International Vertical Integration and Economic Growth

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Korea's trade patterns with U. S. in industrial products are remarkably different from those with Japan. Korea has been running deficits visa vie Japan every year since mid 1960s, whereas she has been running surpluses visa vie U. S. during the same period. These trade patterns can be a manifestation of an international vertical integration between Korea and Japan, with U. S. acting as a third country. Thus since 1960s Korea has been buying capital goods developed and produced in Japan to manufacture final goods. This arrangement allowed Korea to achieve economic growth as rapid as that of Japan, as she was able to tap into the advanced technology developed in Japan. Korea's faster growth then can be partly explained by the catch up effect. Here U. S. offered huge markets in which Korea was able to sell the final goods produced with Japanese technology. This paper explains these observed trade patterns with an endogenous growth model where an international vertical integration promotes more rapid economic growth not only for the advanced country, but also for the developing country. (*JEL* classifications: O11, O14)

I. Introduction

An important feature of Korean economic development since the early 1960s is the concurrent and rapid growth in the overall economy and foreign trade. This has led many economists to propose various trade-led growth explanations of Korean development experiences. See for example, Hong (1994), Lee (1992), and Nam (1995). However, existing explanations do not clearly show through

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what mechanism the growth in foreign trade could have induced the growth of the overall economy. This paper is an attempt to provide one such mechanism.

Before we explain our mechanism, we want to point out a particular aspect of trade patterns in manufacturing observed in Korea since 1960. Throughout the period Korea's two most important trading partners in manufacturing have been U. S. and Japan. However, Korea's trading patterns with each country have been quite different. Korea has experienced large and persistent trade deficits visa vie Japan. With U. S., on the other hand, Korea's trade balances in industrial products have consistently shown surpluses during the period. Thus, in terms of the direction of trade, we find that Korea has been importing a large amount of capital goods, parts, and intermediate goods from and exporting a comparatively small amount of final goods to Japan. On the other hand Korea has been exporting a large amount of final goods to and importing a comparatively small amount of capital goods, parts, and intermediate goods from U. S.

These observed trade patterns suggest themselves a few questions. Why do we observe such trade patterns? What roles have they played in the transformation process of the Korean economy? Are they linked in any way to the mechanism that has made the rapid growth of the Korean economy possible? This paper is an attempt to answer these questions. For this we extend Riviera-Batiz & Romer (1991), in which costless knowledge spill-over among trading partners makes the international stock of knowledge bigger and hence countries grow faster. Our model instead assumes costly knowledge transfer. In fact we assume that trade in knowledge is impossible. Instead countries can trade capital goods that embody knowledge. Nevertheless, trades among countries with different stock of knowledge could result in an increase in growth rates of all countries. This happens when trades induce advanced and less developed countries to enter into de facto international vertical integration arrangement. When trades are newly allowed, the altered profit prospects may induce advanced countries to shift resources from the final goods sector to the R&D sector, and less developed countries from the R&D sector to the final goods sector. When these occur, the realignment in the division of labor would speed up the knowledge production processes, thereby raising growth rates.

When knowledge producers enjoy monopoly right, less developed countries who completely rely on imported capital goods may find themselves at the mercy of advanced countries. This happens when an advanced country imposes restrictions on capital goods trades to exploit her monopoly position. Therefore, in practice, less developed countries have incentives not to completely forego their own technology development potential.

This paper has four sections. In Section II we develop the basic model of an endogenous growth for a closed economy. In section III we extend the results of Section II to a two-country setting. There we show that as vertical integration occurs between the advanced and developing countries, growth rates increase for the advanced as well as developing countries. There we will also consider situations in which less developed countries might want to develop their own technology. Section IV concludes the paper.

II. Long Run Growth in a Closed Economy

A. The Model

1) Consumption and Savings

Consider an economy populated with a large number of people who have identical lifetime utility functions of the following form:

$$u=\int_0^\infty e^{-\rho}\frac{C(t)^{(1-\sigma)}-1}{1-\sigma}dt, \tag{1}$$

where $C(t)$ = consumption at time t, ρ = a time discount rate, and σ = the elasticity of inter-temporal substitution. The consumer is endowed with initial asset $Z(0)$ and one unit of human capital H that he supplies to the market to earn labor income $w(t)$. He also earns interest income $r(t)Z(t)$. Thus his total income is $w+rZ$, which he uses for consumption and savings Z. The periodic budget constraint is given by,

$$\dot{Z} = w + rZ - C.$$

It is a standard result in growth theory that the optimum choice of consumption and savings satisfies the following condition along the balanced growth path:

$$r=\rho+\sigma g. \tag{2}$$

where g denotes the growth rate of per capita consumption.

