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Vertical Foreign Direct Investment, Knowledge
Spillovers and the Global Growth: A Q-theory Approach

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1. Introduction

Formal economic theories modeling the impact of foreign direct investment (FDI) from developed to developing countries (a North-South FDI framework or a vertical FDI) on long-run growth through knowledge spillovers have only appeared in the past decade. The purpose of this vertical FDI is to exploit the lower wage rate in the host country. This is obviously profitable for multinational corporations (MNCs) themselves. However, is it good for the long-run growth of the host, the home, and the global economy? Most North-South FDI studies focus on the effect of knowledge spillovers on host countries. Findings of these models are mixed due to different assumptions and different setups of the models. However, the later parts of the question are almost neglected, since many vertical FDI models take the assumption that the amount of FDI and knowledge in the host country are so small that FDI have no effect on the home or the global economy.

The amount of FDI has increased dramatically during the past decade as developing countries gradually reduced their investment barriers. Therefore, the effects of vertical FDI on home and global economy should no longer be neglected. This research combines Grossman-Helpman (1991a), Baldwin-Braconier-Forslid (2001) and Lai (1998) into an endogenous vertical FDI and growth model to fill this gap. It contributes to the literature by studying the effects FDI-related knowledge spillovers on the rate of multinationalization, the investment level in R&D, and the global long-run (knowledge capital) growth rate.

Also, in contrast to empirical findings, almost all of the FDI and growth studies assume that knowledge is homogenously contributed to northern innovation regardless of

its sectors and geographic locations.¹ Do different kinds of spillover from FDI function differently in affecting growth? And what if the knowledge capital stocks in developing countries are not small enough to be neglected? This study formally models these questions by separately examining intra-industry spillovers, local learning-by-doing spillovers, and FDI spillovers through imitation, and by allowing the reverse spillovers from host to home countries.

The model developed here predicts that a lower imitation rate in the host country leads to a higher rate of multinationalization and a lower level of R&D investment in the home country. As a result, global knowledge capital grows more slowly in the long run. This is because a lower level of imitation rate provides MNCs a longer period of monopoly power and profits. Therefore, a larger share of firms in the North wants to be MNCs. As more varieties are transferred from

with the presence of FDI, the rate of innovation decreases in the long run and the world loses, because the terms of trade gain in the North cannot eliminate the negative welfare effect of both the terms of trade loss in the South and the reallocation of manufacturing that results in higher prices being paid for a larger fraction of products. Glass-Saggi (2002) shows that a low imitation rate makes both MNCs and northern firms safer, generates resource wasting, and reduces both FDI and innovation.

Other important results of this research are that a higher disadvantage cost, smaller wage gap between regions, and smaller elasticity of substitution between varieties reduce the expected profits of MNCs. In turn, this leads to a lower rate of multinationalization and a higher level of investment, and thus a higher long-run growth rate.

The rest of the paper is arranged as follows. Section 2 surveys relevant recent studies. Section 3 develops a simple static model that does not consider knowledge capital accumulation or spillovers. Section 4 adds endogenous knowledge capital growth. Knowledge capital accumulation is carried out only in the North. Learning experiences from previous knowledge and local production processes are separately studied. In this version, the model is solved by using Tobin's Q approach, and spillovers from MNCs to the South are ignored. Section 5 introduces uncertain southern imitation (from MNCs to the South).

2. Literature review

Economic research on knowledge transfer and spillovers confirms that one of the main channels for knowledge transfer is the activities of MNCs. MNCs are results from two types of FDI: FDI between developed countries similar in levels of wage rate and technology advancement (symmetric FDI) and FDI from developed countries to developing countries, where developed countries have higher level of technology and developing countries have lower wage rates (asymmetric FDI). The effects of asymmetric FDI on host countries are most frequently studied and the findings are different due to different setups and assumptions. Helpman (1993) shows that if the imitation rate is low enough with the presence of FDI, the South suffers from a deterioration of the terms of trade and from the reallocation of manufacturing that results in higher prices being paid for a larger fraction of products. Lai (1998) finds that a lower rate of imitation encourages the North to increase the rate of multinationalization, which raises the growth rate of the South.

In addition, many economists consider that the amount of FDI is small compared to the size of the home economy. Thus, they assume that FDI has little effect on the home country, and most asymmetric FDI studies focus only on host countries (Lai (1998) and Grossman-Helpman (1991a)). Helpman (1993) overcomes this gap and shows that a low imitation rate decreases the rate of innovation in the long run and the world loses from resource wasting when reallocating it into a larger share of higher pricing products. Glass and Saggi (2002) use a product cycle model to examine this question. They show that a low imitation rate makes both MNCs and northern firms safer, generates resource wasting, and reduces both FDI and innovation.

