ / Parameters $\downarrow$	$\widehat{n}$	$\widehat{Y}$	ι	R	$\frac{w_S^* L_S}{Y}$	ω	ω^m
δ	$+$	$+$	$+$	$+$	0	$+$	$+$
L_N	$?^1$	$?^1$	$?^1$	$?^1$	0	$?^2$	$?$
L_S	0	0	0	0	0	$+$	$+$
m	0	0	0	0	0	0	$?^3$
θ_1	0	$+$	$+$	0	$-$	$+$	$+$
θ_3	0	$+$	$+$	0	$-$	$+$	$+$
θ_2	0	$+$	$+$	$+$	$-$	$+$	$+$
$\alpha\ [\sigma'(\alpha) < 0]$	0	$-$	$+$ if $\widehat{n}>\widehat{n}^*$ $-$if $\widehat{n}<\widehat{n}^*$ 0 if $\widehat{n}=\widehat{n}^*$	$-$	$+$	$-$	$-$
$\alpha\ [\sigma'(\alpha) > 0]$	0	$+$	$+$	$-$	$+$	$-$	$-$
$\alpha\ [\sigma'(\alpha) = 0]$	0	0	$+$	$-$	$+$	$-$	$-$
ρ	0	0	$-$	$-$	0	$-$	$-$

Note: Each entry presents the sign of the partial derivative of the corresponding first-row-variable w.r.t. the corresponding first-column-parameter.

[1]The sign is $\gtreqless 0$ if and only if $f'(L_N) \gtreqless 0$.

[2]The sign is $\gtreqless 0$ if and only if $\mu(L_N) \gtreqless 1 + \frac{\widehat{n}}{\rho}$.

[3]The sign is $\gtreqless 0$ if and only if $\mu(L_N + m) \gtreqless \left(1 + \frac{\widehat{n}^m}{\rho}\right)\left(\frac{L_S + L_N}{L_S - m}\right)$.

Some remarks follow from Table 1.

Remark 3 *Investment share need not rise monotonically with TFP growth rate, although investment is induced by TFP growth.*

Specifically, as opposed to existing R&D models, higher growth rate may be accompanied by lower or constant investment share (along with higher R&D share). As we noted earlier, this occurs because product differentiation – a possible source of TFP growth – may affect investment share both directly via the monopoly effect and indirectly via the growth effect. The monopoly effect is ignored by existing R&D models because they (choose to) ignore capital in intermediates production. Hence they ignore an interesting case where investment share may not increase with TFP growth.

Remark 4 *Increased share of R&D spending need not be accompanied by higher growth rate, and vice versa, although R&D is the engine of growth.*

Specifically, increased share of R&D spending may be accompanied by lower or constant growth rate (and lower investment share) if product differentiation has, respectively, adverse or no impact on TFP growth $[\sigma'(\alpha) \geq 0]$.[23] Conversely, higher growth rate may be accompanied by lower or constant R&D share (along with higher investment share). Lower R&D share may occur if $\sigma'(\alpha) > 0$. If increased dependence on capital in manufacturing (larger θ_1 or θ_3) stimulates investment and magnifies the growth effect of any given TFP growth, R&D share may stay constant. This leads us to:

Remark 5 *By (implicitly) assuming product differentiation always increases TFP growth* $[\sigma'(\alpha) < 0]$, *existing R&D growth models may exaggerate the role of R&D in growth.*

Remarks 3 and 4 highlight the importance of incorporating capital in all manufacturing sectors, and of treating the effect of product differentiation on TFP generally. Summarizing over these remarks, we record:

Proposition 5 *Higher growth rate is accompanied by increased share of spending on either investment or R&D, but not necessarily both. It is accompanied by both if it stems from larger* $\widehat{n}$, θ_2 *or (assuming* $\sigma'(\alpha) < 0$ *and* $\widehat{n} < \widehat{n}^*$*) smaller* α, *all of which imply faster TFP growth.*

