IMF Working Paper

WP/98/140

INTERNATIONAL MONETARY FUND

European I Department

From Autarky to Integration: Imitation, Foreign Borrowing, and Growth

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September 1998

Abstract

The effects on growth of the integration of an autarkic country into the world economy are analyzed, focusing on the differing roles of imitation and innovation in human capital accumulation. The country initially concentrates on imitation of foreign knowledge; subsequently, as it approaches the knowledge frontier, innovation plays a greater role. Late developers catch up with the rest of the world more rapidly than early developers, reflecting the relatively large imitation opportunity available to them. Restrictions on foreign borrowing reduce the speed of adjustment to the steady state and lower growth and welfare for the country that imposes them.

JEL Classification Numbers: F15, F43, O31, O41

Keywords: Growth, Imitation, Innovation, Knowledge Gap, Foreign Borrowing

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[1]The author thanks Carlo Cottarelli, Casey Mulligan, Jonathan D. Ostry, and seminar participants at the University of Chicago and Georgetown University for helpful comments and suggestions.

Contents

SUMMARY

This paper analyzes the transitional and steady-state effects of opening an economy to foreign technology and ideas. Impediments to the flow of knowledge, such as those that exist under autarky, result in large opportunities for imitation of foreign knowledge when such barriers are removed. Therefore, in the transition from autarky to integration, a country initially concentrates heavily on imitation, for which there exists a large catch-up opportunity. Subsequently, as the knowledge gap narrows and the stock of human capital rises, indigenous innovation plays a greater role and growth slows.

Late-developing countries tend to catch up more rapidly than countries that developed earlier, reflecting the fact that late developers face a larger knowledge gap—and, therefore, a lower cost of imitation—than earlier developers. As a result, during the initial stages of integration, the late developer will have a faster rate of imitation and total human capital accumulation than a country that developed earlier.

For countries that are far from the technology frontier, and for which the return to human capital investment is correspondingly high, international capital markets will be relied upon to meet consumption needs. Restrictions on foreign borrowing will prolong the adjustment toward the steady state and alter the time profiles of the main macroeconomic variables by diverting resources from investment to current production. Specifically, the imposition of capital controls depresses both growth and consumption relative to the case of perfect capital mobility and lowers welfare.

I. INTRODUCTION

The main difference [between economic development today and in the past] is that today the process is much faster. It took the United States 50 years after 1840 to double per capita output. China turned the same trick in a decade after 1978.

(The Economist, January 4, 1997)

Over the past two decades, an unprecedented number of countries have been engaged in comprehensive programs of macroeconomic stabilization and structural reform—often associated with an "opening up" of their economies, i.e., the abandonment of previously autarkic policies in favor of social, political, and economic liberalization. On the economic side, these opening-up programs have typically proceeded along many tracks—from reductions in restrictions on current international transactions to capital account liberalization involving freer policies governing foreign direct investment and a less pervasive use of capital controls, all the way to reductions in knowledge barriers, which—alongside improvements in information technology and telecommunications—have enabled countries to access technologies and ideas from foreign sources more easily than in the past.

An important and longstanding issue in the economics of opening up relates to the impact on growth of various liberalization policies. While a sizable literature dealing with the growth effects of trade and capital account liberalization exists, relatively little research has been undertaken on the transitional and steady state effects of opening up an economy to foreign technology and ideas, which is the main subject of this paper. In addition, because the growth effects of opening up depend upon the economy's access to international capital markets, this paper examines how capital account restrictions affect economic growth in the context of a model where imitation of foreign ideas—together with indigenous innovation—are the main forces driving the growth process.

In the model developed below, impediments to the flow of knowledge such as exist under autarky result in large opportunities for imitation of foreign technologies when such barriers are removed. In the transition from autarky to integration in the world economy, a country will initially concentrate heavily on imitation, for which there exists a large catch-up opportunity. Subsequently, as it acquires more of the imitation spillover and its technical maturity increases, human capital accumulation will increasingly take the form of innovation. Another implication of the model is that a late developing country will take less time to accumulate a given level of human capital than an earlier developed country because of the greater body of knowledge—and imitation potential—available to the late developer. This faster catch-up—which characterized the development of a number of Asian countries in the post-War years—represents an "advantage" to developing late.

During the transition, when the return to investment is high, countries will rely on world capital markets to provide some of their consumption needs. Restricting access to international capital markets will prolong the adjustment process by diverting resources from investment to production. As a result, the rate of growth and the present value of output will be reduced. Since consumption smoothing through production is less efficient than smoothing through international borrowing and lending, capital controls will result in a welfare loss for the country that imposes them.