Finally, early models of MNCs do not include knowledge spillovers (Grossman and Helpman (1991a) and Helpman (1993)), so that MNCs play no direct role in their models in determining the endogenous growth rate. Later models of MNCs fill this gap, but few distinguish different types of knowledge spillover. Lai (1998) is an example. For simplicity his model assumes that, regardless of location and type, knowledge has the same spillover effect. This is different from the empirical findings of Jaffe, Trajtenberg and Henderson (1993), Sjöholm (1996), and Keller (2001), find that the scale of the spillover effects from knowledge transfer is geographically limited and the scope of technology diffusion is severely limited by distance

A central issue for further analysis is how different channels of spillovers operate. Baldwin-Braconier-Forslid (2001) distinguishes the effect on innovation of intra-industry spillovers and local learning-by-doing effects. They apply Tobin's Q approach to solve the model. Their study is for symmetric FDI only, where long-run growth is driven by ceaseless knowledge innovation and knowledge spillovers directly affect the endogenous growth rate via innovation and resource reallocation. FDI is undertaken to reduce transportation costs. The main result is that the share of MNCs among all firms² is positively correlated with the long-run growth rate. The intuition is that for symmetric countries, FDI generates production in both regions. This provides more local learning-by-doing effects as the share of MNCs increases. Their empirical test on seven manufacturing industries in nine OECD-countries for the period 1979 to 1991 confirms that both the intra-industry effect and FDI spillovers are positively correlated with the growth rate of labor productivity.

² The share is defined as the ratio of number of MNCs to the number of all firms in each country. This ratio is not solvable so that it is assumed to be a parameter.

3. The Static Model

This section develops a static North-South model of MNCs. In this model, the incentives for FDI, instead of saving transportation costs as in a model of symmetric countries, is to exploit the lower wage in the South. Therefore, instead of producing in both regions, MNCs transfer all production to the South. Appendix 1 provides a full description of the derivations for the static model.

3.1 Consumers

Two final goods are produced: Y is the homogenous (e.g. agricultural) good and X is the manufacturing good with horizontally differentiated varieties.

Consumers have preferences over both goods and their utility function is:

$$U = \ln (C_X^\phi C_Y^{1-\phi}), \quad (1)$$

where $C_X \equiv \left\{ \int_0^{n+m+s} [c_i]^{1-1/\varepsilon} di \right\}^{\frac{1}{1-1/\varepsilon}}$ is consumption of good X. It is a composite of all

differentiated varieties of goods, where the elasticity of substitution between varieties is ε

with $\varepsilon > 1$. C_X is (is consu7)7.8(ptioneen vay i., th)uthboth

of X. The price that optimizing firms charge consumers is $p = w/\alpha$, where w is the marginal cost and $0 < \alpha = 1 - 1/\varepsilon < 1$.

3.3 FDI

The share of knowledge capital owned by MNCs is $S^M = K^M / (K^N + K^M)$, and the share owned by northern firms is $S^N = K^N / (K^N + K^M) = 1 - S^M$.⁴ Also define $S^S = K^S / (K^N + K^M)$ as the knowledge available to the South compared to that available in the North. Superscripts indicate the owner of the knowledge.

For firms completing innovation in the North, the choice between being an MNC or a northern firm is based on the following equation with complementary slackness:

$$S^M (1 - S^M) \left[\frac{\pi^N}{F} - \frac{\pi^M}{F(1 + \Gamma)} \right] = 0 \quad (3)$$

$$\Rightarrow 0 \leq \Gamma \leq w^{\varepsilon-1} - 1. \quad (5)$$

This shows that FDI exists only when the northern wage (wage gap between two regions) or the elasticity of substitution between varieties are large enough. If

¹ 1

where $C_X \equiv \left\{ \int_0^{n+m+s} [c_i]^{1-1/\varepsilon} di \right\}^{\frac{1}{1-1/\varepsilon}}$ and $\varepsilon > 1$. The parameter $\rho > 0$ measures the rate of time preference. Utility maximization generates the same demand function as in section 3.1 and an Euler equation $\dot{E}/E = r - \rho$, where r is the rate of return to savings.

4.2 Knowledge Capital

The innovation sector in the North performs all R&D. Each unit of new knowledge capital is produced with a_I units of northern labor, where a_I measures the efficiency of innovation in the R&D sector. It is:

$$a_I = \frac{1}{(K^N + K^M) + \lambda K^S + \mu n}, \quad (7)$$

where $1 \geq \lambda \geq 0$ and $\mu \geq 0$.

