5-2003

Catch-up Growth Based on International Talent Mobility in an Idea-Based World

Yu QUAN
National University of Singapore

Hian Teck HOON
Singapore Management University, hthoon@smu.edu.sg

SMU ECONOMICS & STATISTICS
WORKING PAPER SERIES

Catch-Up Growth Based on International Talent Mobility in an Idea-Based World

Yu Quan
Hoon Hian Teck

May 2003

Paper No. 11-2003

Catch-Up Growth Based on International Talent Mobility in an Idea-Based World

Yu Quan

National University of Singapore

Hian Teck Hoon*

Singapore Management University

May 2003

Abstract

We show how catch-up growth can result when immigrant ties of talented people to their home countries facilitate technology diffusion from world technological leaders to developing countries. The aspect of immigrant link we focus on is knowledge spillover through various programs of international exchange to draw upon the expertise of the individuals who have migrated—a type of *externality* effect on the

*Correspondence Address: Professor Hian Teck Hoon, School of Economics and Social Sciences, Singapore Management University, 469 Bukit Timah Road, Singapore 259756, Republic of Singapore; e-mail: hthoon@smu.edu.sg; tel: (65)-6822-0248; fax: (65)-6822-0833.

home country. In our model, we distinguish between public technology and private technology, both of which differ across countries. The size of the talent pool in each country determines the number of skilled workers and indigenous technology levels. The consequent gap in talent wage results in a flow of talent from South to North. We show, however, that when the externality effect is sufficiently strong, there is a phase of growth during which a "reverse brain drain" naturally occurs. Our model's prediction is consistent with the experience of Taiwan, which saw a reverse flow of talented people during the 1970s onwards after losing them in the 1950s and 1960s.

JEL classification: F21, F23, O14

Keywords: catch up, talent mobility, knowledge spillover

1. Introduction

There is an emergent view in the growth literature that the big gap in income levels across countries is due to differences in the levels of total factor productivity (Hall and Jones (1999); Parente and Prescott (2000)). From this perspective, the explanation for the East Asian economic miracle lies in the ability of these countries to get closer to the world technology frontier within a relatively short time. This raises a question: What are the channels through which technology has diffused from the advanced to the developing economies? According to Coe and Helpman (1995), the main intermediaries through which technology has diffused from the advanced countries to these technological followers are international flows of goods and capital. In this paper, we explore another mechanism that we believe is also important as a medium through which technology transfer can occur. This is the role played by immigrant ties of talented people to their home country.

Our basic idea is this. If it is in the advanced economies that knowledge is created most rapidly, both in higher educational and research centers as well as in private sector R&D labs, losing talent to the advanced economy might actually provide another conduit through which the developing economy can catch up technologically provided that the immigrant link is built upon. The aspect of immigrant link we focus on is knowledge spillover through various programs of international exchange to draw upon the expertise of the individuals who have migrated—a type of *externality* effect on the home country. If the externality effect is sufficiently strong, the consequent narrowing of the technology gap due to the immigrant link, which will be reflected in increasingly higher talent pay in the developing economy, will lead to a reversal of the international talent flow at some point.

In our model, we make a distinction between the technology development in the private sector and that within the public R&D and higher education sector, which in turn differ across countries. (Public R&D and higher education sector is used here as a shorthand for institutions like universities, colleges, public R&D and training centers.) We suppose that talented people work in both the public R&D and higher education sector as well as the private R&D sector. The former sector not only produces skilled workers through the teaching role of talent but also conducts public technology research. Talent that is employed in the private sector engages in patented R&D and helps companies holding the patents to achieve a monopoly position in the machine market. However, as Jafee (1989) and Sanders (1992) have empirically documented, academic research in university has significant commercial spillovers to local industries. At the same time, although many technologies are patented, companies can choose disclosure in a timely fashion. Since techniques can often be transferred only at considerable cost, firms will still have the willingness to share knowledge through publication (Stephan, 1996). The reputation of the lab, which is directly related to publication activity, also affects the ability of the company to hire scientists and engineers. In addition, problems that academic scientists address often come from ideas developed through a consulting relationship with industry (Stephan, 1996). Finally, scientists in public and private sectors often have a strong interaction linkage through seminars and joint projects.[1] Therefore, there is a strong empirical basis for assuming that both private and public technologies are interdependent, as we do in this paper, being determined by the scientists hired in both sectors.

The size of the talent pool in each country, which in this paper we shall take as given, determines the number of skilled workers and indigenous technology levels. North is assumed to have a larger stock of talent than South. The consequent gap in talent wage then results in a flow of talent from South to North. The task we have set for ourselves is to ask whether a general-equilibrium model that abstracts from any other form of international technology transfer than through the immigrant link of talent can generate the

[1] In fact, the research of some scientists and engineers in companies like IBM, AT&T and Du Pont is virtually indistinguishable from that of their academic counterparts. A number of scientists from Bell Labs, Du Pont, IBM, Smith Kline and French, Sony and General Electric have been awarded the Nobel Prize (Stephan, 1996).

result that a period of brain drain is naturally followed by a period of "reverse brain drain." We find that, indeed, when the externality effect is sufficiently strong, there is a phase of growth during which talent that has left returns to the source country. Our model's prediction is consistent with the experience of Taiwan, which saw a reverse flow of talented people during the 1970s onwards after losing them in the 1950s and 1960s.

Another satisfying prediction that our model is able to generate is that in the catch up there is an endogenous enhancement of technology development in higher education and research institutions, in conformity with the experience of the four East Asian tiger economies. For example, there are now six universities in Hong Kong and three universities in Singapore with faculty members who have obtained higher degrees from developed countries like America, England, and Canada. In Singapore in the 1970s, only the University of Singapore and the Singapore Institute for Standards and Industrial Research actively conducted public research. Now the number of public R&D institutions and centers has grown to 15. The Taiwanese model can be aptly described as a SME-public research institute innovation model (Wong, 1995). Because of limited resources, the state played an important role in diffusing process technologies to the SMEs through the establishment of various product technology consortia. The most successful example is the notebook computer consortium coordinated by the Industrial Technology Research Institute. Over the past 15 years, it has been estimated that over 60 such R&D consortia have been established in various industrial sectors in Taiwan and the "reverse brain drain" constitutes the main talent in those institutes and in the private sector (Wong, 1995). The quality of some public R&D and higher education institutions in these economies has now come close to world class status.