2) Production of Final Goods

A large number of identical firms produce final goods using the following technology:

$$Y = H_Y^{1-\beta} \left[\int_0^A x(z)^\beta dz \right], \tag{3}$$

where H_Y and $x(z)$ represents respectively the amount of human capital and capital good of type z hired by final goods producers. Here $z \in [0, A]$, i.e., there is a continuum of capital goods of type z. β is a common productivity parameter for the capital goods. The index A also represents the stock of general knowledge in the economy. If $x(z) = x$, $\forall z$, (3) reduces to $Y = AH_Y^{(1-\beta)} x^\beta$ We assume no depreciation for capital goods.

Final goods producing firms behave competitively, taking output price P, wage rate w, and rental price of capital good $P_x(z)$ as given. Measuring all prices in units of Y, i.e., taking final goods price P as identically 1, we have the following profit function,

$$\pi_Y = H_Y^{1-\beta} \left[\int_0^A x(z)^\beta dz \right] - wH_Y - \int_0^A P_x(z) x(z) dz. \tag{4}$$

Solving for the first order conditions we get,

$$H_Y = \left(\frac{1-\beta}{w} \right)^{\frac{1}{\beta}} \left[\int_0^A x(z)^\beta dz \right]^{\frac{1}{\beta}} \tag{5}$$

$$x(z) = \left[\frac{\beta}{P_x(z)} \right]^{\frac{1}{1-\beta}} \cdot H_Y. \tag{6}$$

These are a pair of implicit demand functions for human capital and capital good. Combining (5) and (6) we obtain a demand function for $x(z)$ of the following form,

$$x(z) = \left[\frac{\beta}{P_x(z)} \right]^{\frac{1}{1-\beta}} \left(\frac{1-\beta}{w} \right)^{\frac{1}{\beta}} \left[\int_0^A x(z)^\beta dz \right]^{\frac{1}{\beta}}. \tag{7}$$

When the variety of available designs or stock of knowledge A is very large, a change in $P_x(z)$ has negligible influence on $\int_0^A x(z)^\beta dz$ and demand for $x(z)$ is defined as a simple decreasing function of $P_x(z)$.

3) Capital Goods Production

In order to produce capital good $x(z)$, a producer must purchase a blueprint from an R&D firm. A blueprint not only confers the capital good producer know-how, but it also entitles him with an exclusive right to use it. Because of this feature, a producer of $x(z)$ becomes a monopolist. Let $P_A(z)$ be the value of the blueprint to make $x(z)$.

We assume a simple production process for $x(z)$: A capital good producer purchases and repackages the final output into capital good $x(z)$ following the instructions given in the blueprint. He sells (rents) $x(z)$ at $P_x(z)$ and incurs in each period a rental cost $rP_A(z)$ for the blueprint and an implicit rental cost $rx(z)$ for the durable 'raw' material. Hence profit for the producer of $x(z)$ is given by,

$$\pi_x(z) = P_x(z)x(z) - rx(z) - rP_A(z). \tag{8}$$

A producer of $x(z)$, being a profit maximizing monopolist, optimally sets the capital goods price $P_x(z)$ taking the demand for $x(z)$ as given. The first order condition of doing so is given as,

$$P_x(z) = \frac{r\int_0^A x(z)^{\beta} dz}{\beta \int_0^A x(z)^{\beta} dz + (1-\beta)x(z)^{\beta}}, \quad \text{for all } z \in [0, A]. \tag{9}$$

Since all producers are symmetrically situated, it must be the case that $P_x(z) = P_x$ and $x(z) = x$, for all z. Thus from (9) we get,

$$P_x = \frac{rA}{\beta A + (1-\beta)}. \tag{10}$$

When the number of existing designs A is large, that is, when the stock of knowledge is large, as is assumed here, (10) becomes,

$$P_x = \frac{r}{\beta}. \tag{11}$$

Finally, the long run equilibrium condition of zero profit tells us that P_A must be equal to $(P_x - r)x/r$. From (11) this is equivalent to,

$$P_A = \frac{(1-\beta)}{\beta}x. \tag{12}$$

4) R&D Production

Blueprints are produced in the R&D sector. There a producer combines human capital and existing knowledge stock to produce new blueprints. The production technology is give by,

$$A - \delta H_A A, \tag{13}$$

where H_A and A represent respectively the amount of human capital hired in R&D sector and the knowledge stock. A blueprint producer has to pay the competitive wage rate w to hire human capital H_A, but he can use the existing knowledge stock A free of charge.