From Table 1 we also see that higher growth rate based on larger δ, θ_1, θ_3 or θ_2 is accompanied by greater N-S wage gap. This is because larger θ_1, θ_3 or θ_2 implies increased share of spending on capital and thus lower wage share for manufacturing labor in S. Further, larger δ or θ_2 implies increased share of R&D spending and thus higher wage share for R&D labor in N. This leads us to:

Remark 6 *Stronger learning effect of FDI and more dependence on capital and intermediates in manufacturing generate positive links between growth rate and N-S wage gap by raising the wage share of N-workers and/or reducing that of S-workers.*

[23] Due to the specilization pattern of the model, ρ also affects investment and R&D shares without affecting growth rate.

On the other hand, higher growth rate based on changes in L_N or m may also be accompanied by greater N-S wage gap. As explained earlier, this happens if scale effects are strongly positive, so that larger L_N or m generates a strong wage-share effect that dominates their respective country-size effect. It also happens if scale effects are negative, in which case smaller L_N or m generates a weak wage-share effect that is dominated by their respective country-size effect. This leads us to:

Remark 7 *Changes in the size of N (e.g. due to (changes in) migration from S) may generate positive links between growth rate and N-S wage gap, if scale effects are either negative or strongly positive.*

In summary, we record:

Proposition 6 *If scale effects are non-positive* $[f'(L_N) \leq 0]$ *and returns to specialization do not decrease with product differentiation* $[\sigma'(\alpha) \leq 0]$, *higher growth rate is always accompanied by greater* N-S *wage gap.*[24]

Proposition 6 identifies (empirically relevant) conditions under which higher growth rate is accompanied by greater N-S wage gap. As we have seen, the result derives from at least one of two effects related to wage shares. First, most factors increasing the growth rate tilt wage shares in disfavor of manufacturing workers in S (cfr. Remark 6). Second, scale effects link wage share to country size in a way that favors R&D workers in N (cfr. Remark 7). Our analysis sheds light on static views which focus on the country-size effect alone and ignore wage-share effects.

Finally, from Table 1 we also record:

Remark 8 *Smaller discount rate implies (i) higher investment share; (ii) higher R&D share; and (iii) greater* N-S *wage gap.*[25]

Intuitively, smaller ρ means lower rental price for capital, $\left(\rho + \widehat{Y}\right)$. This increases the equilibrium capital-output ratio and hence ι. Less discounting also raises the present value of innovations, thus raising the wage share of R&D workers in N (i.e. the R&D share R) and N-S wage gap.[26]

[24] Faster growth is accompanied by smaller N-S wage gap if: (i) it is based on larger L_N or m and scale effects are positive but weak; or (ii) it is based on larger α and returns to specialization decrease with product differentiation $[\sigma'(\alpha) > 0]$.

[25] Due to the assumed specialization pattern, ρ does not affect long-run growth rate.

[26] When $\rho \to 0$ (and $\widehat{n} > 0$ is finite), (19), (21) and (24) yield $\lim_{\rho\to 0} \iota = (\theta_1 + \alpha\theta_2\theta_3)$, $\lim_{\rho\to 0} R =$

3.6 Employment and income distribution in S

Making use of (22a), (22b) and (22c), and noting $w_F = \beta w_S$, (15) can be re-written as

$$\Psi\left(\frac{Y}{w_S}\right) = L_S, \tag{26}$$

$$\text{where } \Psi \equiv \left[(1-\theta_1-\theta_2)\left(\gamma_{Sy} + \frac{1-\gamma_{Sy}}{\beta}\right) + \frac{(1-\theta_3)\,\alpha\theta_2}{\beta}\right].$$

Solving (26) w.r.t. $\left(\frac{w_S}{Y}\right)$, plugging the result in (22a), (22b) and (22c) and noting again $w_F = \beta w_S$, we find the following employment structure in S:

$$L_{Sy} = (1-\theta_1-\theta_2)\,\gamma_{Sy} L_S/\Psi, \tag{27a}$$

$$L_{Fy} = (1-\theta_1-\theta_2)\left(\frac{1-\gamma_{Sy}}{\beta}\right) L_S/\Psi, \tag{27b}$$

$$L_x = (1-\theta_3)\left(\frac{\alpha\theta_2}{\beta}\right) L_S/\Psi, \tag{27c}$$

where γ_{Sy} is S-firms' share of the final-goods market.