At the early stage of economic development in these economies, many excellent local graduates went overseas to study and worked there after obtaining their higher degrees because of the lack of high-quality universities domestically and lower local wages. As these economies gradually developed, more overseas graduates with higher degrees have been attracted back to the home country because of improved salary and better working environment. See, for example, the case of Taiwan highlighted in Figure 1 and Figure 2. From Figure 1 and Figure 2, we observe that more and more overseas talent returned to Taiwan from the early 1970s as the Taiwanese economy developed. Figure 2 plots the ratio of returnees to students going abroad, and shows both the annual ratio as well as the 9-year moving average ratio. The smoothing ratio shows that in the 1950s and 1960s, Taiwan experienced brain drain. However, since the 1970s, Taiwan has been experiencing reverse brain drain, with small fluctuations in the late 1970s and late 1980s.[2]

How do we explain the reverse brain drain following the loss of talent overseas? In examining the Taiwanese experience, Wu (1985) has pointed out that among the talent staying overseas, many of them have been attracted to go back to Taiwan as visiting scientists, professors, engineers, and

[2] A study by Chang (1992) shows that, in her sample, at least a third (33.9 percent) of returnees work in the university while 7.4 percent work in research organizations in Taiwan. Another study by Yao (1981) over the period 1960-79 shows that 58.5 percent of returnees have Ph.D. degrees and 37.9 percent have M.A. degrees.

so on.[3] These people can be persuaded to work in Taiwan on a longer-term basis. In Singapore, the government provides financial support for top students to study in world-class universities overseas with a bond to serve the country after graduation. There are also others, however, who choose to study overseas under alternative financial arrangements. Realizing the difficulty of drawing back overseas talent immediately on a permanent basis, and perhaps spurred on by Taiwan's strong innovation system network linkage with overseas talent and firms in the US, Singapore's Minister of State for Education and Manpower recently launched the Singapore Overseas Network (SON) to tap the talent of Singaporeans overseas, many of whom "enjoy the distinction of having worked in two or more markets". For those who are not yet ready to return, SON is used as a platform for them to help enhance entrepreneurship and innovation in Singapore. Visiting overseas scholars and technology professionals can greatly aid the process of public technology and education integration, thereby strengthening the developing economies' private technology catch-up. In addition, overseas talent directly contributes to the developing economies' private technology through MNCs' technology transfer, or technology collaboration with local companies or through

[3] Chang (1992) reports in her study that under the auspices of the National Science Council and the Ministry of Education of Taiwan, more than 3,700 overseas scientists and experts and 2,500 established scholars have returned to Taiwan as visiting professors or as research professors. National development conferences have also been sponsored at the Taiwanese government's expense to discuss science and technology development, social welfare, politics, and education involving more than 3,000 overseas scholars and professionals.

technology spin-offs. Consequently, while the technological follower suffers a direct loss of talent, which impedes its pace of technological advance, this is offset by an indirect gain through its talent being able to work in the technologically more advanced leader country. This facilitation of technology transfer, paradoxically through the loss of talent overseas, ultimately leads to a reverse brain drain as the follower country catches up technologically. It is surprising that the presence of such a network linkage has tended to be neglected in most models of international economic development.

Instead, the mainstream of economic theory in the 1970s held that brain drain is an unmitigated loss to the home country and unambiguously harms those left behind. The research focus was on the systematic examination of the tax arrangements that should govern highly skilled migration (Baumol, 1982; Bhagwati and Partington, 1976; Mirrlees, 1982; Pomp and Oldman, 1979; Wilson, 1980). For example, India, the Philippines, Cuba and Italy are often cited as negative examples of the loss from brain drain (Bhagwati, 1983). Johnson (1965) may be the first economist to emphasize the advantages of brain drain to the countries of origin and destination. He argued that the migrants can make a large transfer to the home country in a way that is likely to compensate for the education cost to the country of origin. In pointing to an externality effect, Gould (1994) comes close to the analytical insight of our paper. He illustrates empirically that immigrant information can play an important role in determining US bilateral trade flows. Immigrant ties include the knowledge of home country's market, language, preference, and business contacts that can potentially decrease the transaction cost of bilateral exchange. Therefore, migrants can facilitate bilateral trade between the host and home countries. Our paper points to how immigrant links lead to an increase in worldwide technology transfer and how the “overseas brain stock” contributes to both the source and receiving countries. This mechanism is relevant in light of the work in endogenous growth, especially that emphasizing human capital externalities such as that by Lucas (1988), and diffusion of knowledge and technology such as that by Romer (1990).[4]

To study the effect of talent mobility on technology diffusion and education integration in the international economy, we introduce a public R&D and higher education sector to the endogenous technological change model of Romer (1990) in a two-country setting. We obtain higher wage for talent in the North compared to that of the South due to a larger talent stock in the North. Talent will move from South to North in response to the higher wage. An implication of the model without the presence of an overseas talent externality effect in Section 2 is that the mobility of talent will reduce Southern growth and talent will never have an incentive to return to the home country. Section 3 extends the model to incorporate the externality effect of Southern overseas talent on the source country’s public and private technologies. This externality effect refers to the contribution that talent from the South makes to raising the technology level and training of skilled workers in their home

[4]Mountford (1997) presents a model highlighting a different mechanism through which a brain drain could be good for the source country. His idea is that a person who faces a chance of being able to emigrate, and so faces a higher expected earning stream, is induced to acquire higher skills. Since, *ex post*, not everyone successfully emigrates, the source country ends up with a higher average skill level in a world with some brain drain allowed.

country as visiting scholars and advisors, even though they live and work in the North. The loss of talent overseas paradoxically facilitates technology diffusion, which we describe as an externality effect, thus enabling the technological follower to catch up to the technological leader. As mentioned, this effect seems to have been important in the economic development of Taiwan, especially so in the eighties and nineties. Section 4 presents the conclusion, the discussion of some public policy implications and the limitations of our paper.

2. Structure of the model without overseas talent externality effect

Any paper attempting to discuss growth in an idea-based world articulated by Lucas (1988), Romer (1990) and Grossman and Helpman (1991), as this paper attempts to do, must face the Jones (1995a) critique, commonly referred to as the problem of the scale effect. This class of endogenous growth models produces the result that an increase in the stock of resources engaged in the R&D activity leads to a permanent increase in the economy's growth rate. Kremer (1993), in a very innovative piece of work entitled, "Population growth and technological change: One million B.C. to 1990," finds that the growth rate is positively related to the size of the world population, which we take the R&D resources to be proportional to, and so finds support for this class of models. Looking at the U.S. economy over a century long, however, Jones (1995a) finds that although the number of R&D scientists and other measures of research intensity have increased quite steadily, there is no evidence that the growth rate of the U.S. economy has also increased in tandem. He proposed (Jones, 1995b), instead a semi-endogenous growth model where the economy's growth rate is proportional to the rate of growth of population. In his model, increasing the size of the talent pool has a scale effect on the level, but not the growth rate, of GDP per capita.

In trying to grapple with the differing levels of technology sophistication in the North-South segments of the world in our paper, what assumptions should we make about the scale effect? If we adopt the Jones' characterization (applied to the U.S.) that the pace of technology development is proportional to the national population growth rate, we would end up with the counterfactual implication that technology development proceeds more rapidly in the South than in the North since the South has obviously the higher population growth rate. A way to deal with this counterfactual implication is to suppose that *no* technology development takes place in the South at all, and that the technology frontier is pushed ahead only by efforts of scientists in the North, which is then diffused to the rest of the world. Yet, for the purpose of our analysis, it is important to take note that even in developing countries, there are universities where both teaching and research do take place although the knowledge frontier there is not proceeding as rapidly as in advanced economies. In fact, as pointed out earlier, we want to be able to explain how the quality of higher education and research institutions endogenously improves in the catch up. We will, therefore, proceed in our modeling efforts by adopting the original Lucas-Romer-Grossman-Helpman formulation, treating the world stock of talent as given, with the North having a larger stock. When we allow for international migration, part of the Southern stock of talent will emigrate to the North in response to the higher talent wage. Population growth through natural increase in North and South is assumed to be zero although North will face population increase through in-migration while Southern population will decrease or increase depending on out-migration and reverse brain drain.[5]

