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**FOREIGN DIRECT INVESTMENT
AND SPILLOVERS: GRADUALISM
MAY BE BETTER**

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ABSTRACT

Foreign Direct Investment and Spillovers:
Gradualism May Be Better

The standard argument says that in the presence of positive spillovers foreign direct investment should be promoted and subsidized. In contrast, this Paper claims that the very existence of such spillovers may require temporarily restricting and taxing inward FDI. Our argument in favour of gradual liberalization is based on two stylized features of spillovers: first, technology transfers – and subsequent spillovers – are limited by the economy's absorptive capacity; and second, spillovers take time to materialize. By letting in capital more gradually, initial investment has the time to create spillovers – and upgrade the economy's absorptive capacity – before further investment occurs. This allows subsequent capital inflows to benefit from greater technology transfers. As a result, the economy converges to a steady state with a superior technology and a greater capital stock.

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1 Introduction

The standard argument says that in the presence of positive spillovers foreign direct investment should be encouraged and subsidized. According to this view, transition economies should implement a "big bang" liberalization of foreign investment, and additional fiscal measures should be adopted to ensure high enough levels of foreign investment. This belief in spillovers has prompted countries across the globe to apply a variety of incentive schemes to attract foreign investment (Hanson, 2001).

Yet, some emerging economies have followed a much more gradual approach in liberalizing the inflow of foreign capital. China, for instance, started opening up some of its coastal areas at the end of the 1970s, following Deng Xiaopeng's "Open Door Policy", and has since then continued to liberalize inward FDI in a piecemeal fashion (Chunlai, 1997). This slow dismantling of restrictions has been justified as a way of limiting internal opposition to the reform process (Qiang and Laffont, 1999). It may also reflect a trial and error approach to liberalization (Jia, 1994). Of course other reasons may warrant a cautious approach to liberalizing the inflow of foreign capital. For instance, FDI may compete local industry out of the market, reducing the host country's welfare (Glass and Saggi, 1999). In addition, the empirical quest for spillovers has become increasingly elusive in recent years, further weakening the case for subsidizing and promoting FDI (Aitken and Harrison, 1999).[1]

The contribution of our paper is to provide a novel rationale for the gradual liberalization of inward FDI. We claim that the very presence of positive spillovers may require temporarily restricting foreign investment.[2] This goes against the accepted wisdom that spillovers should imply encouraging and subsidizing foreign investment. In particular, we deviate from the standard literature on FDI and spillovers in two ways. First, we show that, in the presence of spillovers, gradualism can be welfare superior compared to a "big bang" approach. Second, the corresponding optimal policy may require foreign investment to be taxed in the early stages of liberalization, and subsidized in the later stages.

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[1] The debate on the existence of spillovers is still largely unsettled though. For instance, a recent paper by Keller and Yeaple (2003) finds significant international technology spillovers to U.S. manufacturing firms. For surveys of this empirical literature, see Blomström and Kokko (1998) and Görg and Strobl (2001).

[2] This does not mean that we are taking a stance on whether spillovers are prevalent or not; rather, we are saying that, even if spillovers exist, these do not necessarily justify a "big bang" liberalization of foreign investment.

These somewhat surprising results obtain once we take into account two stylized features of spillovers: first, technology transfers — and subsequent spillovers — are limited by the economy's absorptive capacity; and second, spillovers take time to materialize. By letting capital in more gradually, initial investment has the time to create spillovers — and upgrade the economy's absorptive capacity — before further investment occurs. This allows subsequent capital inflows to benefit from greater technology transfers. As a result, the economy converges to a steady state with a superior technology and a greater capital stock. It may therefore pay off to restrict foreign investment in the initial stages of liberalization.

Again, the Chinese experience can serve as an illustration. Though the reasons behind Chinese gradualism are diverse and complex, some features of how China opened up to foreign investment lend support to our description. As pointed out by Jia (1994), China started by allowing FDI into some of its coastal cities, because it was believed those areas were best prepared to benefit from technology transfers. It was hoped that those new technologies would then diffuse from the coastline into the hinterland and the interior provinces. As this process took place, more areas were opened up to FDI. In other words, China followed a stepwise strategy. It first channelled FDI to those areas with the highest potential to attract new technologies. It then let the hinterland upgrade its absorptive capacity through a process of technology diffusion. In the meantime larger and larger areas were liberalized, starting at the coast and gradually moving inland.[3]

Our simple theoretical model has the following features. We consider a one-sector small transition economy. There is no domestic capital accumulation and no population growth. Time is discrete. Foreign investment brings technology transfers, which through learning-by-doing lead to an economy-wide externality with a one-period lag. The size of the learning externality is limited by the economy's level of development at the time the investment comes in. Learning is nonappropriable by firms so that technological progress is viewed as a pure externality. We compare the decentralized solution to the planner's solution, and show that gradual liberalization may be welfare improving.

The argument for restricting capital inflows can be split into three different steps. The first step is to show that a given amount of foreign capital leads to a bigger improvement in technology if it comes in more gradually. For example, consider an economy that receives 10 units of foreign investment. If all 10 units enter in the first period, the technology

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[3]See Jia (1994), *op. cit.*, Chapter 4.

transfers will be limited by the host country's absorptive capacity at the beginning of the first period. If, instead, the 10 units enter over two periods, the first 5 units, through learning-by-doing, upgrade the economy's absorptive capacity by the beginning of the second period, so that the last 5 units are able to benefit from greater technology transfers. As a result, the economy's technology improves more if the 10 units come in over two periods.

The second step is to show that gradual liberalization leads to a steady state with a more advanced technology and a greater capital stock. This is easy to see: if the gradual inflow of a given amount of foreign capital brings greater technological progress, the returns to capital will also be greater. If the same capital stock can sustain higher returns, then the same returns can sustain a bigger capital stock. As a result, when the economy's returns to capital converge to the world interest rate, and a steady state is reached, both the technology level and the capital stock will be greater.

The third step is to show that temporary restrictions on foreign investment may be necessary to ensure the optimal outcome. The trade-off between faster short run growth (with lower steady state welfare) and slower short run growth (with higher steady state welfare) would be of no policy concern if it were not for the existence of externalities. But given that technology transfers lead to economy-wide learning externalities, private agents may not have the right incentives to time their investments in a socially optimal way. In that case the social planner may need to intervene by temporarily restricting capital inflows.

After analytically showing that gradual liberalization may be welfare improving compared to the "big bang" approach, we use numerical simulations to illustrate our point. A first exercise assumes that the planner can use quotas to restrain FDI. In our benchmark case, the planner's solution increases welfare by 2.7%, compared to a situation of complete liberalization. A second exercise allows for the use of taxes (and subsidies) to regulate the inflow of FDI. In that case the welfare gain rises to 11%. We find that it pays off to tax foreign investment in the early stages of liberalization, and to switch to subsidizing only when the economy approaches steady state.

This paper makes the point that positive spillovers do not necessarily justify a "big bang" liberalization of foreign investment. Once some of the features of spillovers are taken into account, the optimal strategy is shown to be one of gradual liberalization. The two

stylized facts driving this result require some further justification. The first stylized fact is that spillovers from technology transfers are not instantaneous. In an empirical study of US multinationals, Mansfield and Romeo (1980) find that it takes time for transferred technologies to become known to local firms. Sembenelli and Siotis (2002), using Spanish firm level data, also come to the conclusion that spillovers materialize with a lag. The second stylized fact is that technology transfers — and spillovers — are limited by the host country's level of development. There is a large empirical literature supporting the view that a country's absorptive capacity constrains the set of technologies that can be transferred. It is well known that an improvement in the host country's human capital or an increase in its R&D capacity has a positive effect on technology transfers (see Keller, 2001, for a survey).

Compared to the theoretical work on absorptive capacity (Keller, 1996; Glass and Saggi, 1998), the novelty of our paper is to assume that not only technology transfers depend on absorptive capacity, but that absorptive capacity also depends on technology transfers. This circular causality is important to understand our results. Starting off with low absorptive capacity, large initial inflows of capital lead to limited technology transfers, and thus to limited improvements in absorptive capacity. This, in turn, restrains the technological sophistication of future foreign investment. As a result, the host country may lose its attractiveness to foreign investors too soon, reaching a steady state with a low capital stock and a low level of technology. It may therefore pay off to follow a more gradual approach in liberalizing foreign direct investment.