According to the pricing rule (3), firms with the lowest unit cost p_{jy} will capture the entire final-goods market. Now define $\beta^* \equiv \left(\frac{B_F}{B_S}\right)^{\frac{1}{1-\theta_1-\theta_2}}$ as the labor productivity advantage of FDI firms over S-firms, and notice that $\beta^* \geq 1$ since $B_F \geq B_S$ by assumption. It is then easy to verify that $\beta > \beta^* \Leftrightarrow p_{Fy} > p_{Sy} \Leftrightarrow \gamma_{Sy} = 1$ and $\beta < \beta^* \Leftrightarrow p_{Fy} < p_{Sy} \Leftrightarrow \gamma_{Sy} = 0$. Intuitively, if FDI firms pay an excessive wage premium that exceeds their labor productivity advantage ($\beta > \beta^*$), their unit cost exceeds that of local firms and the latter will capture the entire final-goods market. The opposite occurs if FDI firms pay an insufficient wage premium ($\beta < \beta^*$). If FDI firms pay a neutral wage premium ($\beta = \beta^*$), they will have the same unit cost as S-firms and both types of firms will share the market, but the sharing is indeterminate a priori.[27]

$[\theta_2(1-\alpha)]$, and $\lim_{\rho\to 0}\omega = \frac{\theta_2(1-\alpha)}{(1-\theta_1-\theta_2)+(1-\theta_3)\alpha\theta_2}\left(\frac{L_S}{L_N}\right)$, respectively. Hence, investment share would approach the cost share of capital in world output, R&D share would approach the share of world income accruing to intermediate-goods firms as profits, and the wage gap would depend only on technology parameters and relative country size. None of them would depend on $\widehat{n}$ or $\widehat{Y}$, and all would be higher as compared to the case with $\rho > 0$. The same limit values for ι, R and ω obtain when $\widehat{n} \to \infty$ (and $\rho > 0$). It follows that faster innovation (increase in $\widehat{n}$) and growing consumer patience (reduction in ρ) have qualitatively the same effects on ι, R and ω.

[27] We show in the appendix that, to ensure all manufacturing still takes place in S when $\beta = \beta^*$, we must have $0 \leq \gamma_{Sy} \leq \min\{1, \overline{\gamma}_{Sy}\}$, where the second inequality is strict whenever $\overline{\gamma}_{Sy} < 1$. The parameter $\overline{\gamma}_{Sy} > 0$ is defined in the appendix. We also show that $\overline{\gamma}_{Sy} < 1$ if S is relatively small, in which case the above condition restricts S-firms' market share to be strictly less than 1.

In the last case we have a continuum of balanced growth equilibria with different γ_{Sy}-values which, according to (22) and (27), imply different income distribution patterns and employment structures in S. Consider the non-trivial case where FDI firms pay a positive but neutral wage premium ($\beta = \beta^* > 1$).[28] Because local firms pay lower wages, they will be more labor-intensive. An increase in local firms' market share, γ_{Sy}, will therefore raise their employment (see (27a)) as well as aggregate labor demand in S. The latter forges up $\frac{w_S}{Y}$, and reduces employment in FDI firms (see (27b) and (27c)). The end result is higher income share for workers in local firms at the expense of workers in FDI firms producing Y (see (22a) and (22b)). The income share of workers in FDI firms producing $\mathbf{x}$ remains unaffected (see (22c)). With Cobb-Douglas technologies, employment adjustments offset any effects of γ_{Sy} on wages, so N-S wage gap remains unaffected (see (24)). We summarize the results formally in:

Proposition 7 *Let* $\beta = \beta^* > 1$. *Then:*
(i) $\frac{\partial L_{Sy}}{\partial \gamma_{Sy}} > 0, \frac{\partial L_{Ny}}{\partial \gamma_{Sy}} < 0, \frac{\partial L_x}{\partial \gamma_{Sy}} < 0;$
(ii) $\frac{\partial}{\partial \gamma_{Sy}} \left(\frac{w_S L_{Sy}}{Y} \right) > 0, \frac{\partial}{\partial \gamma_{Sy}} \left(\frac{w_F L_{Fy}}{Y} \right) < 0; \frac{\partial}{\partial \gamma_{Sy}} \left(\frac{w_F L_x}{Y} \right) = 0;$
(iii) $\frac{\partial \omega}{\partial \gamma_{Sy}} = 0.$

The magnitude of FDI firms' wage premium, β, also affects employment structure and income distribution in S. Starting from $\beta \geq \beta^*$ and $\gamma_{Sy} > 0$, higher wage premium will raise $\frac{w_F}{Y}$ and reduce employment in better-paying FDI firms (see (27b) and (27c)). This generates surplus labor which is absorbed by less well-paying local firms (see (27a)) through a decline in $\frac{w_S}{Y}$. The end result is increased polarization among S workers, with fewer employed at higher wage (relative to global income) in FDI firms, more employed at lower wage (relative to global income) in local firms, and wider wage gap between FDI and local firms. With Cobb-Douglas technologies in manufacturing, labor income in each type of firms comprises a fixed share of output which is not affected by β, cfr. (22a), (22b) and (22c). Any effects of β on wages are therefore exactly offset by concurrent adjustments in employment structure, so that N-S wage gap remains unaffected (see (24)). We summarize the results formally in:

Proposition 8 *Let* $\beta \geq \beta^*$. *Then:*
(i) $\frac{\partial L_{Sy}}{\partial \beta} > 0, \frac{\partial L_{Ny}}{\partial \beta} < 0, \frac{\partial L_x}{\partial \beta} < 0;$

[28] The case $\beta = \beta^* = 1$ is trivial because then FDI and local firms are identical: They pay equal wages and are equally productive.

(ii) $\frac{\partial}{\partial\beta}\left(\frac{w_S L_{Sy}}{Y}\right) = \frac{\partial}{\partial\beta}\left(\frac{w_F L_{Fy}}{Y}\right) = \frac{\partial}{\partial\beta}\left(\frac{w_F L_x}{Y}\right) = 0$*; and*
(iii) $\frac{\partial\omega}{\partial\beta} = 0$.

A comparison of Propositions 7 and 8 immediately follows. While increases in β and γ_{Sy} both shift employment from FDI to local firms, they affect income distribution in S differently. Higher wage premium by FDI firms increases domestic wage gap and polarization in S without affecting income distribution among different worker groups. In contrast, enhancing the market share of local firms redistributes income in the final-goods sector in favor of those working in these firms. Domestic wage gap remains unaffected.[29]

4 Conclusion

This paper has re-examined the sources of long-run growth and wage gap in a N-S model with trade and FDI. The analysis is summarized in Figure 1. Long-run growth rate depends on the rate of innovation and manufacturing technology. The wage gap between N and S depends on their sizes as well as wage shares. Determinants of growth rate may affect investment and R&D shares in various ways. So increased share of R&D spending need not be accompanied by higher growth rate, and vice versa, although R&D is the engine of growth. Likewise, investment-output ratio need not rise monotonically with productivity growth, although investment is induced by productivity growth. Determinants of growth rate may also affect wage shares. As a result, higher growth rate is normally accompanied by greater N-S wage gap in the long run. Scale effects in R&D link wage share to country size through the rate of innovation, so the effect of country size on wage gap becomes ambiguous, depending on the direction and magnitude of scale effects in R&D. Both FDI and S-N migration may affect growth rate and N-S wage gap.