Consider first a single closed economy. There is a single final good produced with the following production function: $Y = (1-\alpha-\beta)^{-1} L_u^\alpha L_s^\beta \int_0^A x_i^{1-\alpha-\beta} di$, where Y is final output, L_u is unskilled labor, L_s is skilled labor and x_i is the output of machine i. We impose the conditions $0 < \alpha, \beta, \alpha + \beta < 1$. The atomistic suppliers of the final good operate in a perfectly competitive environment, choosing the optimal employment of each type of labor and the optimal demand for x_i with i ranging from 0 to A. The following first-order conditions are obtained after imposing the condition of symmetry so that $x_i = x_j = x$:

$$A(\frac{\alpha}{1-\alpha-\beta}) L_u^{-(1-\alpha)} L_s^\beta x^{1-\alpha-\beta} = w_u, \tag{1}$$

$$A(\frac{\beta}{1-\alpha-\beta}) L_u^{\alpha} L_s^{-(1-\beta)} x^{1-\alpha-\beta} = w_s, \tag{2}$$

$$L_u^\alpha L_s^\beta x^{-(\alpha+\beta)} = p_x, \tag{3}$$

where w_u is unskilled wage rate, w_s is the skilled wage rate, and p_x gives the relative price of machine, all measured in terms of the numeraire good, which is the final output.

Machine i is produced in a monopolistically competitive environment using the design blueprint protected by patent. We suppose that the marginal

[5]To keep our analysis simple, we will assume that only talent is free to emigrate. Production workers do not face this option.

cost is a constant γ measured in units of the final good and is the same for all i. The MC=MR rule gives, under symmetry, the following condition: $p_x = \gamma/(\alpha+\beta)$. Without loss of generality for our purpose, we set $\gamma \equiv \alpha+\beta$ so we simply have

$$p_x = 1. \tag{4}$$

Motivated by the empirical evidence that both private and public sector technologies are interdependent, being determined by the scientists employed in both sectors, we posit the following specifications for technology development:

$$\begin{aligned} \dot{A} &= AS^{(1+\eta)/2}S_p^{(1-\eta)/2};\ 0<\eta<1, \\ \dot{A}_p &= A_pS^{(1-\eta)/2}S_p^{(1+\eta)/2}, \end{aligned}$$

where A is a measure of private-sector technology development, A_p is a measure of public-sector technology development, S is the stock of talent employed in private-sector R&D and S_p is the stock of talent employed in the public-sector R&D and higher education sector. (A dot represents a time derivative.) We let the total stock of talent available be given by $\bar{S}$ so full employment of talent implies:

$$\bar{S} = S + S_p. \tag{5}$$

Along a balanced growth path, $\dot{A}/A = \dot{A}_p/A_p = g$, which implies that

$$S = \frac{\bar{S}}{2}, \tag{6}$$

$$S_p = \frac{\bar{S}}{2}, \tag{7}$$

$$g = \frac{\bar{S}}{2}. \tag{8}$$

Talent working in the public R&D and higher education sector plays the dual role of teacher-researcher. In the teaching role, we assume that to maintain the quality of teaching, universities maintain a certain student-faculty ratio. Training is instantaneous so letting λ be the student-faculty ratio, we have

$$L_s = \lambda S_p. \tag{9}$$

Also, letting the total number of production workers employed in the manufacturing facility be $\bar{L}$, we have, since $\bar{L} = L_u + L_s$, that

$$\bar{L} = L_u + \lambda S_p. \tag{10}$$

Let us now determine the market remuneration for talent. We note that to generate one additional private-sector R&D blueprint, that is, to obtain $\dot{A} = 1$, we need $S = [A^{2/(1+\eta)} S_p^{(1-\eta)/(1+\eta)}]^{-1}$ units of private-sector talent so

$$\text{current private sector R\&D cost} \equiv \frac{w_T}{A^{\frac{2}{1+\eta}} S_p^{\frac{1-\eta}{1+\eta}}},$$

where w_T is the real remuneration to private-sector talent. With free entry into the private-sector R&D activity, the value of a firm, V, must be driven to equal the current R&D cost. Along a balanced growth path, $V = \pi/r$, where $\pi = (p_x - \gamma)x$ and r is the real interest rate. With our earlier normalization, $\pi = [1 - (\alpha + \beta)]x$. To solve for x, we use (4), (9) and (10) in (3) to obtain

$$x = \left(\bar{L} - \frac{\lambda \bar{S}}{2}\right)^{\frac{\alpha}{\alpha+\beta}} \left(\frac{\lambda \bar{S}}{2}\right)^{\frac{\beta}{\alpha+\beta}}. \tag{11}$$

Using (11), we obtain an expression for dividend per share:

$$\pi = [1 - (\alpha + \beta)] \left(\bar{L} - \frac{\lambda \bar{S}}{2}\right)^{\frac{\alpha}{\alpha+\beta}} \left(\frac{\lambda \bar{S}}{2}\right)^{\frac{\beta}{\alpha+\beta}}. \tag{12}$$

To obtain an expression for the equilibrium real interest rate, we posit a representative household with the utility function: $\int_0^\infty (1-\theta)^{-1}[C_t^{1-\theta} - 1] \exp^{-\rho t} dt$, where $\theta > 0$, and the following intertemporal budget constraint:

$$\int_0^\infty C_t \exp^{-\int_0^t r_s ds} dt = W_0 + \int_0^\infty Y_t \exp^{-\int_0^t r_s ds} dt - \int_0^\infty T_t \exp^{-\int_0^t r_s ds} dt,$$

where ρ is the subjective rate of time preference, W_0 is initial non-human wealth and T denotes the lump-sum tax imposed to finance public-sector talent, whom we assume is also paid w_T. The government, who hires public sector talent, is assumed to match what private sector talent is paid, and meets the wage bill from its tax revenue. In equilibrium, $T = w_T S_p$. The Keynes-Ramsey rule coming out from solving the representative agent's optimization problem gives, along a balanced growth path, $g = \theta^{-1}(r-\rho)$. Using (8), we then have an expression for the equilibrium real interest rate:

$$r = \frac{\theta \bar{S}}{2} + \rho. \tag{13}$$

Using the free entry condition along with (12) and (13), we have, after some rearrangement and collection of terms, an expression for the equilibrium talent wage:

$$w_T = \frac{[1-(\alpha+\beta)](\bar{L} - \frac{\lambda \bar{S}}{2})^{\frac{\alpha}{\alpha+\beta}} \lambda^{\frac{\beta}{\alpha+\beta}} (\frac{\bar{S}}{2})^{\frac{\beta}{\alpha+\beta}+\frac{1-\eta}{1+\eta}} A^{\frac{2}{1+\eta}}}{\frac{\theta \bar{S}}{2} + \rho}. \tag{14}$$

Notice from (14) the role played by the interdependency between private and public technology development. We can see that when $\eta = 1$, the case where there is no interdependency, a one percent increase in A leads to exactly a one percent increase in w_T, ceteris paribus. This is no longer the case when $0 < \eta < 1$, where there is a positive spillover between technology development in the two sectors. In the latter case, a one-percent increase in A leads to a greater than one percent increase in w_T. This is because an increase in private sector technology development benefits the pace of public sector technology development, which then feeds back positively onto private sector technology development and so on in a convergent manner, hence increasing the reward to talent more than proportionately.