2 Setup of the Model

Consider a small one-sector economy with initially a closed capital market. The aggregate production function is

$$Y = AK_0^\alpha L^{1-\alpha} \tag{1}$$

where A is a technology parameter; K_0 is the capital endowment; and L is the quantity of labor, which is taken to be constant. In the closed economy there is no capital accumulation and no technological progress. In the absence of depreciation, this implies that production does not change over time. Assuming competitive markets, the economy's rental price of capital is

$$r = \alpha A (\frac{L}{K_0})^{1-\alpha} \tag{2}$$

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Once capital markets are opened, foreign capital flows in, accompanied by technology transfers. To be more specific, the economy attracts foreign investment if at the time of capital market liberalization its rental price r is greater than the world interest rate r^*. But this is not the end of the story. Foreign investment brings technological progress, which in turn leads to further capital inflows. Before describing these dynamics in detail, we need to be more precise about technological progress in our discrete-time model.

To keep things tractable, we assume that technology transfers upgrade the entire economy's technology level. This happens through a process of learning-by-doing. In other words, learning spillovers are a pure externality, nonappropriable by firms, and affecting the whole economy.[4] Though clearly simplifying, this assumption does not drive our results: the rationale for gradual liberalization — as opposed to a "big bang" approach — is not due to technological progress being an economy-wide externality.

Instead, the optimality of piecemeal liberalization has to do with two stylized features of spillovers from FDI.

Stylized fact 1 *Technology transfers — and spillovers deriving from them — are limited by the host country's absorptive capacity.*

Stylized fact 2 *Spillovers from technology transfers take time to materialize.*

The first stylized fact says that the host country's absorptive capacity constrains the set of technologies that can be transferred (Glass and Saggi, 1998). This idea dates back to Abramovitz (1986) who argued that a country's catch up potential depends on its technical competence. There is ample empirical support for this view. For instance, in a study of 69 countries Borenzstein et al. (1998) find that the absorptive capacity of developing economies — as measured by their stock of human capital — limits the adoption of advanced technologies.[5]

The second stylized fact says that new technologies do not achieve their full potential at the moment of introduction (Young, 1991, 1992). In a study of technology transfers by U.S. multinationals, Mansfield and Romeo (1980) show that it takes time for transferred technologies to become known to local firms. Using Spanish firm level data, Sembenelli

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[4]This differs from the vintage capital story, where subsequent generations of machines become technologically more advanced. In that case, we would expect learning to be vintage-specific (Solow, 1960). Young (1991) takes an intermediate view by assuming that new capital creates limited spillovers to older vintages.

[5]For further empirical references, see Keller (2001).

and Siotis (2002) analyze the dynamic effects of FDI and also find evidence suggesting that spillovers are not instantaneous.

These two stylized facts translate into the following two properties of the technology function in our discrete time model.

Property 1 *The set of technologies that can be transferred through foreign investment at time t is limited by the host country's absorptive capacity, measured by its technology level at the beginning of time t.*

Property 2 *Technology transfers due to foreign investment at time t cause positive spillovers at time $t + 1$.*

To clarify the first property, we can think of the rest of the world being at the technology frontier. Technologies are ranked by their level of sophistication. As in Young (1991), there is a natural order to learning: an economy must first dominate simple technologies before it can move to more advanced ones. The same holds for technology transfers through foreign investment. The host country's level of technical competence — its absorptive capacity — constrains the set of technologies that can be transferred.

Regarding the second property, the literature has generally considered learning to be either a function of cumulative production (Young, 1991) or investment (Kaldor, 1957; Arrow, 1962). The former view reflects the idea that learning requires experience, and thus time; the latter view claims that learning can only be sustained through continued investment. In some sense our model combines these two views: learning is a function of technology transfers — and thus of investment —, but it materializes with a one period lag.

Properties 1 and 2 allow us to postulate the following technology function:

$$A_{t+1} = A_{t+1}^* - (A_{t+1}^* - A_t)e^{-\lambda(K_t - K_{t-1})}$$

where

$$A_{t+1}^* = \begin{cases} A_t + \gamma & \text{if } A_t + \gamma \le A^* \\ A^* & \text{else} \end{cases} \tag{3}$$

where λ and γ are exogenously given parameters. An example may help to highlight the features of this function. In period t we start off with technology level A_t. In period t foreign investment, $K_t - K_{t-1}$, is accompanied by technology transfers, which lead to a

higher level of technology A_{t+1} in period $t+1$. Technological progress between t and $t+1$ depends in a concave way on the amount of foreign investment in period t. However, this learning function has an upper bound A_{t+1}^*, because the economy's absorptive capacity at time t constrains the set of technologies that can be transferred. More specifically, the technology can never improve by more than γ between any two periods t and $t+1$, without of course ever surpassing the world's technology frontier A^*.

Assuming the capital market is opened up at time $t = 1$, the economy's production function now requires time subscripts:

$$Y_t = A_t K_t^\alpha L^{1-\alpha} \tag{4}$$

where $K_t = K_0 + \sum_{s=1}^{t}(K_s - K_{s-1})$. Since returns to foreign capital are paid to foreign investors, domestic welfare at time t is defined as the discounted sum of future GNP — i.e., the discounted sum of labor income and domestic capital income:

$$\sum_{s=t}^{\infty} \beta^{s-t}\{w_s L_s + r_s K_0\} \tag{5}$$

where $w_s = (1-\alpha)A_s(K_s/L)^\alpha$ and $r_s = \alpha A_s(L/K_s)^{1-\alpha}$.

3   Steady state welfare

We start by describing the dynamics of the "big bang" approach. This refers to the complete and immediate liberalization of inward FDI. Given that technological progress is a pure externality, nonappropriable by firms, and affecting the entire economy, in each period capital flows in until the host country's returns to capital are equal to the world interest rate. More specifically, if at time $t = 1$, when all restrictions on capital inflows are lifted, r_1 is greater than r^*, foreign investment comes in until returns equalize. By the beginning of period $t = 2$ the economy has learned how to use the technologies transferred by foreign investment in period $t = 1$. This technological progress raises the host country's returns once again above r^*, thus attracting a fresh inflow of foreign investment. These dynamics continue until the economy converges to a steady state.

The next proposition says that in the case of a "big bang" liberalization the host country's steady state technology will be strictly below that of the rest of the world.

Proposition 1 *Under a "big bang" liberalization of inward FDI, the steady state level of technology is strictly below A^*.*

PROOF. See Appendix A.1.

The intuition is straightforward: if technological progress is not sufficiently strong to compensate for the effects of capital inflows, the rental price of capital converges to the world interest rate before technologies converge. While obviously depending on the shape of our technology function, our claim makes sense: it is unlikely that foreign investment alone will suffice to bridge the technology gap of emerging economies.

Imposing (temporary) capital controls increases steady state welfare. This is stated in the next proposition.

Proposition 2 *Gradualism in the form of imposing (temporary) controls on the inflow of foreign capital raises the host country's steady state welfare compared to the "big bang" approach.*

PROOF. See Appendix A.2.

To understand this result, go back to our two stylized facts: technology transfers are limited by the host economy's absorptive capacity, and learning how to use those transfers takes time to materialize. By restricting foreign investment, the economy has the time to learn about the technology transfers from the previous period, thus upgrading its absorptive capacity before more capital comes in. This allows future foreign investment to transfer more sophisticated technologies. It follows that for a given stock of foreign capital, the economy reaches a higher level of technology — and returns are higher — if that capital came in more gradually. If the same capital stock can sustain higher returns, then the same returns can sustain a greater capital stock. Therefore, compared to the steady state under the "big bang" approach, when returns eventually converge to the world interest rate, the capital stock will be greater and the technology more advanced.