The paper suggests that existing R&D models may exaggerate or under-estimate the role of R&D in growth. Exaggeration may arise from implicitly assuming that product differntiation always raises TFP growth. Under-estimation may arise from choosing to

[29] As already noted, the result that neither β nor γ_{Sy} affects ω hinges on Cobb-Douglas technologies whereby (manufacturing) labor income comprises a fixed share of output. With alternative specifications of technology, β or γ_{Sy} may affect average wage in S and ω. Further, if we allow for unemployment in S initially, there is downward pressure on wages in S a priori. Then an increase in β is likely to enlarge the wage gap and an increase in γ_{Sy} reduce it.

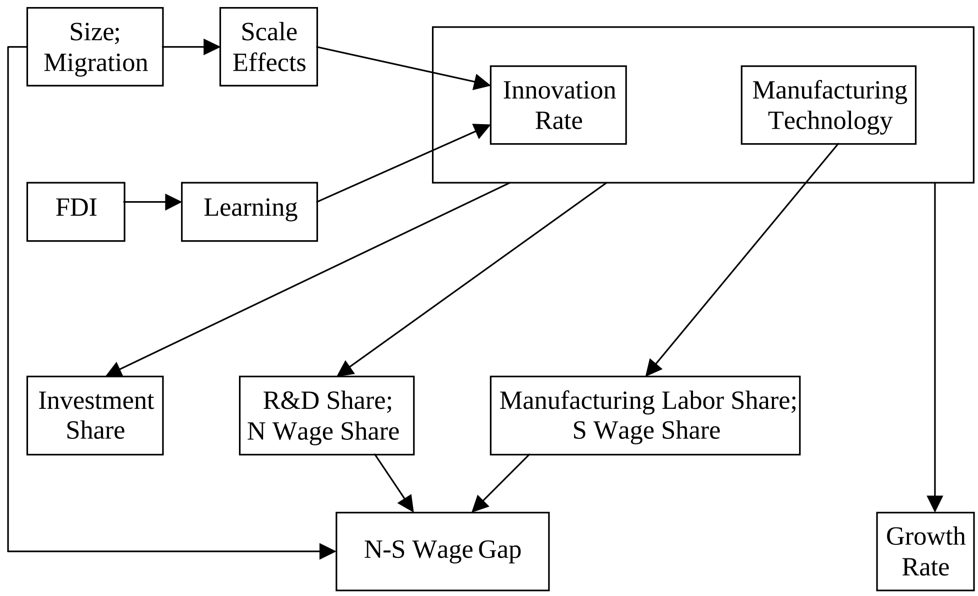

Figure 1:

ignore capital, thus ignoring that investment (including FDI) may enhance the growth effect of R&D. Only by coincidence will these two effects exactly cancel out.

Our analysis can shed light on recent debates on the causes of growing wage inequality in industrial countries. Suppose we re-interpret the model as depicting an integrated economy with two types of labor, skilled R&D labor and unskilled manufacturing labor, each with its own labor market (and with full revelation of skill types). Then the model predicts that higher growth rate in this integrated economy is driven by faster pace of innovation or/and technological biases against unskilled manufacturing labor. Moreover, higher growth rate is normally accompanied by greater wage gap between skilled and unskilled workers. This highlights the impacts of R&D-based growth dynamics and technological biases on wage inequality between skilled and unskilled workers, which supplements the existing literature.

The paper can be extended in several directions in future work. We have already mentioned the generalization to less extreme global specialization patterns, with some manufacturing in N and some R&D (or imitation) in S. Provided N continues to engage predominately in R&D and S predominately in manufacturing, the main results of the paper will continue to hold. Growth rate, however, will also depend negatively on the discount rate, as is commonly found in the literature. Another interesting, albeit admittedly difficult, extension is to include endogenous human capital accumulation and examine the effect of growth on inter-country wage gap in that framework. Dinopoulos and Segerstrom (1999) have already proposed a useful framework for examining *intra*-country wage gap in such a setting.