B. Equilibrium

We assume the market for human capital to be competitive. Consequently wage rates for H_Y and H_A must be identical. Human capital would be allocated between the final goods sector and the R&D sector so that their respective value marginal product should be equalized. Therefore, the condition

$$w = P_A \delta A = (1-\beta) H_Y^{-\beta} A x^{\beta} \tag{14}$$

must hold. Finally, equations (6), (11), (12), and (14) suggest the followings:

$$w = (1-\beta)\left(\frac{\beta^2}{r}\right)^{\frac{\beta}{1-\beta}} A$$

$$P_A = \left(\frac{1-\beta}{\delta}\right)\left(\frac{\beta^2}{r}\right)^{\frac{\beta}{1-\beta}}$$

$$x = \frac{\beta}{\delta}\left(\frac{\beta^2}{r}\right)^{\frac{\beta}{1-\beta}}$$

$$H_Y = \frac{r}{\beta\delta} \text{ and } H_A = \frac{\beta\delta - r}{\beta\delta}$$

Note that these are all functions of yet to be determined interest rate r.

Along the balanced growth path, per capita output and per capita consumption grow at the same rate as the speed of technological progress. That is, $A/A = Y/Y = C/C = g$. Since $g = \dot{A}/A = \delta H_A$ and $H_A = (\beta\delta - r)/\beta\delta$ from above, we have the following pair of relationships:

$$g = \frac{\beta\delta - r}{\beta} \text{ and } r = \rho + \sigma g.$$

Solving these two simultaneously, we get the following equilibrium growth and interest rates:

$$g = \frac{\beta\delta - \rho}{\beta + \sigma} \tag{15}$$

$$r = \frac{\beta(\rho + \sigma\delta)}{\beta + \sigma}. \tag{16}$$

Finally, substituting (15) and (16) into the relationships given above, we get

$$P_x = \frac{\rho + \sigma\delta}{\beta + \sigma} \tag{17}$$

$$P_A = \frac{(1-\beta)}{\delta}\left[\frac{\beta(\beta+\sigma)}{\rho + \sigma\delta}\right]^{\frac{\beta}{1-\beta}} \tag{18}$$

$$w = (1-\beta)\left[\frac{\beta(\beta+\sigma)}{\rho + \sigma\delta}\right]^{\frac{\beta}{1-\beta}} A \tag{19}$$

$$H_Y = \frac{\delta\sigma + \rho}{\delta(\beta + \sigma)} \tag{20}$$

$$H_A = \frac{\beta\delta - \rho}{\delta(\beta + \sigma)} \tag{21}$$

$$x = \frac{\beta}{\delta}\left[\frac{\beta(\beta+\sigma)}{\delta\sigma + \rho}\right]^{\frac{\beta}{1-\beta}} \tag{22}$$

$$Y = \left[\frac{\sigma\delta + \rho}{\beta(\beta+\sigma)}\right] Ax. \tag{23}$$

These are prices, allocations, and outputs for our model economy in dynamic equilibrium.

C. Implications of the Closed Economy Equilibrium

1) Preference, Productivity, and Economic Growth

The growth rate g given by (15) shows that g is increasing in δ and β, but decreasing in ρ and σ. The parameter δ represents productivity of the R&D production, hence an increase in δ raises g.

The parameter β represents the productivity of the capital goods in final goods production. Therefore, an increase in β induces final goods producers to put more $x(z)$ into the production process. This increase in demand for $x(z)$ raises capital goods price $P_x(z)$, which in turn raises profits of producing capital goods $x(z)$. When capital goods production becomes more profitable, the R&D producer (the producer of the blueprint) can charge a higher price $P_A(z)$ for the blueprint from capital goods producers. Hence production of the R&D goods becomes more profitable with an increase in β. The increase in profits induces an R&D producer to hire more human capital. When additional human capital is allocated to the R&D sector, the speed of technological progress rises. This is why the growth rate g rises with an increase in β.

An increase in ρ or σ means either the typical consumer becomes more time impatient or it becomes harder for him to substitute current consumption for future consumption. This induces the consumer to decrease savings, which in turn raises the interest rate. An increase in the interest rate reduces the profit of producing capital goods. This in turn lowers the price of the blueprint $P_A(z)$. As the value of a blueprint declines, an R&D producer would hire less human capital than before. When this happens, the speed of technological progress slows down, hence growth rate g declines.

Equation (16) shows that in our model the equilibrium interest rate is determined not only by the time discount rate ρ, but also by the parameters σ, β, and δ. Specifically, the real interest rate is positively related to all of these parameters.

2) Suboptimality of the Decentralized Solution

The stock of existing knowledge is a public good. When an R&D firm develops a blueprint, it also generates knowledge. This knowledge is added to the existing stock, which makes future R&D activities more productive. However, there is no way that an individual R&D firm can capture the social returns of doing so. Consequently less than optimal amount of human capital will be allocated to the R&D sector. The result is a growth rate lower than the optimal level.