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$$K = K^N + K^M + K^S \cdot S$$

which reduces the innovation cost of new knowledge capital. Furthermore, the higher is λ the bigger effect southern knowledge has on northern innovation.

For simplicity, capital in the South is assumed fixed at its endowed level. There is no imitation, learning, nor innovation of knowledge capital held by MNCs.⁹ Therefore, as the knowledge capital held by the North increases overtime, S_0^S approaches zero. That is, the global capital growth rate approaches the growth rate of knowledge capital held by the North. Finally, the growth rate of knowledge capital held by the South is zero.

4.3 FDI

For firms completing innovation in the North, their choice between becoming an MNC or northern firm is based on the following equation:

$$S^M (1 - S^M) \left[\frac{\Pi^N}{F} - \frac{\Pi^M}{F(1 + \Gamma)} \right] = 0, \quad (10)$$

where $\Pi^i \equiv \int_{s=0}^{\infty} e^{-rs} \pi_s^i ds$ is the expected lifetime profits of firm i ($i = N, M$) and π^i is the

instantaneous operating profits. These profits, derived in Appendix 1.2, are

$$\pi^M = \pi^S = \frac{(1 - \alpha)\phi \cdot E}{w^{1-\varepsilon} n + m + s} = \frac{(1 - \alpha)\phi \cdot E}{(K^N + K^M)[w^{1-\varepsilon}(1 - S^M) + S^M + S^S]}$$

$$\pi^N = \frac{(1 - \alpha) \cdot w^{1-\varepsilon} \cdot \phi \cdot E}{w^{1-\varepsilon} n + m + s} = \frac{(1 - \alpha) \cdot w^{1-\varepsilon} \cdot \phi \cdot E}{(K^N + K^M)[w^{1-\varepsilon}(1 - S^M) + S^M + S^S]}$$

In these profit functions, everything is time invariant except for the global expenditure (E) and $(K^N + K^M)$. However, calculation of equilibrium innovation in equation (9) shows

⁹ The next section adds imitation into the model, where southern firms learn from knowledge held by MNCs. Further extension, where the South perform innovation but with a lower efficiency level instead of imitating, is completely a different research and would be done in a separate paper.

that $(K^N + K^M)$ changes at the rate of $g^N = L_I A$. In order to know what π^i is and how it changes overtime, expenditure (E) with knowledge capital accumulation is solved in Appendix 2.3 as

$$E = \frac{L^S + wL^N - wL_I}{1 - \phi(1 - \alpha)}. \quad (11)$$

The amount of labor invested in producing new knowledge capital is L_I . It is the state variable, which implies that $\dot{L}_I = 0$ in steady state. Since labor endowments are fixed, equation (11) and the Euler equation imply that $\dot{E} = 0$ and $r = \rho$ in equilibrium. That is, the global nominal expenditure is time invariant. From the profit functions, profits decrease at the rate

and the cost of the capital”¹⁰. Tobin’s Q implies $q \equiv V/F = 1$. In other words, in equilibrium, the ratio of the value of a firm (V) to its fixed cost (F) should equal one

The model implies that $q^N \equiv V^N/F = q^M \equiv V^M/(1+\Gamma)F = 1$ in equilibrium. The

value of the firm at time t is $V_t \equiv \int_{s=t}^{\infty} e^{-r(s-t)} \pi_s^i ds = \pi/(\rho + g^N)$ ($i = N, M$). Using MNCs to

illustrate the calculation, Appendix 2.4 provides this solution for the amount of labor engaged in innovation in equilibrium:

$$L_t^* = \frac{(L^S + wL^N)(1-\alpha)\phi A - w[1-\phi(1-\alpha)]\rho[S^M + (1+\Gamma)S_0^S + (1+\Gamma)w^{1-\varepsilon}S^N]}{w[1-\phi(1-\alpha)]A[S^M + (1+\Gamma)S_0^S + (1+\Gamma)w^{1-\varepsilon}S^N] + w\phi A(1-\alpha)} \quad (12)$$

From this amount and equation (9), the equilibrium capital growth rate is

$$g^{N*} = \frac{(L^S + wL^N)(1-\alpha)\phi[1 + \mu(1 - S^M)] - w[1 - \phi(1 - \alpha)]\rho}{w} \quad (13)$$

If some amount of northern labor is hired in the innovation sector, a positive amount of new knowledge capital is generated along the grow

How does a change in the share of capital held by multinationals affect the capital growth rate? Consider that

$$\frac{\partial g^*}{\partial S^M} = \frac{(L^S + wL^N)(1 - \alpha)(-\phi\mu)}{w} \leq 0 \quad (14)$$

That is, a higher rate of multinationalization implies a lower long-run capital growth rate.