5 Appendix

Derivation of (18)

In a BGE, constant $\gamma_{jy} \equiv \frac{Y_j}{Y}$ and $\gamma_C \equiv \frac{C}{Y}$ imply, respectively,

$$\widehat{Y}_j = \widehat{Y}, \tag{28}$$

$$\widehat{C} = \widehat{Y}. \tag{29}$$

(14) and (29) imply

$$r = \rho + \widehat{Y}, \tag{30}$$

i.e. r is constant in a BGE (as both ρ and $\widehat{Y}$ are constant). (13b) then implies q is also constant, or

$$\widehat{q} = 0. \tag{31}$$

Noting (31) and (28), (5a) and (12a) imply, respectively,

$$\widehat{K}_{jy} = \widehat{Y}, \tag{32}$$

$$\widehat{K}_x = \widehat{Y}. \tag{33}$$

Noting L_{jy} is constant in a BGE and (28), (5b) implies

$$\widehat{w}_j = \widehat{Y}. \tag{34}$$

Noting (31) and (34), (9) and (10a) imply

$$\widehat{p} = (1 - \theta_3)\,\widehat{Y}. \tag{35}$$

Noting (35), (10b) yields

$$\widehat{x} = \widehat{Y} - \widehat{p} - \widehat{n} = \theta_3\widehat{Y} - \widehat{n}. \tag{36}$$

Since L_{jy} is constant and $x(i) = x$ by (10b), we find from (1) and (2) that

$$\widehat{Y}_j = \theta_1\widehat{K}_{jy} + \theta_2\,(\sigma + 1)\,\widehat{n} + \theta_2\widehat{x}. \tag{37}$$

Plugging (28), (32) and (36) in (37), we can solve for $\widehat{Y}$. Noting (29), (32), (33) and (34), we obtain (18) in the text. □

Derivation of (19)

In view of (18), investment share ι can be written as $\iota = \gamma_K \widehat{Y}$ where

$$\gamma_K \equiv \frac{K_x + K_{Sy} + K_{Fy}}{Y}$$

is the overall capital-output ratio. Making use of (12a) and (5a), and noting $Y_S + Y_F = Y$, we find

$$\gamma_K = \frac{\theta_1 + \alpha\theta_2\theta_3}{q}. \tag{38}$$

From (13b) and (30) we find

$$q = \rho + \widehat{Y}. \tag{39}$$

Plugging (39) in (38) and the result in $\iota = \gamma_K \widehat{Y}$, we obtain (19). □

Proof of Lemma 1

Plugging (18) for $\widehat{Y}$ in (19) and differentiating w.r.t. α, we find

$$\frac{\partial\iota}{\partial\alpha} = \theta_2\widehat{n}\frac{\rho\left(1-\theta_1-\theta_2\theta_3\right)\left[\theta_2\theta_3\left(\sigma+\alpha\sigma'\right)+\theta_1\sigma'\right]+\sigma^2\theta_2^2\theta_3\widehat{n}}{\left[\rho\left(1-\theta_1-\theta_2\theta_3\right)+\theta_2\sigma\widehat{n}\right]^2}.$$

Define $\eta \equiv \frac{\alpha}{\sigma(\alpha)}\sigma'\left(\alpha\right)$. Then it follows that $\frac{\partial\iota}{\partial\alpha} > 0$ iff

$$\widehat{n} > \widehat{n}^* \equiv -\frac{\rho\left(1-\theta_1-\theta_2\theta_3\right)\left[\alpha\theta_2\theta_3\left(1+\eta\right)+\theta_1\eta\right]}{\sigma\theta_2^2\theta_3\alpha}. \quad \square$$

Derivation of (21)

In view of (17), the income share of N workers can be written as

$$\frac{w_N L_N}{Y} = \left(\frac{vn}{Y}\right)\widehat{n}, \tag{40}$$

where $\left(\frac{vn}{Y}\right)$ is the innovation-output ratio for the global economy. From (10c) and (10b) we obtain $\frac{\pi}{v} = \frac{(1-\alpha)pxn}{vn} = \left(1-\alpha\right)\theta_2\left(\frac{Y}{vn}\right)$ which, upon substitution in (13a), yields

$$\left(1-\alpha\right)\theta_2\left(\frac{Y}{vn}\right) = r - \widehat{v}. \tag{41}$$