The optimal growth rate is determined as the solution to the following planning problem:

$$\text{Max} \int_0^\infty e^{-\rho t} \frac{C^{1-\sigma}-1}{1-\sigma} dt$$

$$\text{s.t. } \dot{K} = H_Y^{1-\beta} K^{\beta} A^{1-\beta} - C$$

$$\dot{A} = \delta H_A A$$

$$H_Y + H_A = 1,$$

where the per capita human capital stock is normalized to be 1 and the capital stock K is defined as $K=Ax$. It is a simple exercise to derive the optimal growth rate for the above problem. It is given by,

$$\bar{g} = \frac{\delta - \rho}{\sigma},$$

which is clearly higher than the equilibrium growth rate g given in (15).

3) Industrial Policy

Appropriate policies can be designed to alleviate the suboptimality problem. In this context we can think of a subsidy to encourage the production of capital goods or a subsidy to encourage the R&D activity. We now investigate implications of each policy. In this exercise we assume that the subsidy is financed with a lump-sum tax on income.

(i) An investment subsidy

Let us first consider the effects of a subsidy given to capital goods producers that lowers the effective price of the 'raw' materials. Let η, which is smaller than 1, be the subsidy parameter. Specifically, assume that a capital goods producer now incurs an implicit rental cost of ηr, rather than r, to buy one unit of raw material. However, he has to pay P_A to maintain his monopoly position.

When effective cost of capital is ηr, it is optimal to set the price of capital goods at $P_x = \eta r/\beta$, which is clearly lower than it was before.[1] Since P_x declines, more of $x(z)$ would be employed in the production of Y and the marginal productivity of H_Y rises. This induces the final output producer to employ more human capital.

When an investment subsidy is given to a capital goods producer, he makes larger profits than before. However, the increase in profits is wholly transmitted to the developer of a blueprint via an increase in the price of the blueprint.[2] The increase in P_A raises the value marginal product of H_A, which is given by $P_A \delta A$. As a result R&D firms would demand for more human capital, too.

When $P_x = \eta r/\beta$, then $\pi_x = \eta r(1-\beta)x'/\beta$, where x' denotes the increased demand for x. The latter is given by $x' = (\beta^2/\eta r)^{1/(1-\beta)} H_Y'$. The price of the blueprint under the subsidy policy is given by $P_A = \eta(1-\beta)x'/\beta$. It can be shown that $\eta x'$ is larger than x, the optimal amount of x produced without the investment subsidy. Finally, the market clearing condition for human capital implies that the following must hold.

[1] In our model the interest rate r is not affected by this type of a subsidy policy.

[2] Each blueprint is unique, hence it commands the monopoly price.

$$P_A A \delta = (1-\beta)(H_Y')^{-\beta} A(x')^{\beta} \tag{24}$$

When we substitute the new values of P_A and x' given above into the equilibrium condition to solve for H_Y', we get $H_Y' = r/\beta\delta$ which is exactly the same as before. Even with an investment subsidy the allocation of human capital H between final goods production and R&D production activities does not change. Consequently, the equilibrium growth rate remains unchanged, too.

In conclusion, an investment subsidy does not affect growth rate. Neither does it affect the interest rate. We must point out at this point that this result is model specific and may not hold in general.

(ii) A technology subsidy

Consider now a subsidy given to the capital goods producers that lowers the effective price of a blueprint. Let the new price of a blueprint be P_A' and let $\xi P_A'$ be the price a capital goods producer pays when the subsidy is given. Here the policy parameter ξ is smaller than 1.

From the equilibrium condition of zero long run profits for the capital goods producers, we know that $P_A' \xi = (P_x - r)x/r$ must hold. Therefore, $P_A' = (P_x - r)\, x/r\xi$. This is the price of a blueprint that an R&D firm actually receives. Note that P_A' is higher than P_A, the price of a blueprint without the subsidy. This increase in the price of a blueprint raises the value marginal product of H_A. Consequently, R&D producing firms would hire more human capital than before. When more H is allocated to the R&D sector, the speed of technological progress, hence economic growth rate, goes up, too.

When we solve simultaneously the market clearing condition for H, $P_A' \delta A = (1-\beta)(H_Y)^{-\beta} Ax^{\beta}$, the new price of a blueprint $P_A' = (P_x - r)x/r\xi$, and the optimal combination rule of x and H_Y $x = (\beta^2/r)^{1/(1-\beta)} H_Y$, for H_Y, we get $H_Y = \xi r/\beta\delta$. Therefore, $H_A = (\beta\delta - \xi\rho)/\beta\delta$.

Finally, the equilibrium growth rate under the technology subsidy is given by,

$$\tilde{g} = \frac{\beta\delta - \xi\rho}{\beta + \sigma\xi},$$

which is larger than the equilibrium growth rate without a subsidy, g.

A technology subsidy does raise the growth rate by inducing R&D producers to employ larger amount of human capital. Furthermore, a judicious choice of ξ as a function of the underlying parameters could be made so that the resulting growth rate $\tilde{g}$ could be equalized to the optimal growth rate $\bar{g}$.