This occurs because MNCs bring varieties to the South for production. This reduces the number of varieties produced in the North and reduces the possibilities of learning-by-doing in the North. Therefore, knowledge he

Simple calculations show that the efficiency of innovation, the new capital stock invented, and the capital growth rate in the North are the same as those described in the previous section. In addition, since the new knowledge only comes from northern innovation, and imitation by the South does not affect the knowledge capital pool, the growth rate for the whole world remains $g = \dot{K}/K = g^N/(1+S_0^S)$.

The imitation by southern firms ensures that the stock of knowledge capital in the South grows. This growth rate is

$$g^S = \frac{\dot{K}^S}{K^S} = \frac{\frac{j}{1+\Gamma} K^M}{K_0^S + \frac{j}{1+\Gamma} K^M} \quad (15)$$

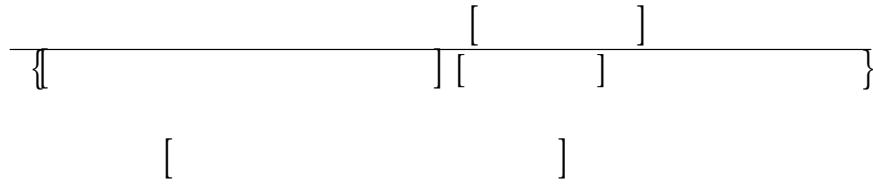
Appendix 3.1 shows that $g^S = g^N = g = L_I A$ in the steady state.

5.2 Production of X

As before, northern firms, those MNCs whose products have not been imitated by the South, and the original Southern firms engage in monopolistic competition for differentiated varieties. Prices are w/α for northern goods and $1/\alpha$ for varieties not yet imitated in the South. After a variety is copied, the multinational firm and southern firms producing the same variety are assumed to engage in limit pricing (Bertrand) competition. Therefore, the price index of X is:

$$P_X = \left[\left(\frac{1}{\alpha} \right)^{1-\varepsilon} s_0 + \left(\frac{1}{\alpha} \right)^{1-\varepsilon} (m - j \cdot m) + 1^{1-\varepsilon} \cdot j \cdot m + \left(\frac{w}{\alpha} \right)^{1-\varepsilon} n \right]^{\frac{1}{1-\varepsilon}} \quad (16)$$

Profit functions show that profits fall at the rate of g^N . Since g^N is time invariant in equilibrium, the expected profits are $\Pi^N = \pi^N / (\rho + g^N)$ and $\Pi^M = \pi^M / (\rho + j + g^N)$.



MNCs. Thus, at the margin, firms in the North prefer to remain there instead of becoming a MNC. Fewer new varieties are taken to the South while more are kept in the North. Through the learning-by-doing spillover, innovations are more prevalent because more varieties are kept in the North for production.

Figure 2 shows that a higher imitation rate raises the level of R&D investment in the North (to get more new varieties). The intuition is obvious: as the risk of losing monopolistic power increases for MNCs, more new varieties are needed to maintain the market share and profits, which requires a higher level of investment in R&D in the North. It is clear that only when the imitation rate is high enough, about 0.2 in this case, investment in R&D is positive and is positively correlated with the imitation rate.

Figure 3 shows that a higher imitation rate leads to a lower long-run knowledge capital growth rate. Both of the features in Figures 1 and 2 imply that the North gets more new varieties and that MNCs enjoy more monopolistic profits before their old varieties are copied. More importantly, as described in equation (9), both the raises in R&D investment and the decrease in the rate of multinationalization increase the long-run

affected by the rate of multinationalization — a higher rate of multinationalization (due to a lower imitation rate) reduces both the level and efficiency of R&D investment, which decreases the long-run knowledge capital growth rate.

Third, there is no disadvantage cost for setting up a multinational firm in Lai (1998) as this model does. Thus, higher rates of multinationalization do not result in more lost in knowledge capital on the way from the North to the South in his model as it does here.

However, this result of the negative relationship between the rate of multinationalization and long-run growth rate is consistent with Helpman (1993) and Glass and Saggi (2002). Helpman (1993) uses the welfare analysis and shows that, if the imitation rate is low enough with the presence of FDI, the rate of innovation decreases in the long run and the world loses, because the terms of trade gain in the North cannot eliminate the negative welfare effect of both the terms of trade loss in the South and the reallocation of manufacturing that results in higher prices being paid for a larger fraction of products. Glass-Saggi (2002) uses a product cycle model to show that a low imitation rate makes both MNCs and northern firms safer, generates resource wasting, and disincentives both FDI and innovation.