4 Optimal path of foreign investment

Although temporarily restricting the inflow of foreign investment increases steady state welfare, this comes at the cost of lower short run growth. The economy therefore faces a tradeoff. On the one hand, limiting capital inflows increases long run welfare. On the other hand, by slowing down capital accumulation and technological progress, restricting foreign investment dampens the economy's short run growth.

In this section we study this tradeoff by numerically solving the social planner's problem and comparing it to the benchmark case of complete capital market liberalization. In doing so, we distinguish between two cases, depending on the policy instruments available to the social planner. We start by looking at the possibility of introducing quotas on foreign investment. Though this is enough to show that temporary restrictions may be welfare improving, we would expect taxes to lead to a Pareto superior outcome by providing additional government income. In a second exercise we therefore consider taxes as a way of controlling capital inflows, and confirm our prior. A further advantage of analyzing taxes (and subsidies) consists in allowing us to compare our results to the standard case for subsidizing foreign investment.

4.1 Optimal path of foreign investment using quotas

In this exercise the social planner determines the optimal path of foreign capital inflows using quotas. In other words, for each period a maximum amount of foreign investment is announced. As soon as the quota for a given period is reached, no further capital is allowed to enter.[6] To determine these quotas, the planner solves the following maximization problem:

$$\max_{\{K_t, A_{t+1}...\}} \sum_{t=1}^{\infty} \beta^{t-1}[w_t L + r_t K_0] \tag{6}$$

$$\text{s.t. } A_{t+1} = A_t + \gamma - \gamma e^{-\lambda(K_t - K_{t-1})}$$

$$w_t = (1-\alpha)A_t K_t^\alpha L^{-\alpha}$$

$$r_t = \alpha A_t K_t^{\alpha-1} L^{1-\alpha}$$

$$r_t \geq r^*$$

$$A_1, K_o \text{ given}$$

According to (6), the planner chooses both the sequence of capital stocks and the sequence of technologies that maximize the discounted sum of future GNP; however, it should be obvious that the first and the last constraint imply that the sequence of capital stocks determines the sequence of technologies. The social planner's only degree of freedom is therefore to decide how much capital to let in each period. However, for reasons of exposition, it is more convenient to write down the maximization problem with respect to

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[6]Alternatively, the government could auction off the rights to invest. In that case quotas would act in the same way as taxes.

both the sequence of capital stocks and the sequence of technologies. Note furthermore from the fourth constraint that the domestic return to capital cannot fall below the world interest rate. If technological progress takes the form of an externality nonappropriable by firms, then under complete capital market liberalization foreign investment comes in until returns equalize. Consequently, quotas can never cause returns to drop below those in the rest of the world.

To solve the problem, we normalize the labor supply to $L = 1$ and substitute the wage and the interest rate expression into the objective function. This gives us the following Lagrangian

$$\mathfrak{L} = \sum_{t=1}^{\infty} \beta^{t-1}[(1-\alpha)A_t K_t^{\alpha} + \alpha A_t K_t^{\alpha-1} K_0] + \mu_{t+1}(A_{t+1} - A_t + \gamma + \gamma e^{-\lambda(K_t - K_{t-1})}) +$$
$$\phi_t(\alpha A_t K_t^{\alpha-1} - r^*)] \tag{7}$$

and the corresponding Kuhn-Tucker conditions for all t

$$\frac{\partial \mathfrak{L}}{\partial K_t} = \beta^{t-1}[\alpha(1-\alpha)A_t K_t^{\alpha-1} + \alpha A_t K_t^{\alpha-2} K_0] + \mu_t \beta^{t-1} \lambda \gamma e^{-\lambda(K_t - K_{t-1})} +$$
$$\beta^{t-1} \phi_t \alpha A_t K_t^{\alpha-2}(\alpha - 1) + \mu_{t+1} \beta^t \lambda \gamma e^{-\lambda(K_{t+1} - K_t)} = 0$$
$$\frac{\partial \mathfrak{L}}{\partial A_{t+1}} = \beta^{t-1} \mu_t - \beta^t \mu_{t+1} + \beta^t[(1-\alpha)K_{t+1}^{\alpha} + \alpha K_{t+1}^{\alpha-1} K_0] + \beta^t \phi_{t+1} \alpha K_{t+1}^{\alpha-1} = 0$$
$$\mu_{t+1} > 0 \quad \text{and} \quad A_{t+1} = A_t + \gamma - \gamma e^{-\lambda(K_t - K_{t-1})}$$
$$\text{either} \quad \phi_t = 0 \quad \text{and} \quad r_t > r^* \quad \text{or} \quad \phi_t > 0 \quad \text{and} \quad r_t = r^*. \tag{8}$$

The Kuhn-Tucker conditions, together with the initial conditions in (6), are then used to numerically determine the optimal path of foreign capital accumulation. The exact algorithm is described in Appendix B.

4.1.1 Benchmark case

To study the quantitative properties of our model, we assume that each period lasts for two years. In other words, it takes two years for foreign investment to have an effect on the host country's technology. Though this may seem like a long lag, Mansfield and Romeo (1980) find a mean time of four years between a technology transfer and access to the new technology by local industry. We use the following parameter values for our benchmark exercise: the world interest rate r is set at 4%; the capital income share takes the standard value $\alpha = 1/3$; and the discount factor β is chosen to be 0.96. Given that we are considering

periods of two years, this corresponds to an annual world interest rate of 2% and an annual discount factor of 0.98. After setting the labor force $L = 1$ and the initial technology level $A_0 = 1$, we choose a domestic capital stock K_0 such that the initial domestic interest rate is $r = 5.5\%$ (or 2.7% annually). In addition, we take the following values for the parameters of the technology function: $A^* = 3$, $\gamma = 0.35$ and $\lambda = 0.05$. These values are consistent with a realistic rate of technological progress. We will return to this issue at the end of this section.

Figure 1 plots the capital stock, investment, technology and welfare (GNP), contrasting the planner's solution (dashed line) to the case of complete capital market liberalization (full line). Though in our simulations each period corresponds to two years, we have relabelled the horizontal axis in our figures to reflect years. This should facilitate interpretation. As expected, the planner's solution ("gradualism") brings short run welfare losses but long run welfare gains, compared to complete liberalization ("big bang"). Under the planner's solution steady state GNP stands at 3.8, compared to a figure of 3.64 in the case of complete liberalization, a difference of about 5%. As for overall welfare, the following result is worth emphasizing:

Result 1 *For the following parameter values $r^* = 0.04$, $r_0 = 0.055$, $\alpha = 1/3$, $\beta = 0.98$, $L = 1$, $A_0 = 1$, $A^* = 3$, $\gamma = 0.35$ and $\lambda = 0.05$, if the planner can use quotas to restrict inward FDI, the discounted sum of future GNP is 2.7% higher under the planner's solution ("gradualism") than under complete capital market liberalization ("big bang").*

This difference in welfare may not seem that substantial, but we have to take into account that the government is not using the most efficient instrument to restrain foreign direct investment. If instead of using quotas, the government were to use taxes, the difference would become a lot bigger. The case of taxes will be studied in section 4.2.

As for the level of technology, Figure 1 shows that its steady state level rises from 1.35 under complete capital market liberalization to almost 1.4 under the planner's solution, an improvement of about 4%. Note that in our model economy the technology level increases by more than 30% over a period of 30 years. This is largely consistent with empirical evidence. As reported by Gourinchas and Jeanne (2003), countries such as Hong Kong, Singapore, Cyprus, Israel and Mauritius increased their productivity relative to the U.S. by more than 25 per cent over the period from 1960-1995. In the specific case of Hong Kong that increase was as high as 78 per cent. As for the capital stock, our model

economy shows it to more than triple over a period of three decades. Again, this is in line with empirical findings. Nelson and Pack (1997), for instance, report that in the Asian transition economies capital per worker increased four-fold over the period 1960-1995. A note of caution is in order though: while over a period of 30 years our results are in line with the cited evidence, it remains true that in our model economy most of the change happens in the first decades following liberalization.