III. International Vertical Integration and Long Run Growth

A. The Two Country Model

Consider now a world economy consisting of two countries each of which is similar in every aspect to the one we have considered in Section II. Variables without an asterisk pertain to the first country. Each has its own knowledge stock A and A^*. Let us assume that there is no overlap between A and A^* so that the stock of world knowledge is $A + A^*$. At the time of opening up A^* is assumed to be larger than A: The (*) country is more advanced than the other.

We assume no international diffusion of knowledge. There exists a complete protection of the intellectual rights. Human capital can not be moved across countries, either. However, intermediate products and financial capital are freely traded. Unidirectional trades in the final output can occur, too.

Let an intermediate good produced and used in the less developed country be denoted as $d(z)$. Similarly let $m(z^*)$ denote intermediate goods of type z^* produced in the advanced country but used in the developing country. Let $d^*(z^*)$ and $m^*(z)$ be their counterparts. Then the production functions for Y and Y^* are given by,

$$Y=H_Y^{1-\beta}\left[\int_0^A d(z)^{\beta}\,dz+\int_0^{A^*} m(z^*)^{\beta}\,dz^*\right] \tag{25}$$

$$Y^*=H^{*\,1-\beta^*}_Y\left[\int_0^A m^*(z)^{\beta^*}\,dz+\int_0^{A^*} d^*(z^*)^{\beta^*}\,dz^*\right], \tag{26}$$

and the R&D technologies are given by, $\dot{A}=\delta H_A A$ and $\dot{A}^*=\delta^* H_A^* A^*$. The citizens of each country have preference structure identical to that we considered in Section II. That is, the typical citizen of each has a utility function of the following form,

$$u=\int_0^{\infty} e^{-\rho t}\frac{C^{1-\sigma}-1}{1-\sigma}\,dt$$

$$u^*=\int_0^{\infty} e^{-\rho t}\frac{C^{*\,1-\sigma}-1}{1-\sigma}\,dt.$$

Except for the fact that each country has different level of accumulated knowledge and different preference and technology parameters, they are essentially identical.

Because of the symmetry built into the model, in equilibrium we must have $d=d(z)$, $m=m(z^*)$, $d^*=d^*(z^*)$ and $m^*=m^*(z)$, for all z and z^*. They are given by,

$$d=\left[\frac{\beta}{P_x}\right]^{\frac{1}{1-\beta}} H_Y,\quad m=\left[\frac{\beta}{P^*_x}\right]^{\frac{1}{1-\beta}} H_Y,\quad d^*=\left[\frac{\beta^*}{P^*_x}\right]^{\frac{1}{1-\beta^*}} H^*_Y,$$

$$\text{and } m^*=\left[\frac{\beta^*}{P_x}\right]^{\frac{1}{1-\beta^*}} H^*_Y.$$

The equilibrium prices of capital goods are determined as before by, $P_x=r/\beta$ and $P^*_x=r/\beta^*$. Note here that interest rates should be identical in each country, since capital is freely mobile. If the productivity parameters β and β^* are also equal in magnitude, it must be the case that $P_x=P^*_x$, and consequently $d=m$ and $d^*=m^*$. If this is the case, then $P_A=P^*_A$ holds, too. In the following we assume this to be the case.

B. International Vertical Integration

1) Vertical Integration

In the above discussion, we implicitly assumed that even after opening up for international trade both countries continue to engage in all three activities: final output production, intermediate goods production, and R&D. However, if at the time of opening up the stock of knowledge is different across countries, one or both countries would completely specialize.[3] Recall that we are assuming $A^*>A$ at the time of opening up.

Since human capital is perfectly mobile within a country, it must earn the same wage rate regardless of where it is employed. Therefore, it must be the case that $VMPH_Y=VMPH_A$, where these denote value marginal products of human capital. Similarly $VMPH^*_Y=VMPH^*_A$ must hold, too. Since capital goods are freely mobile across countries, we must also have $VMPH_Y=VMPH^*_Y$. This then implies that $VMPH_A$ must be equal to $VMPH^*_A$.

However, $VMPH_Y=P_A A\delta$ and $VMPH^*_Y=P^*_A A^*\delta^*$. From above we

[3]Of course, we get complete specialization because the R&D sector has linear production technology.

know that $P^*_A = P_A$. Now $\delta^* > \delta$ is likely to hold true: R&D activity in the advanced country tend to be more productive.[4] In addition to these, we also have $A^* > A$. Therefore, $P^*_A A^*$ must be larger than $P_A A$. Even with $\delta = \delta^*$, $P^*_A A^*$ must still be larger than $P_A A$, because $A^* > A$. In order to focus on the effects of the assumption that $A^* > A$, we will assume $\delta = \delta^*$ in the remainder.

Evidently the equalities can not hold simultaneously. To restore the equalities, one or both country should completely specialize. In fact market forces would induce the advanced country to reallocate human capital away from the final output sector toward the R&D sector, whereas the same forces induce the less developed country to reallocate human capital from the R&D sector toward the final output sector. This reallocation would continue until specialization occurs in at least one country.