Result 1 is summarized from Figures 1 to 4 and all above descriptions.

Result 1: A lower imitation rate leads to a higher rate of multinationalization and a lower level of investment in innovation. As a result, knowledge capital grows more slowly in the long run.

5.3.3 Disadvantage cost, MNCs share and long-run growth rate

Intuitively, if the disadvantage cost (Γ) were to rise, there would be fewer MNCs and the original equilibrium would be broken. To reach a new equilibrium, similar to the previous case, the economy simultaneously must increase the investment level and reduce the rate of multinationalization to get more new varieties, for each corresponding imitation rate. These two responses permit MNCs to earn higher profits from the monopolistic phase to make up the expected reduction in profit from the higher

on the way to the South and the knowledge capital cannot grow at a positive rate. As Γ drops to 0.1, less capital would lose on the way to the South. Therefore, when the

ess4(se21 0 TD9472011 Tc0.1240.634 s y to the South)5.5(andknowledgelongess4(-runess4(.421 -2.3094720D0.0015 Tc0

Intuitively, for everything else the same except that the wage gap increases, the price index for sector X increases and consumption of all varieties decreases. At the same time, since the relative price of northern goods increases, the decrease in consumption of northern goods would be greater than that all other goods produced in the South. Therefore, the relative profit of MNCs increases and more X firms in the North would want to be MNCs. To reach a new steady state, the economy simultaneously must decrease the investment level and increase the rate of multinationalization to get less new varieties.

Figure 7 shows the change in the rate of multinationalization for corresponding

lower-priced ones, relative consumption of northern goods decreases. Therefore, relative expected profits for MNCs increases, so that the effect of an increase in ε on the rate of multinationalization and the long run growth rate would be the same as those in the case of an increasing wage gap. Thus, it makes sense that Figure 9 is similar to Figure 7 while Figure 10 is similar to Figure 8. The only difference is that when the elasticity of substitution is small enough, investment and growth rates become zero.

Result 3 is concluded as the following from the above explanations.

Result 3: Increases in the wage gap or elasticity of substitution between varieties increases the rate of multinationalization, decreases the investment level, and decreases the long-run growth rate.

5.4 Solving for long-run GDP growth rate

Nominal GDP depends on expenditures and investments. Since $\dot{E} = 0$ and $\dot{L}_I = 0$, nominal GDP would also be a constant in steady-state equilibrium. Therefore, the growth rate of *real GDP* is the important variable to analyze. Real GDP equals nominal GDP divided by the price index. Thus, the rate of change in real GDP equals the negative of the rate of change in the price index.

$$g_{GDP}^* = -\frac{\dot{P}}{P} = -\left[(1-\phi) \cdot \frac{\dot{P}_Y}{P_Y} + \phi \cdot \frac{\dot{P}_X}{P_X} \right] = -\phi \cdot \frac{\dot{P}_X}{P_X} \quad (21)$$

$$\text{While } \frac{\dot{P}_X}{P_X} = \frac{1}{1-\varepsilon} g^*{}^{15}$$

¹⁵ See Appendix3.5 for steps.

Therefore,

$$g_{GDP}^* = \frac{\phi}{\varepsilon - 1} g^* \quad (22)$$

Therefore, parameters have the same effect on the long-run economic growth rate as they do to the long-run knowledge capital growth rate: higher imitation rate, lower wage gap between regions, and lower elasticity of substitution between varieties simultaneously increase the rate of multinationalization and decrease the R&D investment level, which decrease the long-run economic growth rate. It is clear that lower rate of elasticity of substitution would increase the economic growth more than it does to the knowledge capital growth rate, since consuming more of the cheaper goods provide higher utility. Besides, higher consumption share in the X sector increases the economic growth rate.

5. Conclusions

This study combines the models of Grossman-Helpman (1991a), Lai (1998), and Baldwin-Braconier-Forslid (2001). It contributes to the literature by separately studying the effects of intra-industry spillovers, local learning-by-doing spillovers and FDI spillovers to the growth of the global economy. It also considers the effects of the wage gap, the fixed cost premium for MNCs, the elasticity of substitution, and the imitation rate on the rate of multinationalization, investment in R&D and the long-run capital growth rate. It provides further theoretical evidence of the relationship between the FDI and growth literature. It also explores a new way, Tobin's Q approach, to study the effects of vertical FDI on global growth through different knowledge spillovers in a with resource allocation constraints.