4.1.2 Sensitivity Analysis

In order to have a clear understanding of what is driving the numerical results, we now perform a sensitivity analysis with respect to the main parameters used in the baseline experiment. Figure 2 shows the performance of the model economy when the social planner cares more about the future. In particular we now set $\beta = 0.99$. Compared to the baseline case, this amounts to putting more weight on long run gains, and less weight on short run losses. As a result, the planner's solution entails stronger restrictions on initial capital inflows. This leads to greater losses in short run GNP and larger gains in steady state GNP. Overall, the quantitative differences between the planner's solution ("gradualism") and complete liberalization ("big bang") become more pronounced.

As a second variation on the benchmark case, we lower γ from 0.35 to 0.1. This corresponds to decreasing the economy's absorptive capacity. Not surprisingly, as shown in Figure 3, the differences between the planner's solution and complete liberalization become less pronounced. Indeed, it is obvious from our technology function (3) that a lower γ reduces the option value of postponing investment.[7] Conversely, a higher γ should lead to stronger restrictions on capital inflows. However, there is a limit to that argument. If γ is high enough, the absorptive capacity of the economy may coincide with the world's technology frontier. In that case, restricting capital inflows would cease to improve the host country's absorptive capacity. This is shown in Figure 4, which sets $\gamma = 0.6$.

A third variation of the benchmark case involves changing λ. Figure 5 shows what happens when we lower λ from 0.05 to 0.03. This corresponds to a more shallow learning curve in each period; a given amount of investment leads to less technological progress. Here again, the option value of postponing investment goes down, so that restricting capital

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[7]For a given level of investment in period t, $K_t - K_{t-1}$, the marginal effect on technology of letting in one more unit of capital is $\lambda\gamma e^{-\lambda(K_t - K_{t-1})}$, whereas the marginal effect on technology by postponing the inflow of the extra unit until next period is $\lambda\gamma$.

inflows becomes less profitable.[8] As a result, the difference between the planner's solution and complete liberalization becomes smaller.

4.2   Optimal path of foreign investment using taxes and subsidies

We now solve for the optimal path of foreign investment, assuming the planner can use taxes and subsidies. Compared to the previous exercise, we should expect taxes to be welfare improving over quotas, as they lead to additional government income during the periods that restrict capital inflows. Moreover, allowing for subsidies, in addition to taxes, enables the planner not just to restrict, but also to encourage foreign capital inflows. Introducing this possibility facilitates comparing our results to the standard case for subsidies when there are positive externalities from foreign investment.

We must be precise about what is being taxed or subsidized. For instance, if subsidies would only apply to investment, and not to the existing capital stock, this would encourage capital to leave the country temporarily to re-enter as new investment. Also, if only foreign investment were to be taxed, and not the entire capital stock, investors might be willing to put up with returns below r^* at the time of entry, to reap returns above r^* in future periods. To keep things simple, we therefore assume that taxes and subsidies apply to the entire capital stock, and not just to new investment.

The social planner's maximization problem can therefore be written as:

$$\max_{\tau_t, A_{t+1}, \dots} \sum_{t=1}^{\infty} \beta^{t-1}[w_t L + r_t K_0 + \tau_t(K_t - K_0)] \qquad (9)$$

$$\text{s.t. } A_{t+1} = A_t + \gamma - \gamma e^{-\lambda(K_t - K_{t-1})}$$

$$w_t = (1 - \alpha)A_t K_t^{\alpha} L^{-\alpha}$$

$$r_t = \alpha A_t K_t^{\alpha-1} L^{1-\alpha}$$

$$\tau_t = r_t - r^*$$

$$A_1, K_o \text{ given}$$

The planner chooses a sequence of tax rates and technologies that maximizes the discounted sum of future GNP plus tax revenues from foreign capital. Though we said before that taxes apply to the entire capital stock, taxing domestic capital does not change domestic welfare. This explains why in the objective function taxes only affect foreign capital. The

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[8]See footnote 6.

first three constraints are obvious. The fourth constraint says that the net return to capital should equal the world interest rate. Since externalities are economy-wide, and since taxes apply to the entire capital stock, agents invest until returns equalize. As in the exercise with quotas, the first and the last constraint imply that the sequence of capital stocks determine the sequence of technologies, so that the planner can only decide how much capital to let in by setting the tax rates. Note that tax rates can be negative; in that case capital is being subsidized.

Using the same parameter values as before, Figure 6 compares the planner's solution with taxes (and subsidies) to the case of complete liberalization. As with quotas, we observe that in the initial periods the planner restrains capital inflows, using taxes. However, the novel result is that in later periods the planner turns to subsidies to encourage foreign investment. Compared to the exercise with quotas, using taxes and subsidies is welfare improving. This was to be expected, as taxing foreign capital leads to additional income, and subsidizing introduces a further degree of freedom.

To be more precise, using taxes and subsidies gives a steady state welfare level of 4.44, an improvement of 17% compared to the case of quotas, and an increase of 22% compared to the case of complete liberalization. Of course these long run gains must be weighted against the short run losses. Whereas the overall welfare gain — as measured by the increase in the discounted sum of GNP — from using quotas was 2.7%, in the case of taxes and subsidies the overall gain rises to 11%. These results can now summarized:

Result 2 *For the same parameters as in Result 1, if the social planner can use taxes and subsidies, the optimal solution requires inward FDI to be taxed in the early stages of liberalization, and subsidized in the later stages. The discounted sum of future GNP is 11% higher under the planner's solution than under complete capital market liberalization.*

The optimality of changing from taxes in the early periods to subsidies later on is not surprising, as there are two opposing forces at work. On the one hand, as in the standard literature, the existence of externalities calls for subsidies. On the other hand, having capital enter gradually increases the size of these externalities, so that taxes may be needed. In the early periods after capital market liberalization, it is likely that the second effect dominates the first one, so that the planner chooses to tax. However, once we get closer to the steady state, and capital inflows have slowed down, the first effect starts to dominate, so that the planner chooses to subsidize. Note that in the standard literature on

foreign investment and externalities, this second force is absent, so that the optimal policy always calls for subsidies.

5 Conclusion

This paper has presented a novel rationale for the gradual liberalization of inward FDI by showing that the presence of spillovers may require temporarily restricting the inflow of foreign capital. This stands in contrast with the standard argument, which claims that spillovers should call for the promotion, rather than the restriction, of foreign investment. Our seemingly surprising result is a consequence of incorporating two stylized features of spillovers into our theoretical model. First, the sophistication of technology transfers — and subsequent spillovers — is limited by the host country's absorptive capacity. Second, spillovers take time to materialize. As a result, if foreign investment enters gradually, it has the time to create spillovers, and upgrade the country's absorptive capacity, before more capital comes in. Subsequent capital inflows will then benefit from greater spillovers. This means that a given amount of foreign investment leads to more technological progress if it enters more gradually. Compared to complete capital market liberalization, restricting foreign investment leads to a steady state with a bigger capital stock and a superior technology.

Although it is well known that spillovers are limited by the host country's absorptive capacity (Keller, 1996), in this paper we point out that the host country's absorptive capacity is also limited by spillovers. This circular causation leads to path dependence: how much technological progress we get from a given amount of foreign capital depends on how fast that capital came in. As shown by our numerical simulations, it may pay off to temporarily restrict foreign investment. Previous explanations of a gradualist approach to liberalizing FDI have typically relied on political economy arguments (Aizenman and Yi, 1998; Laffont and Qiang, 1999). Instead, in this paper we have proposed a simple economic explanation of the same phenomenon.

A   Proofs of Proposition

A.1   Proof of Proposition 1

The proof proceeds in two steps:

(a) Compare the technology function given by (3), henceforth referred to as technology function 1, to technology function $A = A^* - (A^* - A_0)e^{-\lambda(K-K_0)}$ (where $K - K_0$ is the accumulated inflow of foreign investment), henceforth referred to as technology function 2. We show that for any amount of capital inflows, the technology level under technology function 2 is greater than or equal to the technology level under technology function 1.

(b) We then show that under technology function 2 the economy's technology level in stationary state is strictly below A^*.

Step (a) and step (b) then allow us to complete the proof.