The pattern of resource reallocation indicates that the R&D sector becomes smaller and smaller, while the final goods sector becomes larger and larger in the developing country.[5] The reverse is true for the advanced country. Therefore, it is more likely to be the case that the resource reallocation would stop when $H_Y = 1$ and/or $H^*_A = 1$ hold. They do not have to hold simultaneously. Which country attains complete specialization first depends on the relative size of the country. One possibility is the developing country arriving at $H_Y = 1$ first.

In the remaining section we will consider the case where $H_A = 0$, but $H^*_A < 1$. The less developed country would cease to engage in further R&D activities and choose to buy new capital goods from the advanced country. The advanced country enhances her R&D activity by allocating more human capital to this sector. She sells more capital goods to the less developed country. In return for this the advanced country buys a larger amount of the final product from the less developed country. That is, a vertical integration between the advanced and less advanced countries occurs.

2) Determination of the Growth Rate

With $H_A = 0$ we must have $H_Y = 1$ and $\dot{A} = 0$. No more R&D activity

[4]When the advanced country is at the forefront of knowledge development, and when the developing country can easily absorb the vast stock of advanced technology through imitation, this situation can be easily reversed.

[5]Strictly speaking, we must state that all adjustment occurs instantaneously.

occurs and the knowledge stock remains at $\bar{A}$, the level reached at the time of opening up, in the less developed country. The long run growth rate is now determined by the speed of technological progress in the advanced country. The latter is determined as $A/A = \delta^* H^*_A$.

How is H^*_A determined? As was before, $VMPH^*_Y = VMPH^*_A$ must hold to clear the human capital market in the advanced country. $VMPH_Y$ is determined so that $VMPH_Y$ gets equalized to $VMPH^*_Y$ with $H_Y = 1$ and $0 < H^*_Y < 1$. When $H_Y = 1$ and $0 < H^*_Y < 1$, the following must hold:

$$VMPH_Y = VMPH^*_Y = (1-\beta)(\bar{A}+A^*)(\beta^2/r)^{\frac{\beta}{1-\beta}}$$

$$VMPH^*_A = (1-\beta)(\beta/r)(\beta^2/r)^{\frac{\beta}{1-\beta}}(1+H^*_Y)\delta A^*,$$

where $\bar{A}$ is the level of knowledge stock accumulated by the less developed country at the time of opening up. Solving these two simultaneously we get,

$$H^*_Y = \frac{r}{\beta\delta}\frac{\bar{A}+A^*}{A^*} - 1.$$

Since $\bar{A}$ remains unchanged while A^* keeps on growing, the asymptotic value of H^*_Y is simply $(r/\beta\delta - 1)$. Thus the asymptotic value of H^*_A is equal to $(2\delta\beta - r)/\delta\beta$. The asymptotic growth rate then is given by,

$$g^* = \frac{\dot{A}^*}{A^*} = \delta H^*_A = \frac{(\delta\beta - \rho)}{\beta+\sigma} + \frac{\beta\delta}{\beta+\sigma}. \tag{27}$$

Finally, (27) and the relationships $r = \rho + \sigma g$ and $H^*_A = (2\delta\beta - r)/\delta\beta$ imply the following:

$$H^*_A = \frac{2\beta\delta - \rho}{\delta(\beta+\sigma)} \text{ and } H^*_Y = \frac{\delta(\sigma-\beta)+\rho}{\delta(\beta+\sigma)}. \tag{28}$$

Both should be between 0 and 1. The necessary and sufficient condition for this to occur is $\rho/2 < \delta\beta < \rho + \delta\sigma$. In conclusion, when $\rho/2 < \delta\beta < \rho + \delta\sigma$, the long run equilibrium is characterized by $H_Y = 1$, $H_A = 0$, human capital allocation (28), and the growth rate (27).

The growth rate given by (27) is clearly larger than the autarky growth rate given by (15). International trade with vertical integration raises the world growth rate. This happens because as the advanced country allocates a larger proportion of human capital to R&D activities that have become more profitable with the opening up of the country, the speed of technical progress rises. Thus the advanced country grows at a higher speed. The less developed country also benefits from international trade, because the technological progress occurring in the advanced country is transmitted to the less developed country via the importation of newly developed capital goods. In fact the asymptotic long run growth rates are the same in both countries.