The model predicts that with or without spillovers from MNCs to the South, a higher share of knowledge capital held by MNCs unambiguously decreases the long-run capital growth rate. A lower imitation rate in the South leads to a higher rate of multinationalization and a lower investment level in the North, so that the long-run capital accumulation rate is lower, which is consistent with the findings in Helpman (1993) and Glass-Saggi (2002). In addition, a higher disadvantage cost, a smaller wage gap between the regions or a smaller elasticity of substitution between varieties leads to a lower rate of multinationalization, a higher investment level and a higher long-run growth rate. Finally, higher intra-industry spillovers increase the rate of multinationalization and decrease the investment level without affecting the long-run growth rate.

As Blomstrom and Kokko (1998) state, instead of pure imitation from MNCs, the South could protect its market share by investing in new technology by themselves as the North does. Therefore, one of the possible and interesting extensions of this paper is to consider the case where the South also has innovation ability.

Appendix1 The Static Model

1.1 Consumer's problem:

$$\text{Max: } U = \ln(C_X^\phi C_Y^{1-\phi}) \quad (1) \quad \text{Where } C_X \equiv \left\{ \int_0^{n+m+s} [c_i]^{1-1/\varepsilon} di \right\}^{1/(1-1/\varepsilon)} \quad (2)$$

$$\text{s.t. } P_X C_X + C_Y = E$$

$$U = \ln(C_X^\phi C_Y^{1-\phi}) + \lambda[E - (P_X C_X + C_Y)]$$

First order conditions are the following if only (1) is used:

$$1 \quad \frac{\partial U}{\partial C_X} = 0 \quad \Rightarrow \quad \frac{\phi C_X^{\phi-1} C_Y^{1-\phi}}{C_X^\phi C_Y^{1-\phi}} = -\lambda P_X$$

$$2 \quad \frac{\partial U}{\partial C_Y} = 0 \quad \Rightarrow \quad \frac{(1-\phi) C_X^\phi C_Y^{-\phi}}{C_X^\phi C_Y^{1-\phi}} = -\lambda$$

$$3 \quad \text{---} \quad P \quad C \quad) \quad 0$$

$$5 \frac{\partial U}{\partial c_b} = \Rightarrow \frac{C_X^\phi C_Y^{-\phi}}{C_X^\phi C_Y^{-\phi}} \cdot \frac{1}{\varepsilon} \cdot \left(\sum c_i^{-\varepsilon} d_i \right)^{-\frac{1}{\varepsilon}} \cdot \frac{1}{\varepsilon} = \frac{1}{\varepsilon} \cdot \frac{1}{\varepsilon} = \frac{1}{\varepsilon^2}$$

$$M \quad s \quad \frac{\quad - \quad)}{\binom{w}{-} \quad n + \binom{-}{-} \quad m + \binom{-}{-} \quad s} \cdot E = \frac{- \quad \cdot E}{w \quad n + m + s}$$

1.4 FDI or not?

$$\frac{\pi^M}{(1+\Gamma)F} \geq \frac{\pi^N}{F}$$

$$\frac{E}{w \ n \ m \ s} \quad \frac{w \ E}{w \ n \ m + s}$$

2 The production of northern homogeneous good Y: $1/w$ unit of labor \Leftrightarrow 1 unit

$$\text{of Y in the North} \Rightarrow C_Y^N \cdot \frac{1}{w} = L_Y^N$$

3 The production of northern varieties of X: 1 northern worker \Leftrightarrow 1 unit of X

$$\Rightarrow n \cdot c_i^N = n \cdot \frac{\left(\frac{w}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$

4 The production of multinational varieties of X: 1 southern worker \Leftrightarrow 1 unit of X

$$\Rightarrow m \cdot c_i^M = n \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$

5 The production of southern varieties of X: 1 southern worker \Leftrightarrow 1 unit of X

$$\Rightarrow s \cdot c_i^S = n \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$

Therefore,

$$\begin{aligned} L = C_Y^S + C_Y^N \cdot \frac{1}{w} &+ n \cdot \frac{\left(\frac{w}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s} + m \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s} \\ &+ s \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s} \end{aligned}$$

$$L = C_Y^S + C_Y^N \cdot \frac{1}{w} + n \cdot \frac{\alpha w^{-\varepsilon} \phi \cdot E}{w^{1-\varepsilon} n + m + s} + m \cdot \frac{\alpha \phi \cdot E}{w^{1-\varepsilon} n + m + s} + s \cdot \frac{\alpha \phi \cdot E}{w^{1-\varepsilon} n + m + s}$$

$$L^S = C_Y^S + m \cdot \frac{\alpha \phi \cdot E}{w^{-\varepsilon} n + m + s} + s \cdot \frac{\alpha \phi \cdot E}{w^{-\varepsilon} n + m + s}$$