Let us first prove step (a). We start by showing that the marginal effect of capital inflows on the technology level is greater under technology function 2 than under technology function 1. Take some level of technology A'. For technology function 1, we bias the results against us by taking the marginal effect on technology when $I = 0$ (since timing does not matter, we are dropping time subscripts):

$$\frac{\partial A}{\partial I}\big|_{\{I=0, A=A'\}} = \lambda\alpha \tag{10}$$

where $\alpha \leq A^* - A'$. Compare this to the marginal effect on technology of capital inflows under technology function 2: $\frac{\partial A}{\partial I}\big|_{A=A'} = \lambda(A^* - A_0)e^{-\lambda K}$, where K can be derived from the fact that $A' = A^* - (A^* - A_0)e^{-\lambda K}$, so that:

$$\frac{\partial A}{\partial I}\big|_{A=A'} = \lambda(A^* - A') \tag{11}$$

Since $\alpha \leq A^* - A'$, the marginal effect of capital inflows is weakly superior under technology function 2 than under technology function 1. Starting off with identical initial conditions, this implies that for a same amount of capital inflows, the technology level under technology function 2 will be greater than or equal to the technology level under technology function 1. This concludes the proof of step (a).

Let us now prove step (b). Under technology function 2 we know that A^* is only reached if K goes to infinity. But as K goes to infinity, the return to capital goes to 0. Since the world interest r^* is assumed to be strictly positive, in steady state K must be finite, so that the technology level must be strictly below A^*. This concludes the proof of step (b).

From (a) and (b) it follows that the steady state level of technology is weakly inferior under technology 1 than under technology 2, and therefore strictly lower than A^*. ∎

A.2 Proof of Proposition 2

Take the sequence of accumulated capital inflows under complete capital market liberal-ization, $\{K_1, K_2, ..., K_t, K_{t+1}, ...\}$, and call this sequence 1. Following Proposition 1, this sequence reaches a steady state technology level $A^{*1} < A^*$. Now take a different sequence of accumulated capital inflows, $\{K_1/2, K_1, K_2, ..., K_t, K_{t+1}, ...\}$, and call this sequence 2. In other words, the capital inflows during period 1 in sequence 1 are spread equally over two periods in sequence 2; from then onwards period t capital inflows in sequence 2 are identical to period $t - 1$ capital inflows in sequence 1.

The rest of the proof will go through the following steps: (a) It will be shown that for any given level of accumulated capital inflows the technology level is higher in sequence 2 than in sequence 1; (b) This implies that in sequence 2 the technology level A^{*1} is reached for a lower level of capital inflows than in sequence 1; (c) we then design a new sequence of accumulated capital inflows, sequence 3, which coincides with sequence 2 until A^{*1} is reached, after which we let foreign capital come in freely. It is easy to show that sequence 3 (which involves capital controls until A^{*1} is reached) leads to a higher steady state level of technology and welfare, compared to sequence 1 (full capital market liberalization).

We start by proving step (a) and (b). Initial productivity for both sequences is identical: A_1. In sequence 1 capital inflows K_1 give the following technology level:

$$A^1(K_1) = A_1 + \gamma - \gamma e^{-\lambda K_1} \tag{12}$$

As said before, in sequence 2 this same amount of foreign investment K_1 enters equally spread over two periods, so that once learning has occured the technology level increases to:

$$A^2(K_1) = A_1 + 2\gamma - 2\gamma e^{-\frac{\lambda K_1}{2}} \tag{13}$$

The derivative of $A^2(K_1) - A^1(K_1)$ with respect to K_1 is strictly positive if $K_1 > 0$. Given that $A^2(K_1) - A^1(K_1) = 0$ when $K_1 = 0$, this implies that $A^2(K_1) > A^1(K_1)$ as soon as $K_1 > 0$.

To complete the proof of (a) and (b) we now show that if $A^2(K_t) > A^1(K_t)$, then $A^2(K_{t+1}) > A^1(K_{t+1})$. (Note that K_t refers to the period t accumulated capital inflows in sequence 1, and thus to the period $t + 1$ accumulated capital inflows in sequence 2.) In sequence 1 the technology level after an accumulated inflow of K_{t+1} is:

$$A^1(K_{t+1}) = \begin{cases} A^1(K_t) + \gamma - \gamma e^{-\lambda I_{t+1}} & \text{if } \gamma < A^* - A^1(K_t) \\ A^* - (A^* - A^1(K_t))e^{-\lambda I_{t+1}} & \text{else} \end{cases} \tag{14}$$

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where $I_{t+1} = K_{t+1} - K_t$. Likewise, under sequence 2 the technology level after an accumulated inflow of K_{t+1} is:

$$A^2_{t+1} = \begin{cases} A^2(K_t) + \alpha - \alpha e^{-\lambda I_{t+1}} & \text{if } \alpha < A^* - A^2(K_t) \\ A^* - (A^* - A^2(K_t))e^{-\lambda I_{t+1}} & \text{else} \end{cases} \qquad (15)$$

Given that $A^2(K_t) > A^1(K_t)$, there are three possibilities: (i)$\gamma < A^* - A^2(K_t)$ and $\gamma < A^* - A^1(K_t)$; (ii) $\gamma \geq A^* - A^2(K_t)$ and $\gamma < A^* - A^1(K_t)$; (iii) $\gamma \geq A^* - A^2(K_t)$ and $\gamma \geq A^* - A^1(K_t)$. In each of the three possibilities, subtracting (14) from (15) gives us the result that $A^2(K_{t+1}) > A^1(K_{t+1})$. Therefore, if sequence 1 reaches A^{*1} in steady state, it must be that sequence 2 reaches A^{*1} for a lower level of capital inflows. This completes the proof (a) and (b).

We now prove part (c). The capital inflows in sequence 3 are identical to those in sequence 2 until A^{*1} is reached; after that the capital market is fully liberalized, so that capital inflows are determined by the condition that returns to capital should equal the world interest rate. From (b) we know that sequence 2, and thus sequence 3, reaches A^{*1} for an accumulated stock of foreign capital inferior to that in sequence 1. This implies that returns to capital are strictly above r^*. At this point capital markets are fully liberalized, so that capital comes in until returns equalize. Since the technology level in sequence 3 is equal to the steady state level in sequence 1, it is obvious that after the inflow of foreign investment the capital stock in sequence 3 will likewise equal the steady state capital stock in sequence 1. The difference, however, is that sequence 3 has not reached steady state. Since there has been a strictly positive inflow of foreign capital, the technology level in the next period increases, thus pushing returns to capital back above r^*. This leads to further capital inflows, so that in the steady state corresponding to sequence 3 both the capital stock and the technology level are greater than in sequence 1. ∎

B   The Computational Algorithm

The computational procedure used to solve for the optimal solution of the model follows Auerbach and Kotlikoff (1987) and it is an iterative technique often referred to as Gauss-Seidel method. Notice that since the economy undergoes a transition in which conditions change over time and the social planner is assumed to take into account the consequences of current actions on the entire path of future levels of technology, it is necessary to solve simultaneously for allocations in all transition years, so that the solution is time consistent.

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In order to implement this procedure we assume that the economy reaches a steady state in 500 periods and we have checked that it was not binding (in fact in all of the experiments a steady state is reached before period 30). After working out with the first order conditions and substituting away the path of technology, we arrive to the following optimal condition for each K_t at each t

$$\beta^{t-1}A_t\alpha(1-\alpha)[K_t^{\alpha-1} - K_t^{\alpha-1}K_0] + \beta^t\gamma\lambda e^{-\lambda(K_t-K_{t-1})}[(1-\alpha)K_{t+1}^\alpha + \alpha K_{t+1}^{\alpha-1}K_0] +$$
$$\sum_{i=1}^{\infty}\beta^{t+i}[\gamma\lambda e^{-\lambda(K_t-K_{t-1})} - \gamma\lambda e^{-\lambda(K_{t+1}-K_t)}][(1-\alpha)K_{t+i+1}^\alpha + \alpha K_{t+i+1}^{\alpha-1}K_0] = 0. \quad (16)$$

Then, the steps of the algorithm are the following.