Notice also how an increase in the total stock of talent affects w_T, given A. We can identify three effects: (a) Positive spillover of research by public sector talent, captured by the term $(\bar{S}/2)^{(1-\eta)/(1+\eta)}$; (b) Scale effect of $\bar{S}$ on x, captured by the term $[\bar{L} - (\lambda\bar{S}/2)]^{\alpha/(\alpha+\beta)}[\lambda\bar{S}/2]^{\beta/(\alpha+\beta)}$; and (c) interest rate effect, captured by the term in the denominator, $(\theta\bar{S}/2) + \rho$. Through the positive spillover effect identified in (a), an increase in $\bar{S}$ increases the productivity of private-sector research and hence raises w_T. A larger stock of talent increases the number of skilled workers for a given $\bar{L}$ and reduces the number of unskilled workers. If the share of skilled workers, β, in the production function $Y = (1-\alpha-\beta)^{-1}AL_u^{\alpha}L_s^{\beta}x^{1-\alpha-\beta}$ is larger than the share of unskilled labor, α, given $\alpha + \beta$, it is more likely that an increase in $\bar{S}$ increases x and hence increases the value of the firm and consequently w_T. Finally, the higher $\bar{S}$ is, the faster is the economy's growth rate, g. This raises the real interest rate, and hence the discount rate applied to the future stream of dividends. Through this channel, an increase in $\bar{S}$ decreases w_T, given A.

Going beyond the closed economy to look at the North-South version of the model, we shall use an asterisk to denote a Southern variable. Supposing that the parameters α, β, η, θ, ρ, λ, and $\bar{L}$ are identical in North and South so that the only difference we allow is for the stock of talent to differ with $\bar{S} > \bar{S}^*$, we obtain, in the absence of any international talent mobility, that[6]

$$\frac{w_T}{w_T^*} = \left[\frac{(\bar{L} - \frac{\lambda \bar{S}}{2})}{(\bar{L} - \frac{\lambda \bar{S}^*}{2})}\right]^{\frac{\alpha}{\alpha+\beta}} \left[\frac{\bar{S}}{\bar{S}^*}\right]^{\frac{\beta}{\alpha+\beta}+\frac{1-\eta}{1+\eta}} \left[\frac{\frac{\theta \bar{S}^*}{2} + \rho}{\frac{\theta \bar{S}}{2} + \rho}\right] \left[\frac{A}{A^*}\right]^{\frac{2}{1+\eta}}. \tag{15}$$

We will suppose that, when we allow for talent to emigrate, parameters in (15) are such that, given $\bar{S} > \bar{S}^*$, $w_T > w_T^*$. In fact, noting from (8) that the greater stock of talent in North implies a higher rate of growth, w_T will exceed w_T^* in finite time as A/A^* becomes sufficiently large.

There are many factors that influence the migration decision of talent. As a recent OECD study (2002; p. 253) puts it, people migrate to "take advantage of higher wages, more exciting opportunities and changes in life style." We summarize the number of units of Southern talent expressing an intention to migrate to the North by the function $M(w_T/w_T^*)$ such that $M'(\cdot) > 0$. Allowing for international migration of talent from South to North, (15) is transformed to

$$\frac{w_T}{w_T^*} = \left[\frac{(\bar{L} - \frac{\lambda\left(\bar{S}+M(\frac{w_T}{w_T^*})\right)}{2})}{(\bar{L} - \frac{\lambda\left(\bar{S}^*-M(\frac{w_T}{w_T^*})\right)}{2})}\right]^{\frac{\alpha}{\alpha+\beta}} \left[\frac{\bar{S} + M(\frac{w_T}{w_T^*})}{\bar{S}^* - M(\frac{w_T}{w_T^*})}\right]^{\frac{\beta}{\alpha+\beta}+\frac{1-\eta}{1+\eta}} \times$$

[6]In international comparisons, it has been found that pupil-teacher ratios for developed and developing countries are actually quite close. For example, in 1990, the pupil-teacher ratio for Japan is 25 and for China it is 22 (World Education Report, 1993). In our model, we assume that the pupil-teacher ratio is the same for both the North and South. Despite that, we shall find that due to the greater stock of talent in the North, technology grows at a more rapid pace so skilled workers will find their remunerations growing at a more rapid pace in the North than in the South.

$$\left[\frac{\frac{\theta\left(\bar{S}^{*}-M(\frac{w_T}{w_T^*})\right)}{2}+\rho}{\frac{\theta\left(\bar{S}+M(\frac{w_T}{w_T^*})\right)}{2}+\rho}\right]\left[\frac{A}{A^*}\right]^{\frac{2}{1+\eta}}. \qquad (16)$$

In a diagram (not drawn) with w_T/w_T^* on the horizontal axis, the LHS of (16) can be represented as a 45-degree line. For given A/A^*, we can depict the RHS of (16) either as a downward-sloping schedule or an upward-sloping schedule. If upward-sloping, we assume that it is less steep than the 45-degree line and crosses it only once. Then we can write $w_T/w_T^* = \phi(A/A^*)$ with the property that $\phi'(\cdot) > 0$. With this, we can simply express migration as a function of q and write $M(q)$, where $q \equiv A/A^*$ and $M'(\cdot) > 0$.

It is straightforward to see that in such a world, talent in the South has strong incentive to migrate to the North. As the South loses talent to the North, its research capability suffers and its capacity to train workers is reduced. Southern growth steadily declines until all its talent is lost to the North. We obtain the following proposition:

Proposition 1: In a model without the overseas talent externality effect, the higher endowment of talent in the North will lead to a continuous outflow of Southern talent with the consequence that the technology gap and wage gap will become ever greater until all talent is lost to the North.

3. International talent mobility with externality effect

We wish now to capture the notion that the South can benefit from its overseas talent that is currently working in the North through various international exchange programs. Because of the importance of human capital externalities that we stress, whether talent is employed in the private sector or public research institution, the North is the place where new ideas and knowledge frontier are constantly pushed forward at a rapid pace. Since its overseas talent is where the action is, the South paradoxically benefits more the greater the number of its stock of talent working overseas provided that it builds up strong networks to facilitate the international exchange. Those who return permanently to work in the South after a temporary stint of research work in the North lose the benefit of working in a more vibrant research environment in the North. What we want to show now is that if the externality effect is sufficiently strong, reverse brain drain naturally occurs, which generates direct benefits to the South but, by the same token, there is an indirect loss from moving away from a more vibrant research environment. The public technology gap also steadily closes in the transition. We obtain a steady-state condition where there is an equilibrium technology gap—in both public as well as private technologies—sustained by knowledge spillover generated by an overseas talent stock through immigrant links.