Previous literature on the growth effects of capital controls (for example, Modigliani (1986), and Jappelli and Pagano (1994)) focuses on the increase in the saving rate elicited by credit market imperfections and the positive impetus to growth this provides. However, as shown here, borrowing constraints may also have growth-reducing effects through a reduction in the time devoted to education. The result is consistent with De Gregorio (1996), who examines the effects of capital controls in a small open economy with both physical and human capital. However, since the free mobility of physical capital assumed in that model ensures that physical capital flows instantaneously to equalize domestic and world interest rates, the economy is always on its unique steady state growth path. In contrast, in the current model, the growth-reducing effects of capital controls are restricted to the transition period since long-run growth rates are equalized across countries through the imitation technology. Kohn and Marion (1992) also analyze the effects of opening capital markets in the context of a knowledge-based endogenous growth model. Since the change in the domestic interest rate consequent to opening up affects the level of production in thier model, both the stock of knowledge and output growth will be affected. They conclude that the welfare consequences of opening up are ambiguous and depend on the sign of the difference between the autarkic and world interest rates.[2] In the model presented here, eliminating borrowing constraints is always welfare enhancing, independent of the initial level of interest rates.

The remainder of this paper is organized as follows. In Section II, an analytical framework is developed and the solution for the competitive steady state growth path is derived. Section III discusses the transitional dynamics of a small open economy moving from an autarkic position to integration in the world economy. A comparison of the growth dynamics in the presence and absence of international capital markets is undertaken in Section IV. The main conclusions are summarized in Section V.

II. Analytical Framework and Competitive Steady State

Consider a two-country world with N (infinitely-lived) agents in country I and N* agents in country II. Preferences in both countries are given by:

[2]Moreover, long-run growth rates will be equalized only if countries share identical technologies, but initial differences in knowledge stocks ensure that income levels will differ. This contrasts with the model presented here in which both steady state growth rates *and* income levels are equated through the imitation process.

$$\int_0^\infty U[c(t)]\, e^{-\rho t}\, dt, \tag{1}$$

where c(t) is the single consumption good and ρ is the rate of time preference. For tractability, the utility function exhibits a constant intertemporal elasticity of substitution, denoted by $1/\sigma$:

$$U[c(t)] = \frac{1}{1-\sigma}[c(t)]^{1-\sigma} \tag{2}$$

Production of the perishable consumption good requires raw or unskilled labor, μ_x, in combination with human capital, h. Output in each country is produced according to the technology:

$$y(t)=[\mu_x(t)]^\gamma h(t) \tag{3}$$

where $0 < \gamma < 1$. Therefore, output is linear in the stock of human capital, whereas labor effort is subject to diminishing returns. An individual's stock of human capital is a composite factor made up of an amount accumulated by original research and development, h_O, and an amount accumulated by imitation, h_I. These two types of human capital are assumed to be perfect substitutes in the production process.

Individuals are endowed with one unit of labor per period, which is supplied inelastically. As mentioned above, labor allocated to current production is denoted μ_x, while labor allocated to human capital accumulation through imitation (innovation) is denoted μ_I (μ_O). Innovation is subject to learning-by-doing, with the productivity of labor in innovation assumed to increase directly with the stock of human capital previously acquired. Original human capital, which depreciates at the rate δ, evolves according to:

$$\nu_O \equiv \dot{h}_O(t)/h_O(t) = f\,[\mu_O(t)]h(t)/h_O(t) - \delta \tag{4}$$

$$\nu_O^*(t) \equiv \dot{h}_O^*(t)/h_O^*(t) = f^*[\mu_O^*(t)]h^*(t)/h_O^*(t) - \delta \tag{4*}$$

in countries I and II, respectively, where an asterisk denotes a function or variable pertaining to country II. The functions, f and f*, are assumed to be strictly increasing and weakly concave, with f(0) = f*(0) = 0. Concavity of f and f* reflects the increasing difficulty of accumulation at a given point in time.

The acquisition of imitation human capital requires an input of labor, $\mu_I = 1 - \mu_x - \mu_O$, and similarly for country II. This labor input reflects the effort needed to observe and learn from others, to practice reverse engineering, or to convert or adapt the knowledge of others into a usable form. The worldwide body of original knowledge (or knowledge frontier) is defined as the sum over all (N + N*) individuals' stocks of original knowledge:

$$\sum_{J=1}^{N} (h_O)_j + \sum_{1=1}^{N^*} (h_O)_i = Nh_O + N^* h_o^* \tag{5}$$

The potential for imitation is given by the pool of original knowledge developed by everyone else. Hence, the imitation potential is given by:

$$\overline{H} \equiv (N-1)h_O + N^* h_O^* \tag{6}$$

$$\overline{H^*} \equiv Nh_O + (N^*-1)h_o^* \tag{6*}$$

for countries I and II, respectively. Accumulation of original knowledge by any one individual thus not only augments his own stock of human capital but, through imitation, may increase the stocks of other agents as well.