- Given initial conditions K_0 and the initial state of technology A_1 provide a guess for the path of the capital stock $\{K_t\}_{t=1}^{t=500}$.

- Using $\{K_t\}_{t=1}^{t=500}$, and the current state of technology A_t, obtain the optimal capital stock chosen by the planner for each t $\{K_t^*\}_{t=1}^{t=500}$, by means of the first order conditions, subject to the constraint that the maximum inflow of capital is restricted by the world interest rates.

- If the implied $\{K_t^*\}_{t=1}^{t=500}$ are equal to the guesses of the first step the algorithm is stopped. If not, update the guess and go back to the first step.

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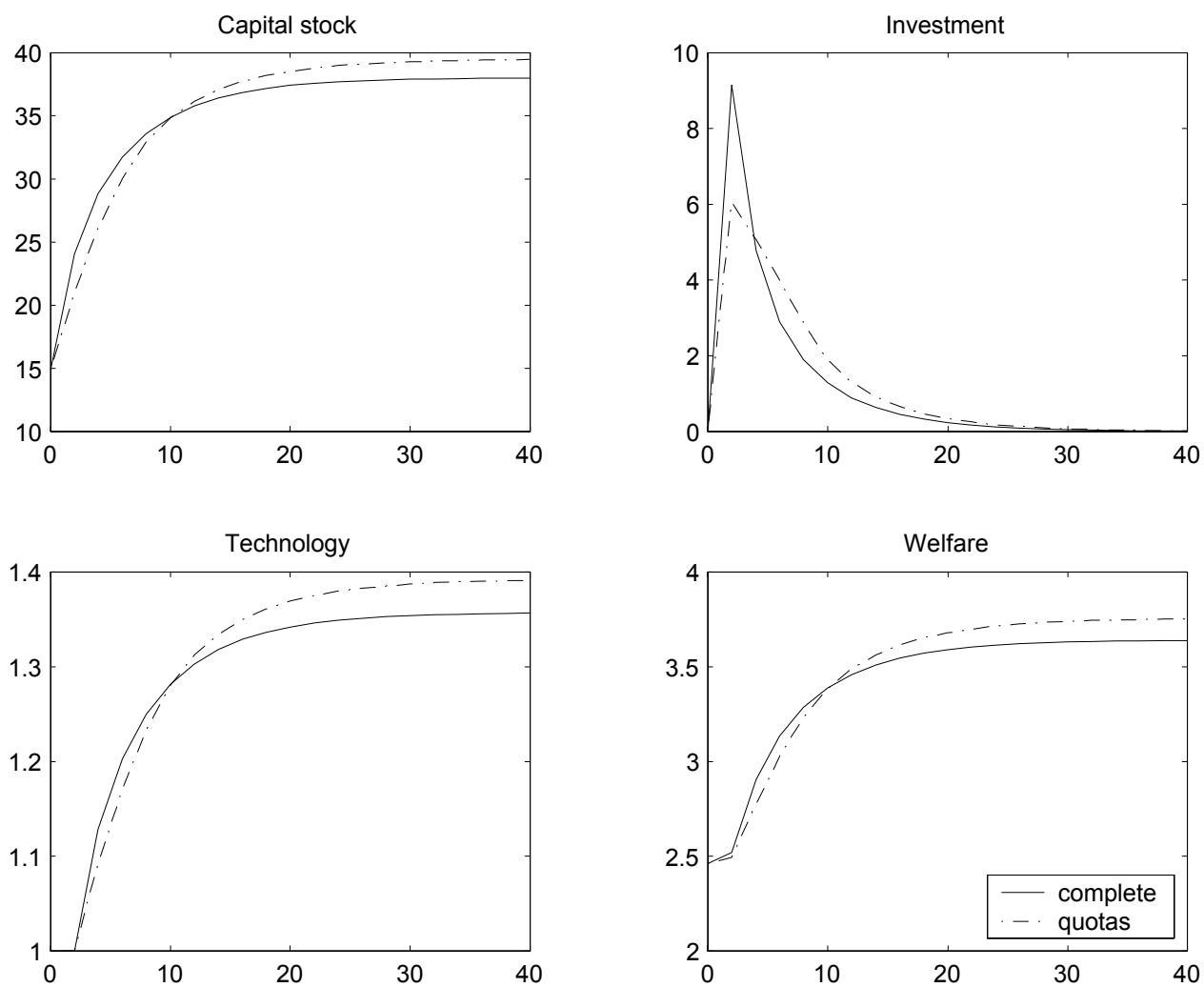
Figure 1: Quotas vs. complete liberalization (benchmark case)
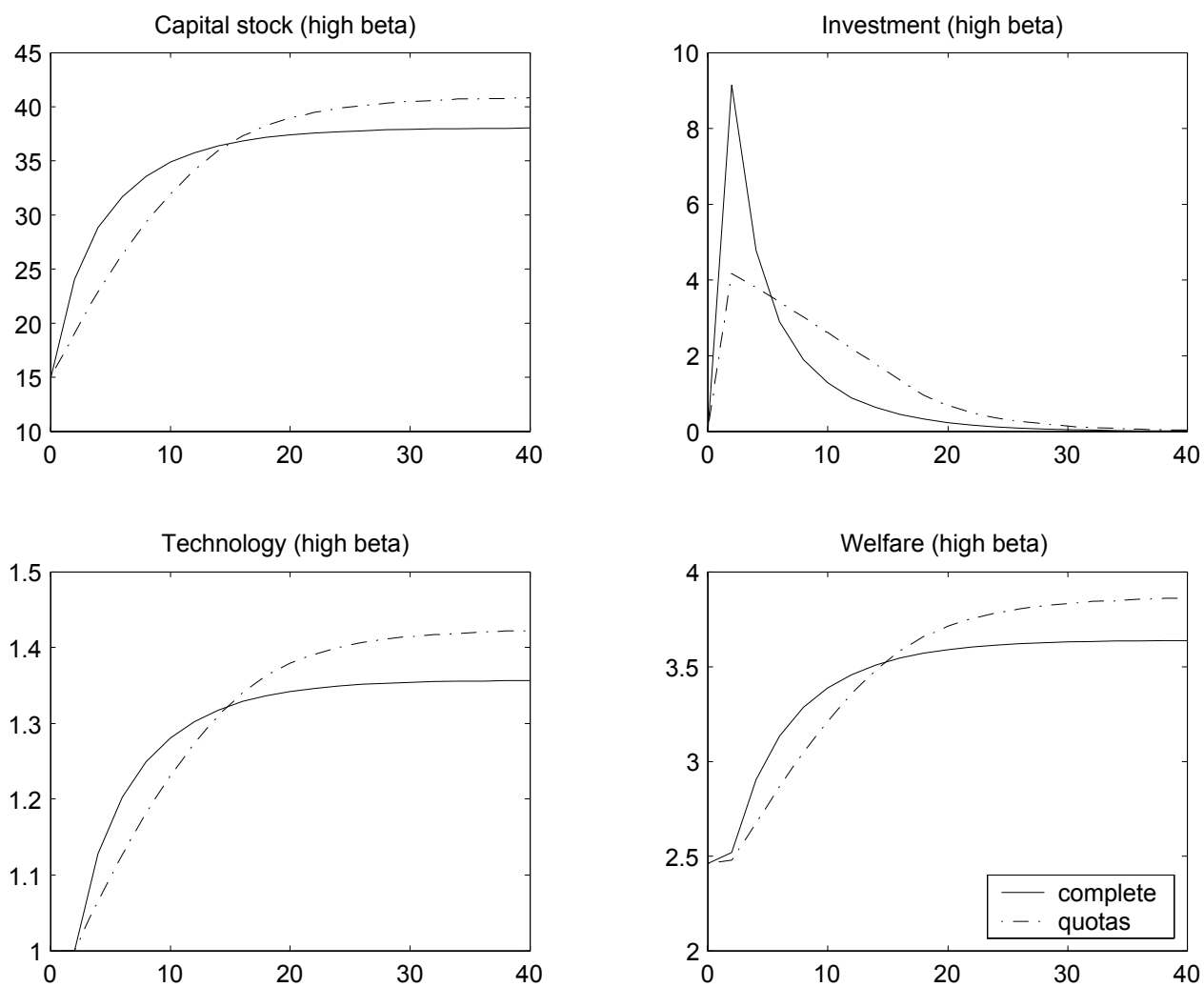
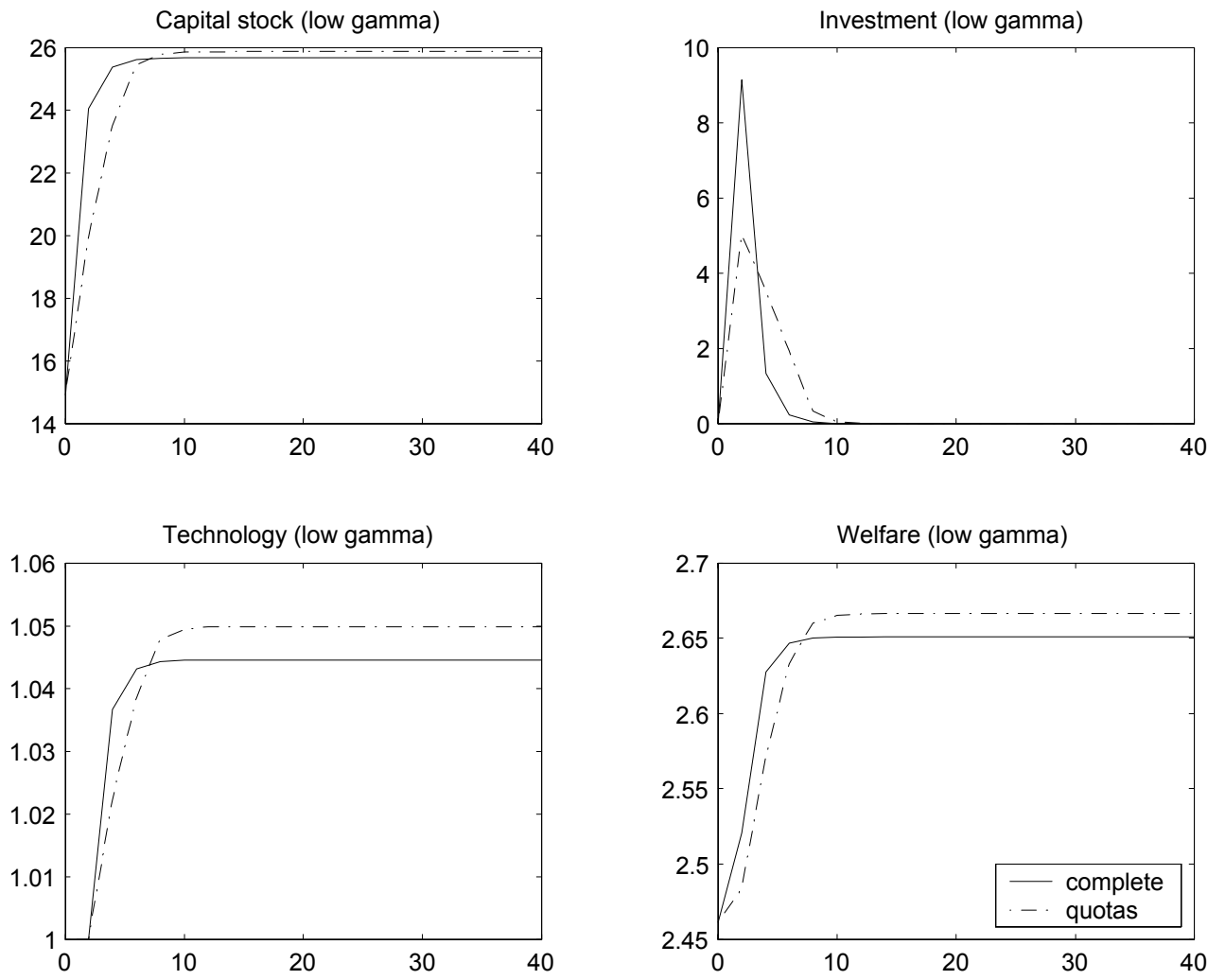Figure 2: Quotas vs. complete liberalization (high discount factor).