Interestingly, after Taiwan has caught up to developed country status, top local graduates nowadays prefer to finish their higher degrees in local universities and find a job in Taiwan upon graduation. The overseas talent pool of Taiwan has shrunk, making the utilization of remaining overseas brain power and building up of overseas talent network linking the domestic economy even more imperative. The Taiwanese government has recognized this, and more official as well as unofficial organizations promoting overseas talent network and technology transfer like the Monte Jade Science and Technology Association have been set up since the early 1990s, especially in the high tech industry in Taiwan.[7]

To introduce the overseas talent externality effect on the South, the accumulation functions of public technology and private technology need to be modified. We assume the externality effect in the public research sector can be represented by $\zeta = f(M(q), k)$, where $q \equiv A/A^*$, introduced earlier, is the North-South private technology gap, $k \equiv A_p/A_p^*$ is the North-South public technology gap, and $\zeta_M > 0$, $\zeta_k > 0$. We have $\zeta_M > 0$ since the more talent overseas, the more South will benefit from the externality effect. We have $\zeta_k > 0$ to capture the benefit of relative backwardness (see Gerschenkron (1962); Findlay (1978)). For simplicity, we use the following functional form:

$$\zeta = f(M(q), k) = k + a_1(q - 1) - c_1, \tag{17}$$

where the first term, k, indicates that the larger the public technology gap, the stronger the catch-up effect; a_1 is a parameter capturing the government's effort to utilize overseas talent; and the constant term c_1 represents exogenous barriers to technology transfers. For example, the reduced cost of cross-border communications made possible by the internet is represented as a decrease in c_1. Assuming that public sector technology development greatly benefits from the externality effect, we set $a_1 > 1$.

Incorporating the externality effect in the public research sector, we can

[7] The OECD report (2002, p. 256) describes a group of Taiwan returnees, characterized as "temporary returnees" or "transnational workers", who work on both sides of the Pacific. It says, "Their families are based in the United States. They play a role as middlemen, linking businesses in the two regions through their personal networks and their technological and market know-how."

describe the evolution of the public sector technology gap as follows:

$$\frac{\dot{k}}{k} = \frac{[\bar{S} + M(q)]}{2} - \frac{[\bar{S}^* - M(q)]}{2} - \zeta = c_1 + c_2 - k - (a_1 - 1)(q - 1), \quad (18)$$

where $c_2 \equiv (\bar{S} - \bar{S}^*)/2$. Rewriting, we have

$$\dot{k} = k[c_1 + c_2 - k - (a_1 - 1)(q - 1)] = \Gamma(k, q), \quad (19)$$

$$\Gamma_{kk}(k, q) = -2 < 0, \quad (20)$$

$$\Gamma_{kq}(k, q) = 1 - a_1 < 0. \quad (21)$$

Turning now to the externality effect in private sector technology development, we assume that it can be represented by $\epsilon = h(M(q), k, q)$ where $\epsilon_M > 0$ since the more overseas talent, the stronger the externality effect; $\epsilon_k < 0$ to capture the idea that if the public technology gap is very wide, the follower country is less capable of absorbing superior private technology from abroad since educated workers have comparative advantage in implementing new technologies (see Nelson and Phelps (1966) for the theoretical argument and Bartel and Lichtenberg (1987) for empirical support); and $\epsilon_q > 0$ (referring to the partial derivative with respect to the third variable, q, in the function) to capture the relative backwardness effect. Again, to simplify, we choose the following functional form:

$$\epsilon = h(M(q), k, q) = q + a_2(q - 1) - k - c_1, \quad (22)$$

where the first term, q represents the relative backwardness effect; a_2 is a parameter capturing the benefits generated from having talent working abroad; and c_1, as before, represents exogenous cross-country barriers to technology transfers. We assume that $0 < a_2 \leq 1 < a_1$ since private technology is less accessible than public technology. The appearance of k with a negative sign in front indicates that a narrower public technology gap facilitates reaping the overseas talent externality benefit in private technology catch up. For example, skilled workers with better grounding in science and mathematics are more adaptive to advanced technology (see Bartel and Lichtenberg, 1987).

Incorporating the externality effect in the private technology sector, we can describe the evolution of the private sector technology gap as follows:

$$\frac{\dot{q}}{q} = \frac{[\bar{S} + M(q)]}{2} - \frac{[\bar{S}^{*} - M(q)]}{2} - \epsilon = k - a_2(q-1) + c_1 + c_2 - 1. \quad (23)$$

Rewriting, we have

$$\dot{q} = q[k - a_2(q-1) + c_1 + c_2 - 1] = \Psi(k,q), \quad (24)$$

$$\Psi_{qq}(k,q) = -2a_2 < 0, \quad (25)$$

$$\Psi_{qk}(k,q) = 1 > 0. \quad (26)$$

Equations (19) and (24) make up a system of two dynamic equations in k and q. The steady-state values (k_{ss}, q_{ss}) corresponding to $\dot{k} = \dot{q} = 0$ are given by

$$k_{ss} = \frac{(c_1 + c_2)(1 + a_2 - a_1) + a_1 - 1}{a_1 + a_2 - 1}, \quad (27)$$

$$q_{ss} = 1 + \frac{2(c_1 + c_2) - 1}{a_1 + a_2 - 1}. \quad (28)$$

Equation (28) gives the commonsensical result that, in steady state, increased effort spent in devising programs to draw upon the expertise of overseas talent, both in the public and private research institutions, so a_1 and a_2 are large lead to a narrower private technology gap. Moreover, relative abundance of talent compared to the North (a small c_2) and lower cross-country communications barriers (a small c_1) lead to smaller private technology gaps. Assuming that $c_1 + c_2 > 1/2$ also ensures that in steady state, there is a positive stock of overseas talent. Noting that we can write, $k_{ss} = c_1 + c_2 - (a_1 - 1)(q_{ss} - 1)$, we note that changes in a_1, c_1 and c_2 have ambiguous effects on k_{ss} since the indirect effects through q_{ss} work in an opposite direction from the direct effects. For example, a reduction in c_1 due to the introduction of the internet directly lowers k_{ss} but since it also leads to reduced q_{ss} and so a reduced number of talented people working overseas, the benefits from international spillover are also reduced, which works to increase k_{ss}.

Conditions (20), (21), (25) and (26) ensure that we obtain global stability. Figure 3 depicts a phase diagram of this system. The stationary locus (KK) representing $\dot{k} = 0$ is negatively sloped while the stationary locus (QQ) representing $\dot{q} = 0$ is positively sloped. The arrows of motion in the four regions are indicated in Figure 3.

Suppose that we start off from an initial position where $k_0 > k_{ss}$ and $q_0 > q_{ss}$ so both the private and public technology gaps are wide, and the economy is in region I. The trajectory traced out in Figure 3 shows that while the public technology gap steadily narrows, there is an initial phase where the private technology gap widens before it reverses and begins to narrow. The reason that the private technology gap initially widens with international emigration of talent has to do with the fact that with the public technology gap being so wide initially, the South is not capable of fully implementing new private technology available from the North—the comparative advantage of educated workers in implementing private sector technology—so the direct effect of losing talent overseas dominates. Ultimately, the narrowing of public technology gap leads to a point where the South can fully benefit from having its talent work in a more attractive research environment in the North. From that point onwards, private technology gap begins to narrow. Corresponding to this time path of the private sector technology gap, $q \equiv A/A^*$, which translates into a corresponding monotonic shift of the talent wage gap, w_T/w_T^*, the units of Southern talent emigrating to the North increase before a brain drain reversal occurs.