(40) implies $vn = \frac{w_N L_N}{\widehat{n}}$ which, given (34) and constant L_N and $\widehat{n}$ in a BGE, yields

$$\widehat{v} = \widehat{Y} - \widehat{n}. \tag{42}$$

Plugging (42) and (30) into (41) and solving for $\left(\frac{vn}{Y}\right)$, we find $\left(\frac{vn}{Y}\right) = \frac{\theta_2(1-\alpha)}{\rho+\widehat{n}}$ which plugged in (40) yields (21). □

Proof of Proposition 2

Plug (7) for $\widehat{n}$ in (24) and differentiate w.r.t. L_N. After some simplification we find

$$\frac{\partial \omega}{\partial L_N} = \frac{\Gamma L_S \widehat{n} \rho}{L_N^2 \left(\rho + \widehat{n}\right)^2} \left[\mu\left(L_N\right) - 1 - \frac{\widehat{n}}{\rho}\right],$$

where $\Gamma \equiv \frac{\theta_2(1-\alpha)}{(1-\theta_1-\theta_2)+(1-\theta_3)\alpha\theta_2} > 0$ and $\mu\left(L_N\right) = \frac{L_N}{f(L_N)} f'\left(L_N\right)$. Proposition 2 follows. □

Proof of Proposition 3

Differentiating (25) w.r.t. m and simplifying, we find

$$\frac{\partial \omega^m}{\partial m} = \frac{\Gamma\left(L_S - m\right)\widehat{n}^m \rho}{\left(L_N + m\right)^2 \left(\rho + \widehat{n}^m\right)^2} \left[\mu\left(L_N + m\right) - \left(1 + \frac{\widehat{n}^m}{\rho}\right)\left(\frac{L_S + L_N}{L_S - m}\right)\right],$$

where Γ and $\mu\left(.\right)$ are defined previously. Proposition 3 follows. □

Conditions ensuring all manufacturing is located in *S*

We need to ensure the following: (i) S firms never produce any Y in N; (ii) N firms never produce any Y in N; and (iii) N firms produce all $x\left(i\right)$ in S.

Let S-firms producing in N be indexed by $j = f$, and let local firms in N be indexed by $j = N$. Condition (i) is satisfied if $p_{fy} > p_{Ny}$ which, in view of (4), is satisfied if we assume

$$B_f < B_N \text{ and } w_f = \beta w_N \geq w_N, \tag{43}$$

i.e. S-firms producing in N are less productive than local firms but do not pay lower wages as FDI firms. Condition (ii) is satisfied if $p_{Ny} > p_{Fy}$ which, in view of (4), is satisfied if and only if

$$\frac{w_N}{w_F} > \left(\frac{B_N}{B_F}\right)^{\frac{1}{1-\theta_1-\theta_2}}, \tag{44}$$

where we assume $B_N \geq B_F$, i.e. N-firms do not become more productive when they produce with FDI in S. Finally, condition (iii) requires that the unit cost of producing $x(i)$ in N exceed that in S: $\frac{q^{\theta_3} w_N^{1-\theta_3}}{B_N} > c$, where c is given in (9). This holds if and only if

$$\frac{w_N}{w_F} > \left(\frac{B_N}{B_F}\right)^{\frac{1}{1-\theta_3}}. \tag{45}$$

Both (44) and (45) require that the wage gap for N-firms between home and FDI production, $\frac{w_N}{w_F}$, exceed the corresponding labor productivity gap. Without loss of generality, we assume $\theta_1 + \theta_2 > \theta_3$ so it suffices to consider (44). From (21) and (26) we find $w_N = \frac{RY}{L_N}$ and $w_S = \frac{\Psi Y}{L_S}$, respectively. Hence,

$$\frac{w_N}{w_F} = \frac{w_N}{\beta w_S} = \frac{R}{\beta \Psi}\left(\frac{L_S}{L_N}\right). \tag{46}$$