Productivity of labor in imitation depends on the distance between the knowledge frontier and one's own stock of human capital, denoted by $(\overline{H} - h_I)$ *and* $(\overline{H^*} - h_I^*)$ in countries I and II, respectively. The larger is this distance, or knowledge gap, the greater is the potential spillover that remains to be acquired, and the lower is the cost of accumulating an additional unit of imitation human capital. Since imitation is costly, the actual amount of imitation will, in general, fall short of the potential external effect and, in the long run, may differ across countries if they have different investment technologies.

Adopted knowledge is assumed to depreciate at the rate δ in both countries. The accumulation technologies for imitation human capital in countries I and II, respectively, are given by:

$$v_I(t) \equiv \dot{h}_I(t)/h_i(t) = g[\mu_I(t)] \{\overline{H}(t) - h_I(t)\}/h_I(t) - \delta \tag{7}$$

and

$$v_I^* \equiv \dot{h}_I^*(t)/h_I^*(t) = g^*[\mu_I^*(t)]\{\overline{H^*}(t) - h_I^*(t)\}/h_I^*(t) - \delta \tag{7*}$$

where g and g * are strictly increasing, weakly concave functions of labor effort, with g(0) = g*(0) = 0.

Individuals in each country seek to maximize the discounted value of utility by choice of labor allocations and a consumption stream, subject to a wealth constraint that the labor-allocation decision engenders. With perfect capital markets, an individual's consumption decision may be separated from his labor allocation/production decision. Heterogeneity introduces the possibility of trade between countries, and thus an individual's current consumption need not, in general, equal his own current production.

Along an equilibrium path,[3] goods and factor markets clear, the interest rate is equated across countries, and the stock of original knowledge used in imitation is equal to the sum of the stocks of all private consumers. The Hamiltonian corresponding to the production problem of country I is:

$$\begin{aligned}\mathcal{H}(h_O,h_I,\lambda,\theta) &= (1-\mu_O-\mu_I)^{\gamma}(h_O+h_I)\\ &+ \lambda[g(\mu_I)[\overline{H}-h_I]-\delta h_I]\\ &+\theta[f(\mu_O)(h_O+h_I)-\delta h_O].\end{aligned} \tag{8}$$

The first order necessary conditions for a maximum are:

$$\gamma\mu_x^{\gamma-1}h = \lambda[\overline{H}-h_I]g' \tag{9}$$

$$\gamma\mu_x^{\gamma-1} = \theta f'. \tag{10}$$

These conditions require that at each date the marginal value of labor be equated in three activities: imitation, innovation, and current production. The price paths of increments to the two types of human capital in country I are governed by:

$$\dot{\lambda} = \lambda[r(t) + \delta + g] - \mu_x^{\gamma} - \theta f \tag{11}$$

$$\dot{\theta} = \theta[r(t) + \delta - f] - \mu_x^{\gamma}, \tag{12}$$

where r(t) is the interest rate at time t. Conditions analogous to equations (9)-(12) govern behavior in country II.

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[3]See van Elkan (1992) for a discussion of the differences between the competitive equilibrium and optimal steady state paths.

In the steady state, labor allocations are fixed and both countries' stocks of human capital grow at the constant common rate, ν. Convergence in growth rates of imitation and original human capital across countries is a consequence of the spillover inherent in the imitation technology, since greater original knowledge generated in one country translates into an equivalent increase in imitation potential worldwide. Furthermore, since labor allocations are fixed, world output grows at the same rate as human capital in the steady state, and each country's contribution to world output is fixed . Letting $relh \equiv h/h^*$ denote the relative per capita stock of human capital in country I, and $\hbar \equiv h_O/h$ *and* $\hbar \equiv h_O^*/h^*$ the share of original in total human capital in countries I and II, respectively, equality of growth rates in the steady state implies that *relh*, $\hbar$ and $\hbar^*$ are constant. Using the first order conditions, equations (11) and (12) can be re-written as:

$$\frac{\dot{\lambda}}{\lambda} = r(t) + \delta + g - \left[\frac{N^* \hbar^*}{relh} + N\hbar - 1 \right] \left[\frac{\mu_x}{\gamma} + \frac{f}{f'} \right] g' \tag{13}$$

$$\frac{\dot{\theta}}{\theta} = r(t) + \delta - f - \frac{\mu_x}{\gamma} f'. \tag{14}$$