Now, the mere presence of an overseas talent externality effect is not sufficient for there to be a reverse brain drain. The externality effect has to be sufficiently strong. In Figure 4, we depict the dynamics for a case where $a_1 + a_2 < 1$. (In contrast, in the case we have just studied, where a reversal of brain drain occurs, the condition $a_1 + a_2 > 1$ is satisfied.) We see in Figure 4 that the public technology gap initially narrows in phase I but then begins to widen in phase II; the private sector technology gap, and consequently the talent wage gap as well, however, steadily widen and so there is never a point of brain drain reversal. We have the following proposition:

Proposition 2: In a model with a sufficiently strong overseas talent externality effect, there is an initial phase of growth when talent migrates from the South to the North. There is, however, a point when a reversal of brain drain occurs.

How long does it take for a reversal of brain drain to occur? To address this question, we present numerical simulations in the Appendix aimed at studying how the time before a reverse brain drain occurs is affected by two alternative strategies: (a) Efforts to boost immigrant links in the public higher education and research sector through visiting professor and scientist schemes to tap on the expertise of overseas talent, amounting to an increase in the parameter, a_1; and (b) Efforts to boost immigrant links in the private R&D sector through initiatives such as the Taiwanese schemes to develop networks with Taiwanese entrepreneurs with firms both in Silicon valley as well as in Taiwan, amounting to an increase in the parameter, a_2. We find that under our parameter restriction, $a_1 + a_2 > 1$, (a) Increasing a_1, holding other things unchanged, reduces the time at which the reversal of brain drain occurs and also reduces both k_{ss} and q_{ss}; and (b) Increasing a_2, holding other things unchanged, reduces the time it takes for the reversal of brain drain to occur and reduces q_{ss} but increases k_{ss}.

The first strategy aims to directly raise the standard of higher education and scientific knowledge in the follower country and to close the public technology gap with the world technology leader. Since educated workers have a comparative advantage in implementing private technology, this strategy results in a closing up of the private sector technology gap as well, implying a narrowing of the talent wage gap. This hastens the return of some of the overseas brain stock. The second strategy, on the other hand, tries to close the private sector technology gap directly, and consequently the talent wage gap is narrowed, thus attracting back home some of its overseas talent. The early return of overseas talent, both in the private and public sectors, means that the source country has fewer units of talent working in the best research environment in the world hence limiting the size of the externality effect. Paradoxically, raising a_2 leads to a widening of the public technology gap.

It is apparent that, provided the externality effect is sufficiently strong, both the North and South end up growing at the same higher growth rate in the steady state with perfect international talent mobility compared to the situation with zero international talent mobility. There is parallel convergence in the sense that in the steady state with free international talent mobility, South grows at the same (higher) rate as North, maintaining a constant gap in the sense of constant ratios such as $q_{ss} \equiv A/A^*$ and $k_{ss} \equiv A_p/A_p^*$. We have the following proposition:

Proposition 3: After talent mobility in a world with sufficiently strong externality effect, both North and South experience in the steady state the same higher technology growth rate compared to a completely immobile world. Consequently, the wages for skilled and unskilled workers as well as talent wage in North and South also grow at the same higher rate.

4. Conclusion

Our paper has highlighted the importance of international mobility of talent in facilitating cross-national technology diffusion, and a policy message emerges from our analysis. From a developing country's point of view, opening up to the world and allowing the outflow of home country talent can eventually facilitate its catch up to the world's technological leader. Home country's private and public technology development is enhanced through the benefit of having its talent work in the best research environment in the world. If strong immigrant ties lead to effective technology transfers, the ensuing growth catch up can raise the standard of living of those left behind.

It is natural that at the beginning of opening up, many talented people will flow out of the developing economy. However, provided that the immigrant link is built upon, part of the overseas talent will return. Hence it is important for the developing economy to build strong overseas talent networks by strengthening its co-operation with international educational and research institutions and by inviting overseas talent to be project advisors in the private sector and encouraging temporary returnees in the form of technology spin-offs. Our analysis suggests that it is inevitable that some Southern talent may still stay in the North but it is precisely their being in the more vibrant research environment that enables them to act as the conduit for superior technology transfer.

Further extension of our model is possible. One might want to allow those returnees who permanently stay in the South to play a more productive role. For example, we can study whether they can establish similar overseas networks with their former colleagues in the North for technology transfer. We can also extend the model to study how the perspective on the issue of foreign talent and its implied public policy differs for small open economies like Singapore, and large economies like China. Today's world is one that competes for international talent. How to attract talent and make use of world talent becomes a major issue for both large and small economies.

References

Bartel, A.P. and F. R. Lichtenberg, 1987, The comparative advantage of educated workers in implementing the new technology, Review of Economics and Statistics, 69, 1-11.

Baumol, W. B., 1982, The income distribution frontier and taxation of migrants, Journal of Public Economics, 18, 343-361.

Bhagwati, J., 1983, International factor mobility, Volume 2 of Essays in International Economic Theory, edited by R. C. Feenstra (The MIT Press, Cambridge, MA).

Bhagwati, J., and M. Partington, 1976, Taxing the brain drain: A proposal, Volume 1 (North-Holland, Amsterdam).

Chang, S. L., 1992, Causes of brain drain and solutions: The Taiwan experience, Studies in Comparative International Development, Spring, 27-43.

Coe, D. T. and E. Helpman, 1995, International R&D spillovers, European Economic Review 39, 859-887.

Findlay, R., 1978, Relative backwardness, direct foreign investment and the transfer of technology: A simple dynamic model, Quarterly Journal of Economics, 92, 1-16.

Gerschenkron, A., 1962, Economic backwardness in historical perspective (Harvard University Press, Cambridge, MA).

Gould, D. M., 1994, Immigrant links to home country: Empirical implication for U.S. bilateral trade flows, The Review of Economics and Statistics, 76, 302-316.

Grossman, G. M. and E. Helpman, 1991, Innovation and growth in the global economy (MIT Press, Cambridge, MA).

Hall, R. E. and C. I. Jones, 1999, Why do some countries produce so much more output per worker than others?, Quarterly Journal of Economics, 114, 83-116.

Jaffe, A. B., 1989, Real effects of academic research, American Economic Review, 79, 957-970.

Johnson, H. G., 1965, The economics of the brain drain: The Canadian case (Minerva).

Jones, C. I., 1995a, Times series tests of endogenous growth models, Quarterly Journal of Economics, 110, 495-525.

Jones, C. I., 1995b, R&D-based models of economic growth, Journal of Political Economy, 103, 759-784.

Kremer, M., 1993, Population growth and technological change: One million B.C. to 1990, Quarterly Journal of Economics, 108, 681-716.

Lucas, R. E., 1988, On the mechanics of economic development, Journal of Monetary Economics, 22, 3-42.

Mirrlees, J. A, 1982, A theory of taxation and migration, Journal of Public Economics, 18, 319-341.

Mountford, A., Can a brain drain be good for growth in the source economy?, Journal of Development Economics, 53, 287-303.

Nelson, R. and E. S. Phelps, 1966, "Investment in humans, technological diffusion, and economic growth," American Economic Review, 61, 69-75.

OECD, 2002, International mobility of the highly skilled (OECD, Paris).