Figure 3: Quotas vs. complete liberalization (low absorptive capacity)
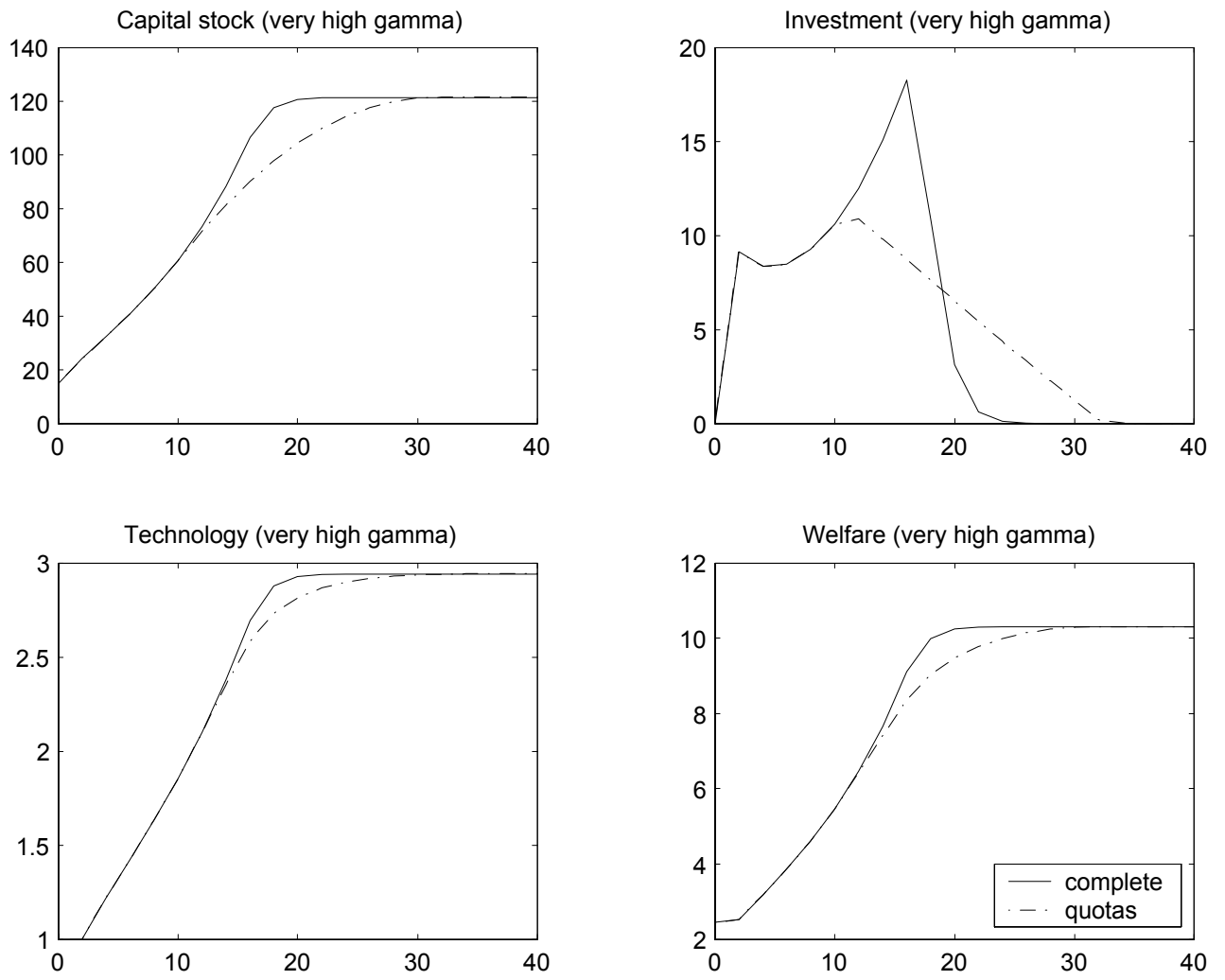
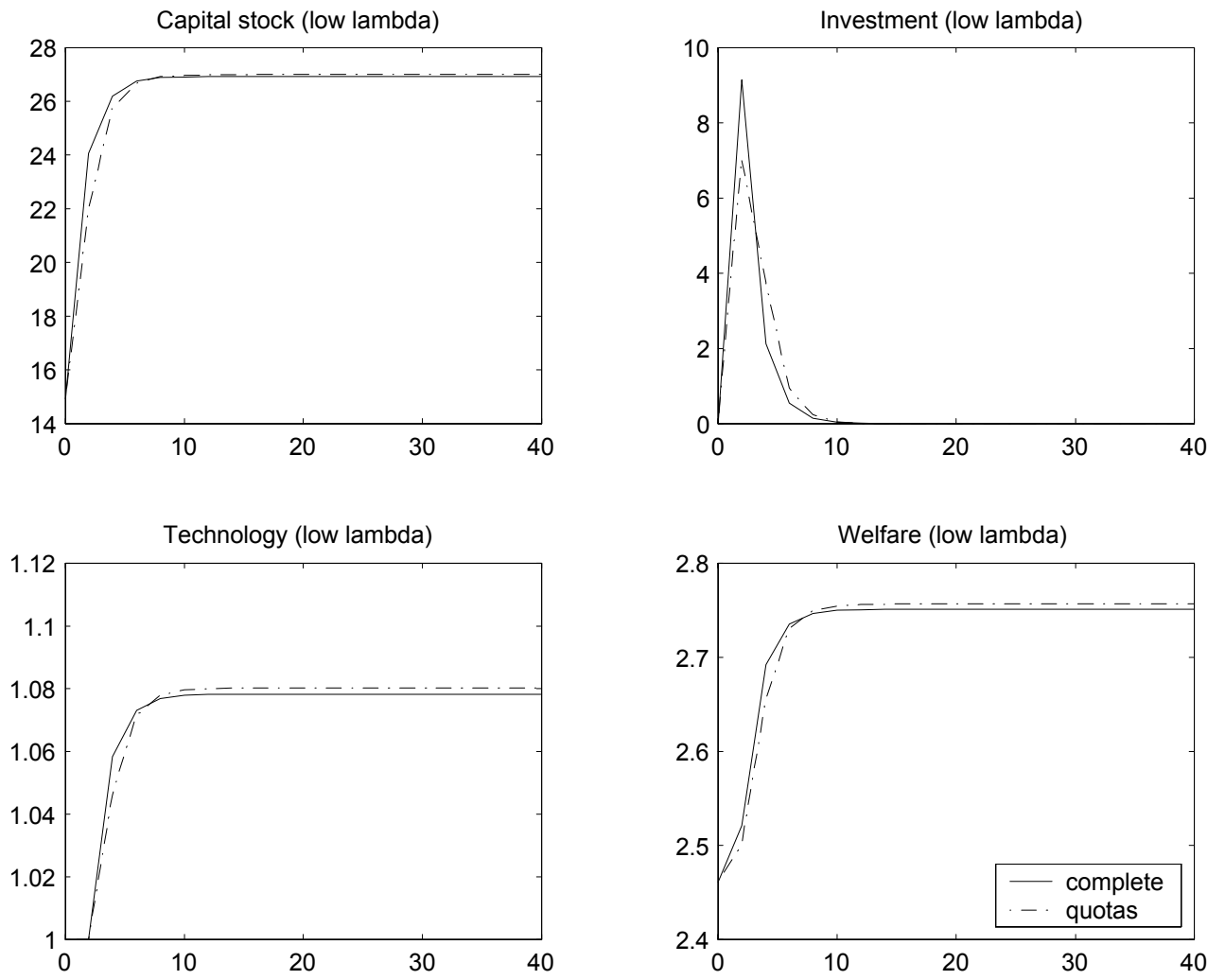Figure 4: Quotas vs. complete liberalization (very high absorptive capacity)