Appendix2 The Benchmark Model

2.1 Growth rate of knowledge capital held by the North.

$$N \frac{N}{N} \frac{M}{M} \frac{I \left[\begin{array}{ccc} N & M & S \\ N & M & \end{array} \right]}{N \quad M}$$

From $F = wa_l$ and $a_l = \frac{L_l}{g^N} \cdot \frac{1}{K^N + K^M} = \frac{L_l}{L_l A (K^N + K^M)} = \frac{1}{A(K^N + K^M)}$,

denominator = $\frac{(1 + \Gamma)w}{A(K^N + K^M)}$

From (14), Numerator = $\frac{(1 - \alpha)\phi \cdot E}{(w^{1-\varepsilon}n + m + s)(\rho + g^N)}$

Plug in $g^N = L_l A$ and E, $\frac{wL}{L A}$

Appendix3 Math calculation and derivation for the imitation model

3.1 Growth rate of southern knowledge capital.

$$g^S = \frac{\dot{K}^S}{K^S} = \frac{\frac{j}{1+\Gamma} \dot{K}^M}{K_0^S + \frac{j}{1+\Gamma} K^M}$$

Divide both numerator and denominator by $(K^N + K^M)$.

$$g^S = \frac{\frac{j}{1+\Gamma} \cdot \frac{\dot{K}^M}{K^N + K^M}}{S_0^S + \frac{j}{1+\Gamma} \cdot \frac{K^M}{K^N + K^M}}$$

Since S_0^S is the initial savings rate, it becomes $\frac{j}{1+\Gamma} \cdot \frac{K^M}{K^N + K^M}$.

$$E = \frac{(L^S + wL^N - wL_I) \cdot \left(w^{1-\varepsilon} S^N + \frac{S^M}{1+\Gamma} - j \cdot \frac{S^M}{1+\Gamma} + S_0^S + \alpha^{1-\varepsilon} j \cdot \frac{S^M}{1+\Gamma} \right)}{(w^{1-\varepsilon} S^N + \frac{S^M}{1+\Gamma} - j \cdot \frac{S^M}{1+\Gamma} + S_0^S) \cdot [1 - (1-\alpha)\phi] + \alpha^{1-\varepsilon} j \cdot \frac{S^M}{1+\Gamma}} \quad (39)$$

3.3 Solve for equilibrium investment level in R&D with imitation:

$$q^M \equiv \frac{V^M}{(1+\Gamma)F} = \frac{\frac{\pi_0^M}{(1+\Gamma)F}}{(1+\Gamma)F} = 1$$

Same as before,

$$\text{Denominator} = \frac{(1+\Gamma)w}{A(K^N + K^M)} \quad (45)$$

From (38), numerator of (44) is

$$\text{Numerator} = \frac{(1-\alpha)\phi \cdot E}{(w^{1-\varepsilon} n + m - jm + \alpha^{1-\varepsilon} \cdot jm + s_0) \cdot (\rho + j + g)}$$

Plug in $g = L_I A$ and E,

$$\text{Numerator} = \frac{(1-\alpha)\phi \cdot \frac{(L^S + wL^N - wL_I) \cdot (w^{1-\varepsilon} n + m - jm + s_0 + \alpha^{1-\varepsilon} jm)}{(w^{1-\varepsilon} n + m - jm + s_0) \cdot [1 - (1-\alpha)\phi] + \alpha^{1-\varepsilon} jm}}{(\rho + L_I A + j)(w^{1-\varepsilon} n + m - jm + s_0 + \alpha^{1-\varepsilon} jm)}$$

$$\text{Numerator} = \frac{(L^S + wL^N - wL_I)(1-\alpha)\phi}{(\rho + L_I A + j) \{ (w^{1-\varepsilon} n + m - jm + s_0) \cdot [1 - (1-\alpha)\phi] + \alpha^{1-\varepsilon} jm \}} \quad (46)$$

Substitute (45) and (46) back into (44) and divide both numerator and denominator by

$(K^N + K^M)$,

$$(L^S + wL^N - wL_I)(1-\alpha)\phi A = (\rho + L_I A + j)w \left\{ [w^{1-\varepsilon} (1+\Gamma)S^N + S^M - jS^M + (1+\Gamma)S_0^S] \cdot [1 - (1-\alpha)\phi] + \alpha^{1-\varepsilon} jS^M \right\}$$