Parente, S. L. and E. C. Prescott, 2000, Barriers to riches (MIT Press, Cambridge, MA).

Pomp, R. and O. Oldman, 1979, Tax measures in response to the brain drain, Harvard International Law Journal, 20 (Winter), 1-60.

Romer, P. M., 1990, Endogenous technological change, Journal of Political Economy, 98, S71-S102.

Sanders, J. M., 1992, Short or long-term macroeconomic returns to higher education, Sociology of Education, 65, 21-36.

Stephan, P. E, 1996, The economics of science, Journal of Economic Literature, 34, 1199-1235.

Wilson, J.D., 1980, The effect of potential emigration on the optimal linear income tax, Journal of Public Economics, 14, 339-353.

Wong, P. K., 1995, National innovation system: The case of Singapore (Science and Technology Policy Institute, Seoul, Korea).

Wu, Y. L., 1985, Becoming an industrialized nation: ROC's development on Taiwan (Praeger Press, New York).

Yao, S., 1981, A study on the Chinese student abroad, 1960-1979 (National Youth Commission, Taiwan).

Figure 1 Number of Taiwanese Overseas Returnees[1,2]

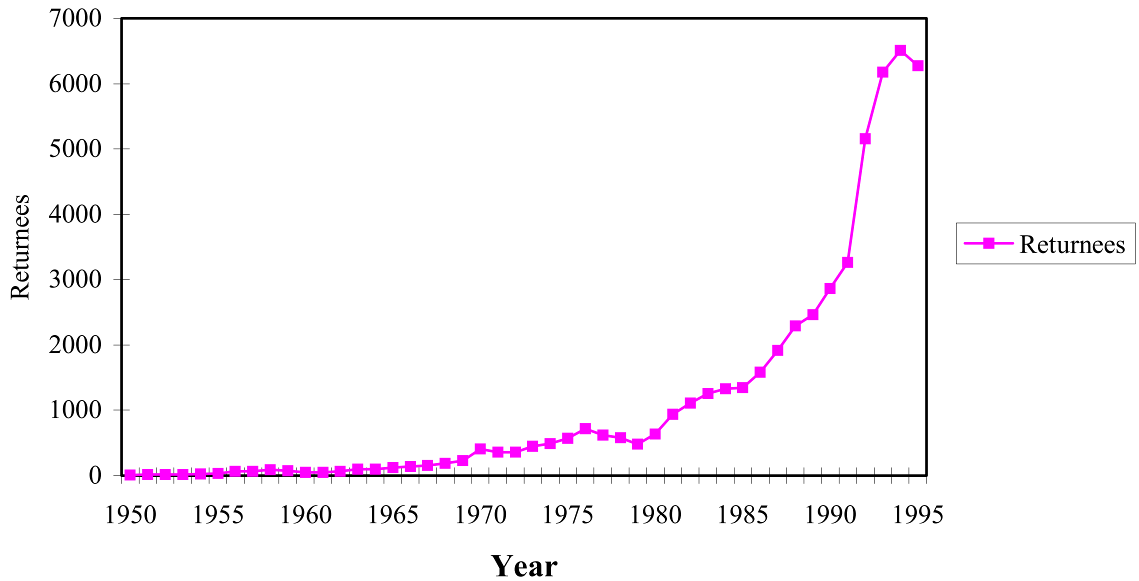
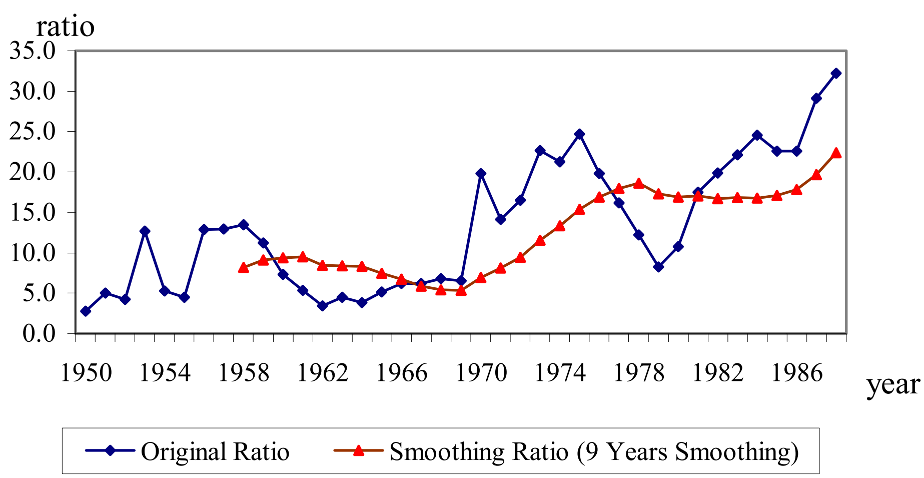


Figure 2 Taiwanese Overseas Talent Return Ratio[3]



Data Source: Ministry of Education, Taiwan (Web-page); Educational Statistics of Republic of China (1999)

Note 1. Patronage refunds of travelling expenses for students returning from abroad have been cancelled since January 1996. Therefore, we only report the data on returnees up to 1995 to avoid fluctuations due to this policy shock.

2. There are no statistics on students returning from abroad since 1998.

3. After 1989, students going overseas did not need to apply through the Ministry of Education (MOE). Therefore, after 1989, MOE could only count the number of students abroad through the number of visas issued by foreign embassies in Taiwan. The data about the number of students abroad after 1989 include short-term students and language students. To avoid statistical measurement inconsistency, we only calculate the return ratio up to 1988.