Differentiating the first order conditions with respect to time, it is clear that in the steady state the prices, λ and θ, are constant. Hence, from equations (13) and (14), the interest rate will also be constant. The extent to which the stock of human capital is diversified between imitation and innovation, the variable, $\hbar \equiv h_o/h$, can be found by equating equations (13) and (14), and similarly for the foreign country. From equation (14), the world growth rate of human capital and output in the steady state is given by:

$$\nu \equiv \frac{\dot{h}}{h} = r + \left(\frac{1-\hbar}{\hbar} \right) f - \frac{\mu_x}{\gamma} f'. \tag{15}$$

Turning to the consumption decision, since preferences are homothetic, consumption growth will depend only on the interest rate. Further, since preferences are identical, consumption growth will be equalized across countries. Together with market clearing, identical homothetic preferences ensure that the common consumption growth rate is equal to the fixed rate of human capital and output growth in the steady state:

$$\frac{\dot{c}(t)}{c(t)} = \frac{\dot{c}^*(t)}{c^*(t)} = \nu. \tag{16}$$

These assumptions imply that no intertemporal trade between countries will occur in the steady state, and that the equilibrium interest rate will be given by:

$$r = \rho + \sigma \frac{\dot{c}}{c} = \rho + \sigma\nu. \tag{17}$$

From equations (15) and (17), the steady state rate of growth in the world economy can be expressed in terms of country I's labor allocations:

$$\nu = -\frac{1}{\sigma}\left(\rho + \delta - f - \frac{\mu_x}{\gamma} f'\right). \tag{18}$$

Equality of growth rates across countries implies that:

$$\gamma[f - f^*] = \mu_x^* f^{*\prime} - \mu_x f'. \tag{19}$$

Equation (18) expresses an arbitrage condition which requires that the instantaneous return from an increase in the amount of labor devoted to current production equal the discounted stream of returns generated by a marginal investment in innovation. From equation (19), it is clear that any cross-country difference in the instantaneous opportunity cost of investing in original human capital is exactly offset by a difference in future returns.

Since $\sigma>0$, equation (18) implies that growth will persist in the long run if the marginal benefit from accumulating a unit of original human capital (measured in terms of its contribution to innovation and current production) is sufficiently large to outweigh depreciation and time preference. In addition, as implied by the imitation technology, the knowledge gap is not closed in a steady state with sustained growth. Finally, it should be noted that characteristics of the steady state do not depend on initial human capital stocks; only preferences and technologies matter.[4] Therefore, if two countries have identical preference and technology parameters, but their human capital stocks differ at some point in time, in the long run each will have identical per capita levels and compositions of human capital, and identical per capita outputs.[5]

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[4]Likewise it is clear that the steady state does not depend on a country's access to international capital markets but only on underlying preference and technology parameters. The neutrality of capital restrictions does not, however, hold in the short run (see Section IV).

[5]Heterogeneous abilities in investment do not affect the convergence of growth rates, but do give rise to differences in per capita income levels. For example, if a country has a

(continued...)

III. Opening Up to Foreign Ideas: Dynamic Adjustment of a Small Open Economy

A. Model Dynamics

This section examines the transitional dynamics of a small open economy, with the rest of the world (ROW) assumed to be in a steady state described by the equilibrium of the world economy in the previous section.[6] Because the country is taken to be small, it cannot affect the world rate of interest, and its innovation activities do not appreciably contribute to the world stock of original knowledge. With the ROW assumed to be in a steady state, two state variables determine the dynamics of the system: the share of original in total human capital in the home country, h; and the relative per capita stock of human capital at home and abroad, *relh*. From the definitions of the two state variables, their laws of motion are given by:

$$\dot{relh} = relh\left[\hbar\nu_O + (1-\hbar)\nu_I - \nu^*\right] \tag{20}$$

$$\dot{\hbar} = \hbar(1-\hbar)(\nu_O-\nu_I). \tag{21}$$

Using an iso-elastic parameterization of the human capital accumulation functions:

$$f(\mu_O) = \phi\mu_O^{\alpha} \text{ and } g(\mu_I) = \psi\mu_I^{\beta}, \tag{22}$$

$$f^*(\mu_O^*) = \phi^*(\mu_O^*)^{\alpha^*} \text{ and } g^*(\mu_i^*) = \psi^*(\mu_I^*)^{\beta^*}, \tag{23}$$

where $0 < \alpha, \beta, \alpha^*, \beta^* < 1$, and $\phi, \psi, \phi^*, \psi^* > 0$, the time paths for the control variables, μ_o and μ_I, are derived from the first order conditions and the constraint on labor:

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[5](...continued)
technological advantage in imitation, it will enjoy higher per capita output than the rest of the world, other things equal. However, if the advantage is in innovation, the rest of the world is the relative beneficiary. See van Elkan (1996) for a discussion of the long-run effects of cross-country differences in investment technologies.