3) Trade Patterns

What is the pattern of international trade in this case? Clearly capital goods produced in the advanced country flow to the less developed country. In return for this, the final output and capital goods produced in the developing country flow to the advanced country. The developing country imports from the advanced country $P_x A^* m$ worth of capital goods. Her capital goods export to the advanced country is $P_x \bar{A} m^*$. Since $m > m^*$ and $A^* > \bar{A}$, it is clear that the underdeveloped country runs a deficit in capital goods trade. The deficit must be financed by the sale of the final products. That is, final products worth of $P_x(A^* m - \bar{A} m^*)$ must go to the advanced country to settle the deficits in capital goods trade. Note here that as A^* increases, that is, as economy grows, trade deficits in capital goods would also increase. It is interesting to find an empirical confirmation of this implication from actual trade patterns in capital goods between Korea and Japan.

C. Trade Restrictions and Long Run Growth

So far we have not imposed any restrictions on trade except for the assumption of no human capital mobility and no diffusion of knowledge across countries. In this section we still maintain these assumptions and introduce some additional restrictions. In order to simplify discussion, we now assume that $A = 0$ from the beginning. The developing country does not own an R&D sector and totally relies on imported capital goods.

An individual producer of the intermediate good in the advanced country does not have the market power to fully generate monopoly rent. However, the government in the advanced country can create an additional economic rent by imposing a royalty on the intermediate goods importing countries. This is possible because a ban on the export of capital goods would bring a total disaster to the developing country, since the latter is completely dependent on the advanced country for the capital goods.

Of course, if a total ban occurs, the developing country would develop her own technology to produce intermediate goods. Thus there is a certain limit for the advanced country to generate an economic rent by imposing the royalty. For example, if there exists a complete specialization also in the advanced country, then the developing country may also impose a punitive tariff on the export of the final products. This will result in a trade war and everyone would lose from it.[6]

Assume that the government of the advanced country imposes a royalty on the final goods producers in the developing country at the rate of τ and redistribute the royalty revenue to the domestic intermediate goods producers. Since we assume here that $A=0$ and consequently $H_Y=1$, the final goods producer in the less developed country now maximizes the following:

$$\pi_Y=(1-\tau)\int_0^{A^*} m(z^*)^{\beta}dz^*-w-\int_0^{A^*} P^*x(z^*)m(z^*)dz^* . \tag{29}$$

For a final goods producer in the developed country, the problem remains the same as before. His objective is to maximize the profit given by the following:

$$\pi^*_Y=H^{*\,1-\beta}_{Y}\int_0^{A^*} d^*(z^*)^{\beta}dz^*-wH^*_Y-\int_0^{A^*} P^*_x(z^*)d^*(z^*)dz^*. \tag{30}$$

For the R&D producers, the problem remains the same as before, too.

However, since capital goods producers now get a portion of the royalty revenue as well as the sales revenue, his profits hence the price of a blueprint would change. The price of the blueprint now becomes,

$$\bar{P}^*_A=P^*_A+\frac{R}{rA^*},$$

where the first component is the same as before, the second component represents the capitalized value of the royalty share,

[6]Note in our model a trade war will hurt the developing country more than the advanced country.

and R is the total royalty revenue.

The equilibrium growth rate changes from g^* to the following:

$$g^{**} = \frac{2\delta\beta - \rho + \beta\delta\phi(\tau)}{\beta + \sigma} = g^* + \frac{\beta\delta\phi(\tau)}{\beta + \sigma} \tag{31}$$

where g^*, given by (27), is the growth rate without government intervention, and

$$\phi(\tau) = (1-\tau)^{\frac{1}{1-\beta}} + \tau(1-\tau)^{\frac{\beta}{1-\beta}} \{\beta(1-\beta)^{1}\} - 1.$$

If $\phi(\tau) > 0$, then, with the imposition of the royalty, the growth rate will rise. This is the case when for the capital goods producer the royalty revenue more than offsets the decrease in export profits. Profit including a share of the royalty and hence the price of the blueprint increase. This makes it more profitable to engage in further R&D, and as a result the speed of technological progress rises. However, there is no guarantee that $\phi(\tau)$ is always greater than zero.

Note that $\phi(0)=0$, $\phi'(0)>0$, $\phi(1)=-1$. For small values of τ, $\phi(\tau)>0$, but for larger values of τ, $\phi(\tau)<0$. Thus unless a judicious τ is selected, imposing a royalty would decrease the growth rate of the advanced country.

Since $\phi(\tau)$ first increases and then decreases as τ increase from 0 to 1, there exists a unique τ^* that maximizes $\phi(\tau)$. By differentiating (31) with respect to τ we can see that when τ is equal τ^* given below, $\phi(\tau)$ attains the maximum:

$$\tau^* = \frac{(1-\beta)^2}{\beta + (1-\beta)^2}. \tag{32}$$

Growth rate maximizing value of τ^* is a function of β. For example, if $\beta = 0.60$, then $\tau^* = 0.2105$. Since τ^* is increasing in β in (32), the more productive the production of capital goods is, the more likely the imposition of a royalty reduces growth rates.