Figure 3 Case of Strong Externality Effect

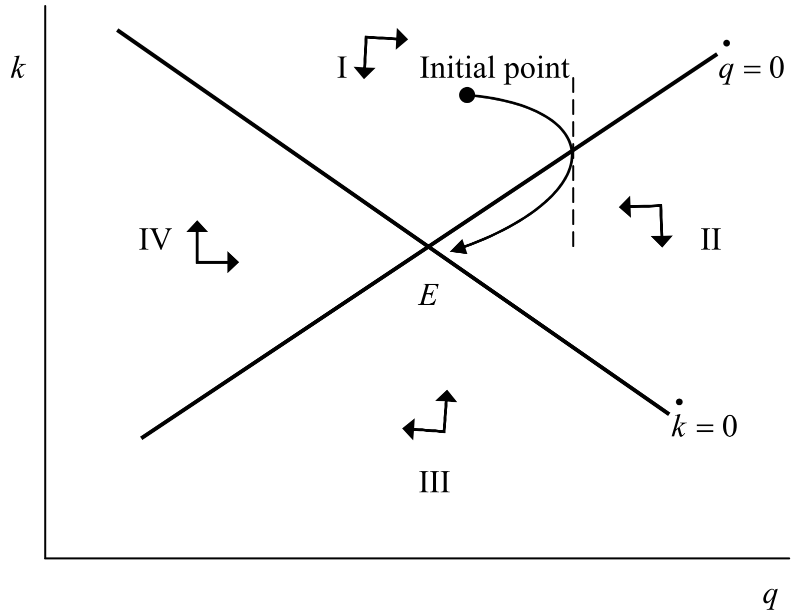
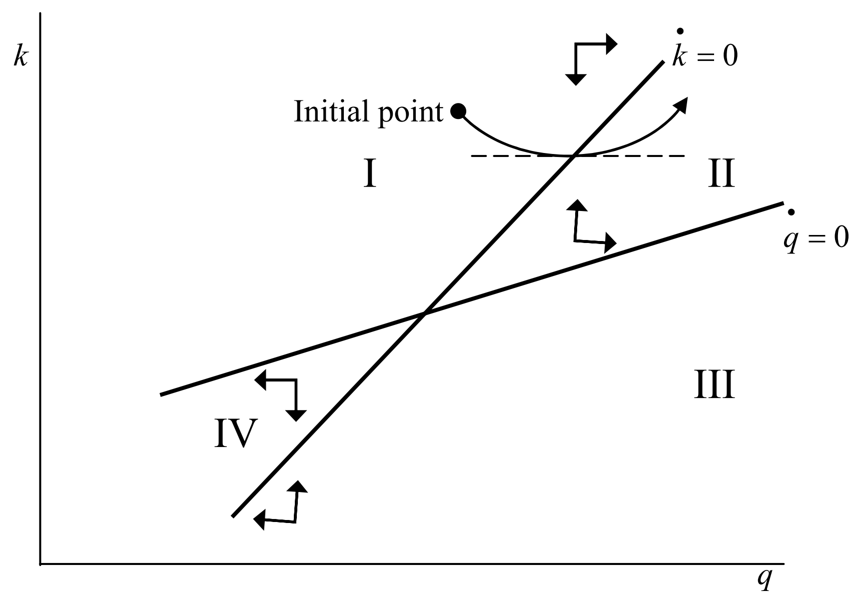


Figure 4 Case of Weak Externality Effect



Appendix. Model's Numerical Simulation:

Recall that the steady-state equilibrium point is given by:

$$k_{SS} = \frac{(c_1 + c_2)(1 + a_2 - a_1) + a_1 - 1}{a_1 + a_2 - 1}$$

$$q_{SS} = 1 + \frac{2(c_1 + c_2) - 1}{a_1 + a_2 - 1}$$

STARTING POINT: $k_o = q_o = 9$; $c_1 = 1$; $c_2 = 3$; $c_1 + c_2 = 4$;		WHEN REVERSE BRAIN DRAIN HAPPENS AFTER TALENT MOBILITY	STEADY-STATE EQUILIBRIUM POINT	
a_1	a_2		k_E	q_E
1.5	1	0.079	1.667	5.667
1.4	1	0.081	2	6
1.3	1	0.084	2.385	6.385
1.2	1	0.089	2.833	6.833
1.1	1	0.093	3.3636	7.3636
1.5	1	0.079	1.667	5.667
1.5	0.9	0.086	1.5	6
1.5	0.8	0.093	1.308	5.385
1.5	0.7	0.106	1.083	6.833

It is interesting to note that when government puts in the greater effort to make use of overseas talent in public technology transfer (a_1 increases, keeping other parameters constant), both public technology and private technology steady-state equilibrium gaps decrease. However, when government puts in effort to make use of overseas talent only in private technology transfer (a_2 increases, keeping other parameters constant), only private technology steady-state equilibrium gap decreases while public technology steady-state equilibrium gap increases.

When will brain drain occur? It is intriguing that the effort to enhance both overseas talent's public technology transfer and private technology transfer (either a_1 or a_2 increases) can shorten the time we need to attract back overseas talent.

Time Unit in our model and Growth rate in the simulation

As shown in the table above, the time we need to attract back overseas talent fluctuates between 0.08 and 0.1. Take the mean value of 0.09 as the time corresponding to Taiwan's case, with reference to the empirical evidence of Taiwan in Figures 1 and 2. We see that the time for overseas talent reversal to happen is around 18 years (1951-1969). Therefore, one unit of time in our simulation is around 200 years.

The interpretation for c_1 and c_2 is as follows. $c_2 = 3$ indicates that the exponential economic growth rate difference between North and Taiwan before talent mobility is around:

$$\frac{3}{200} = 0.015$$

In other words, the growth rate difference in the absence of international talent mobility is around 1.5 percentage points. $c_1 = 1$ represents the exogenous cross-national barrier affecting technology transfer.

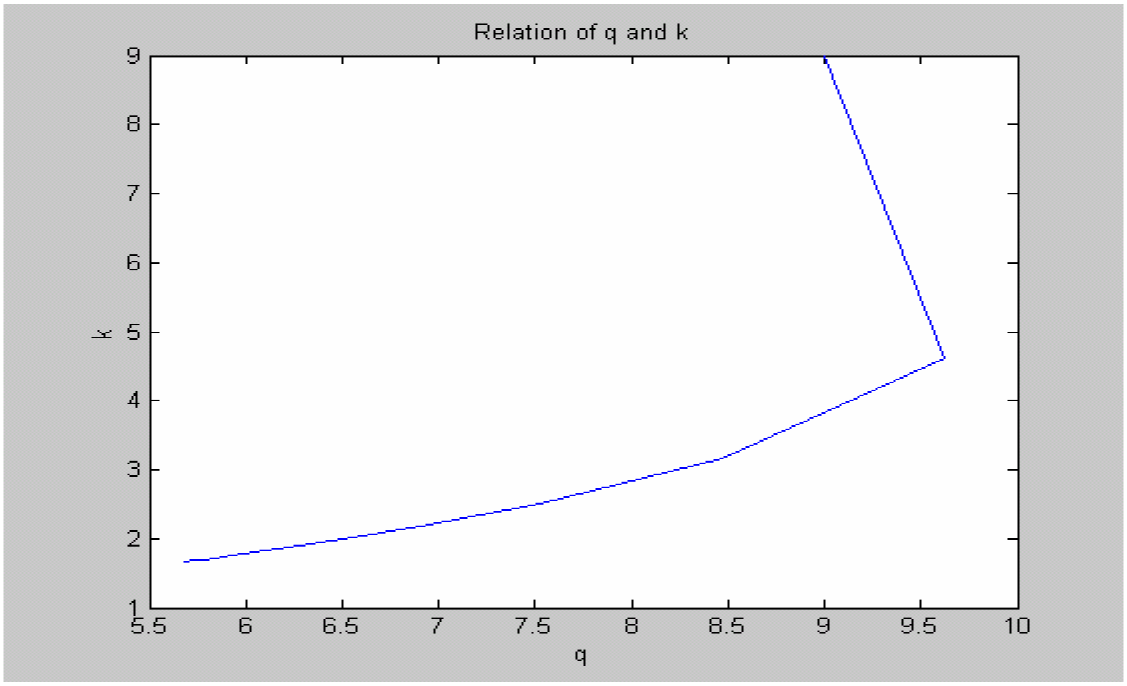
A typical time path of the model is shown below:
When $a_1 = 1.5$; $a_2 = 1$

$c_1 = 1$; (the exogenous cross-national barrier affecting technology transfer)

$c_2 = 3$; (the growth rate difference between North and South in the absence of international talent mobility)

Therefore, the steady-state equilibrium point is:
$k_{SS} = 1.667$; $q_{SS} = 5.667$

See the time path below:


Relation of q and k
k
q
9
8
7
6
5
4
3
2
1
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10