Therefore, equilibrium investment level (L_I) is:

$$L_I^* = \frac{(L^S + wL^N)(1-\alpha)\phi[1 + \mu(1-S^M)] - (\rho + j)w\{w^{1-\varepsilon}(1+\Gamma)(1-S^M) + S^M - jS^M\} \cdot [1 - (1-\alpha)\phi] + \alpha^{1-\varepsilon} jS^M}{w[1 + \mu(1-S^M)]\{w^{1-\varepsilon}(1+\Gamma)(1-S^M) + S^M - jS^M\} \cdot [1 - (1-\alpha)\phi] + \alpha^{1-\varepsilon} jS^M + (1-\alpha)\phi}$$

3.4 Solution of share of MNCs (from Mathematica)

$$^* = \varepsilon \cdot \left[(1+\Gamma) + (1-\varepsilon)(1-\varepsilon^{-1} + \Gamma) + (\varepsilon + \varepsilon^{-1})(1-\varepsilon)(1+\varepsilon^{-1} + \Gamma) \right] \cdot \\ [-\varepsilon^2 + \varepsilon(1+\Gamma - \varepsilon^{-1} + \varepsilon^{-1}) - (\varepsilon - \varepsilon^{-1} + \varepsilon^{-1} - \varepsilon) - \varepsilon^{1+\varepsilon}\phi(1-\varepsilon) \\ - \alpha^\varepsilon \Gamma \phi(1-\alpha) + (\varepsilon + \varepsilon^{-1}) \alpha^\varepsilon \mu \phi(1-\alpha)(1+\Gamma - \varepsilon^{-1})]^{-1}$$

Since the price for Y is one, which is the numeraire, the change in price index of it is zero.

Therefore, the price index for the whole economy is:

$$g_{GDP}^* = - \left[(1-\phi) \cdot \frac{\dot{P}_Y}{P_Y} + \phi \cdot \frac{\dot{P}_X}{P_X} \right] = -\phi \cdot \frac{\dot{P}_X}{P_X} = \frac{\phi}{\varepsilon-1} g^* \quad (49)$$

Figure 3 The relationship between rate of imitation and long-run capital growth

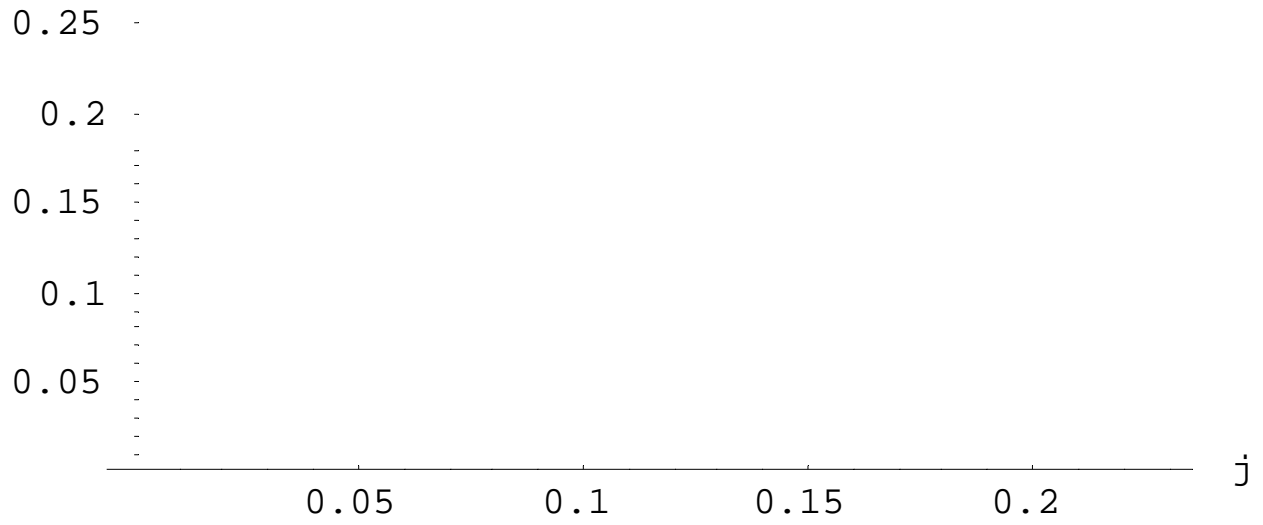


Figure 4 Relationship between the rate of multinationalization and growth

Figure 5 Effects of change in disadvantage

Figure 7 Effects of change in wage gap on rate of multinationalization

Figure 8 Effects of change in wage gap on long-run capital growth rate



Figure 9 Effects of change in ϵ on rate of multinationalization

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