D. An Empirical Application of the Model: Korea's Trade with Japan and US

Korea's trade patterns in industrial products with U. S. are remarkably different from her trade patterns with Japan. With U. S Korea recorded surpluses every year since mid 1960s, whereas with Japan she recorded deficits every year during the same period.

Since 1960s Korea has been running trade deficits with Japan: Every year Korea sold much less to Japan than what she bought from her. This is true for trade balances in industrial products as well as for overall trade balances. The bulk of import from Japan consists of processed raw materials, parts and components, and machinery. These are the types of goods that we call capital goods in our model and they embody new technologies developed in Japan. Korea's export items to Japan, on the other hand, had for a long time remained mainly agricultural, forestry, and fishery products. It is only from the middle of 1980s, when Korea's HCI drive began to bear fruits, that the export share of industrial products to Japan has been increasing. Therefore, Korea's main export items to Japan have not been something that we call final goods for a long time. Instead final goods produced in Korea have mostly been sold to countries other than Japan, especially to America.

Korea's trade balance in industrial products visa vie America has consistently shown surpluses from 1970s. Among those, though, the prolonged and large surpluses that Korea had experienced during the 1980s stand out. Throughout the 80s Korea sold increasingly large amount of electronics, automobiles, steel products, and chemical products to America. These were 'final products' manufactured with processed raw materials, parts and components, and machines imported mostly from Japan.

These observed trade patterns can be a manifestation of the vertical integration arrangement that has been going on between Korea, Japan, and America. In this arrangement Korea has been buying capital goods from Japan and selling final goods to America. Capital goods that embody new technology were apparently easier to buy than the technology itself. Advanced capital goods made in Japan apparently offered a better term than those made in America. Korea has sold final goods more to America, because American markets were more widely open compared to Japanese markets. Were Japanese markets more open, Korea could have sold more final goods to Japan. Likewise, were American capital goods more competitive, Korea could have bought more capital goods from America.

To the extent that Korea's main export items to advanced countries are products that are made with capital goods developed and produced in Japan, Korea is in fact exporting final products 'for'

Japan. Korean manufacturing firms that have relied on capital goods produced in Japan are de facto subcontractors of Japanese firms. From this arrangement both Korea and Japan have gained. Japan gained because she could have larger markets for newly developed capital goods. Korea gained because she could enjoy the benefits of Japanese technological progress embodied in the new capital goods. Finally, both gained because there existed large American markets for the final products.

Will this arrangement be continued? There are important developments that may force Korea to alter the strategy. First, there is a pressure for Korea to buy more from America. In response to this, Korea will buy more from America. Second, there is a recognition that Korean economy is too dependent on Japanese economy. Korea will certainly try to buy capital goods more from countries other than Japan. At the same time Korea will produce more capital goods in Korea. These developments will reduce the extent to which Korea integrates vertically with Japan. With these new developments, Korea's trade deficits visa vie Japan will decrease. This process will accelerate when Japanese markets become more open. Korea's trade surpluses visa vie America have already reversed into deficits: Korea is buying a large amount of raw materials, capital goods, and final products made in America.

IV. Concluding Remarks

We have shown that, when advanced and developing countries are integrated vertically in international trade, economic growth rates in both countries could increase. This would occur when the developing country can fully utilize the technological advances made in the advanced country through import of capital goods, while the advanced country can speed up the technological progress with R&D activities that become more profitable with integration. This result may explain the rapid growth experienced by such countries as Korea and Taiwan that have actively participated in international vertical integration with U. S. and Japan.

However, the implication of the model that growth rates would be equal among all trading countries is completely at odd with the observed fact that Asian Nics have grown much more rapidly than their advanced trading partners. This result partly stems from the fact that we do not allow any advantage to the developing countries of being late in the development stage. If we include catch-up effects in the model by introducing, for example, more rapid technological progress through imitation or imperfect protection of the intellectual property rights, we can generate growth rates for the developing country much higher than those for the advanced country.

The result is also an artifact of our adherence to the steady state analysis. Note that in the model all adjustments occur instantaneously. This implies that the less developed country would experience an infinite growth rate at the time of opening. However, in reality these cannot be true. Less than perfect capital mobility, differences in preference and technology across countries, different initial endowments (of human capital), and the near impossibility for the less developed country to fully utilize all the technology developed in the advanced country all indicate that the adjustments would occur over a prolonged period. During the adjustment period, the developing country would grow much more rapidly than the advanced country.

The international vertical integration may take away from developing countries incentive to develop their own technology. As a result the developing country may eventually become completely dependent on the advanced country for technological improvement. This may pose a threat for the developing country, if advanced countries resort to ex post trade restrictions. In this respect an infant industry protection for the R&D sector can be justified. For example, R&D subsidies may be given, the domestic content requirements could be strengthened, and imitation of and improvement on advanced technology could be encouraged. This policy may create short run inefficiency. However, the long run gains may outweigh the short run losses.

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