As noted in the text, $\gamma_{Sy} = 1$ when $\beta > \beta^*$, $\gamma_{Sy} = 0$ when $\beta < \beta^*$, and γ_{Sy} is indeterminate when $\beta = \beta^*$. Combining these with (46), we can now translate (44) into the following set of parameter restrictions:

Assumption 1 *Let* $\Phi \equiv \theta_2 (1-\alpha)\left(\frac{\widehat{n}}{\rho+\widehat{n}}\right)\left(\frac{L_S}{L_N}\right)$. Then:
(i) If $\beta < \beta^* : \frac{B_N}{B_F} < \left[\frac{\Phi}{(1-\theta_1-\theta_2)+\alpha\theta_2(1-\theta_3)}\right]^{1-\theta_1-\theta_2}$;
(ii) If $\beta > \beta^* : \beta < \overline{\beta} \equiv \frac{\Phi}{1-\theta_1-\theta_2}\left(\frac{B_F}{B_N}\right)^{\frac{1}{1-\theta_1-\theta_2}} - \frac{\alpha\theta_2(1-\theta_3)}{1-\theta_1-\theta_2} > 1$;
(iii) If $\beta = \beta^* : \gamma_{Sy} < \overline{\gamma}_{Sy} \equiv \frac{\overline{\beta}-1}{\beta^*-1}$.

Hence, with insufficient wage premium, (i) requires the labor productivity gap between home and FDI production not be too large. Otherwise it may not pay for N firms to produce in S. With excessive wage premium, (ii) sets an upper bound $\overline{\beta}$ on the wage premium. If FDI firms pay too high a wage premium, it may not be profitable to produce in S. With neutral wage premium, (iii) sets an upper bound $\overline{\gamma}_{Sy}$ on local firms' share of the final output.

Notice that $\overline{\gamma}_{Sy}$ is defined if $\beta^* > 1$ (FDI firms more productive than local firms) and not defined if $\beta^* = 1$ (FDI and local firms equally productive). Notice also that $\overline{\beta}$ is assumed to exceed 1 so that $\overline{\gamma}_{Sy} > 0$. It is now straightforward to verify that $\overline{\beta} < \beta^*$ and $\overline{\gamma}_{Sy} < 1$ iff

$$\frac{L_S}{L_N} < \Omega \equiv \frac{(1-\theta_1-\theta_2)}{(1-\alpha)\theta_2}\left(\frac{\rho+\widehat{n}}{\widehat{n}}\right)\left[\left(\frac{B_N}{B_S}\right)^{\frac{1}{1-\theta_1-\theta_2}} + \frac{\alpha\theta_2}{1-\theta_1-\theta_2}\left(\frac{B_N}{B_F}\right)^{\frac{1}{1-\theta_1-\theta_2}}\right].$$

Hence, if S is relatively small $\left(\frac{L_S}{L_N} < \Omega\right)$, Assumption 1(iii) requires $\gamma_{Sy} < \overline{\gamma}_{Sy} < 1$ when $\beta = \beta^*$. Further, any wage premium $\beta > \beta^*$ would violate Assumption 1(ii) because $\beta^* > \overline{\beta}$. It then follows that $\gamma_{Sy} \in [0, \overline{\gamma}_{Sy})$ in this case, i.e. local firms' market share must be less than $\overline{\gamma}_{Sy} < 1$.[30] Intuitively, local firms pay lower wages and are more labor-intensive than FDI firms. A larger γ_{Sy} therefore increases aggregate labor demand and wages in all firms. When S is relatively small, local wages are relatively high initially. Then S-firms' market share must be small enough $\left(\gamma_{Sy} < \overline{\gamma}_{Sy} < 1\right)$ to ensure that more labor-intensive local firms do not push up aggregate labor demand and wages in S by so much as to render FDI unprofitable.

(43) and Assumption 1 constitute *sufficient* conditions for all manufacturing to take place in S. □

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[30] Note that $\Omega > 1$ if $(1-\theta_1-\theta_2) > (1-\alpha)$. Hence, if the cost share of labor in final output is large enough, then $\gamma_{Sy} = 1$ requires $L_S > L_N$.

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