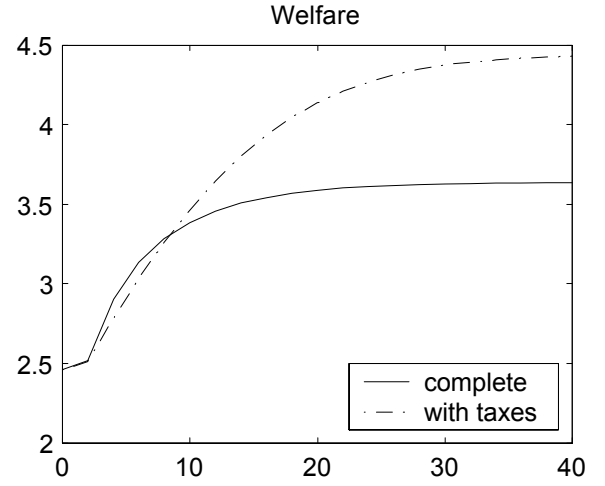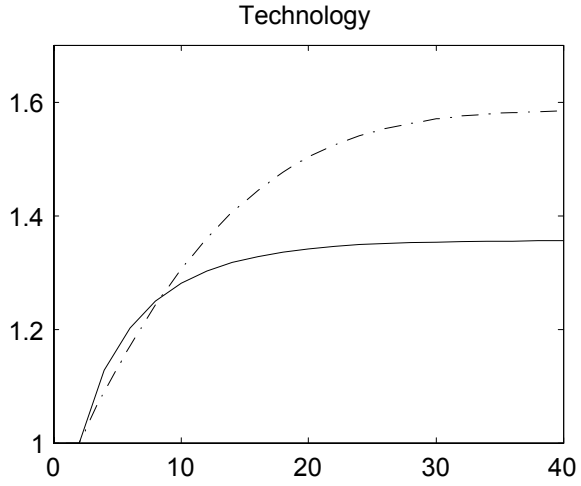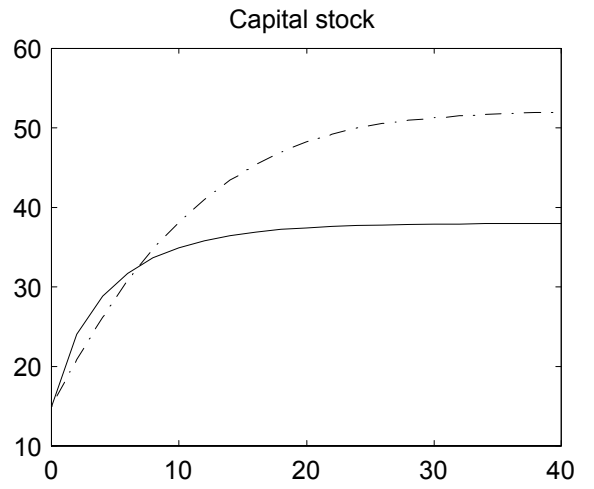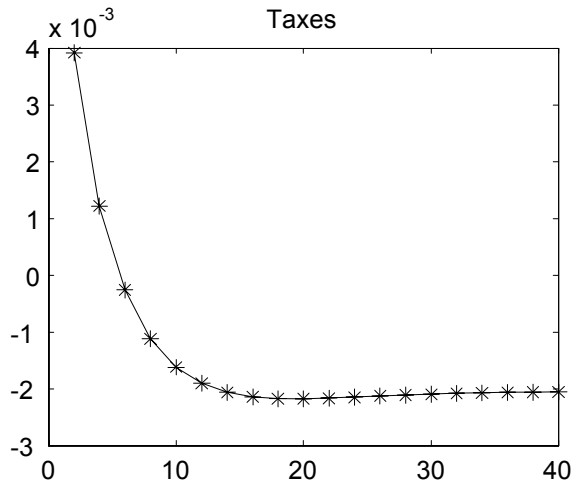Figure 5: Quotas vs. complete liberalization (shallow learning curve)

Figure 6: Taxes (and subsidies) vs. complete liberalization (benchmark case)