[6]The systems of equations characterizing the steady state of the world economy and the small open economy are presented in Appendix I.

$$\dot{\mu}_O = \mu_O \left\{ (1-\alpha)\left[1 + \frac{(\gamma-1)}{(\beta-1)}\frac{\mu_I}{\mu_x}\right] + (1-\gamma)\frac{\mu_O}{\mu_X} \right\}^{-1} * \left\{ \frac{\dot{\theta}}{\theta} + \frac{(\gamma-1)}{(\beta-1)}\frac{\mu_I}{\mu_x}\left[\frac{\dot{\theta}}{\theta} - \frac{\dot{\lambda}}{\lambda} - \frac{\left[N\hbar\frac{\dot{\hbar}}{\hbar} - \frac{N^*\hbar^*}{relh}\frac{\dot{relh}}{relh}\right]}{\left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right]} \right] \right\} \tag{24}$$

$$\mu_{\dot{I}} = \frac{\mu_I}{(1-\beta)}\left\{ \frac{\dot{\lambda}}{\lambda} - \frac{\dot{\theta}}{\theta} + (1-\alpha)\frac{\dot{\mu}_O}{\dot{\mu}_O} + \frac{\left[N\hbar\frac{\dot{\hbar}}{\hbar} - \frac{N^*\hbar^*}{relh}\frac{\dot{relh}}{relh}\right]}{\left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right]} \right\}, \tag{25}$$

where $\frac{\dot{\theta}}{\theta}$ *and* $\frac{\dot{\lambda}}{\lambda}$ are the co-state equations given by equations (13) and (14).

The growth rates of the stocks of human capital are given by:

$$\nu_O = \frac{\phi\mu_O^\alpha}{\hbar} - \delta \tag{26}$$

$$\nu_I = \frac{\psi\mu_I^\beta}{(1-\hbar)}\left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right] - \delta \tag{27}$$

$$\nu = \hbar\nu_O + (1-\hbar)\nu_I = \phi\mu_O^\alpha + \psi\mu_I^\beta\left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right] - \delta \tag{28}$$

The feasible state space is defined by the region where $0 \leq \hbar \leq 1$ and $relh \geq 0$, together with the restriction that the knowledge gap is non-negative:

$$\textit{knowledge gap} \equiv \left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right] \geq 0 \tag{29}$$

Equations (20), (21), (24) and (25) form a non-linear dynamic system in the variables $\hbar$, *relh*, μ_O, and μ_I. Notice that these equations do not depend on the *level* of human capital. Using Mulligan's (1992) "method of progressive paths," the remainder of this section describes the transitional dynamics of the actual non-linear system.

The two paths of the *non-linear* system that are analogous to the fast and slow-transient paths in a *linear* system (i.e., the eigenvectors corresponding to the larger and smaller—in absolute value—stable roots) are referred to in what follows as the backroad and turnpike, respectively. Using a benchmark set of parameter values which meet a number of requirements—including existence of the steady state with a positive growth rate, satisfaction of the transversality conditions, and local saddle-path stability around the steady state—these paths and the corresponding eigenvectors are shown in Figure 1, where the backroad (turnpike) is the negatively- (positively-) sloped dotted path.[7] The steady state is indicated by the intersection of the two trajectories. While the turnpike and backroad are close to the eigenvectors of the linearized system in the neighborhood of the steady state, this is not the case away from this region. In particular, the fast-transient path ignores the non-negativity condition on the relative human capital stocks, *relh*.

Along the turnpike and backroad, both $\hbar$ and *relh* converge monotonically to their long-run levels, referred to below as $\hbar^{ss}$ and $relh^{ss}$, respectively. If initial conditions place the economy on the backroad, where $\hbar > \hbar^{ss}$ and $relh < relh^{ss}$, the rate of imitation will exceed the rate of innovation, and the growth rate of total human capital will exceed its long-run level. Similarly, if initial conditions place the economy on the turnpike, where both $\hbar$ and *relh* are above their steady state levels, the rate of imitation will exceed the rate of innovation, and growth in total human capital will be below its long-run level. These adjustments, implied by equations (20) and (21), are required to reach the steady state. The adjustments along the opposite sections of the turnpike and backroad are symmetrical.

To solve for the dynamics from an initial position in the state space, note that the dynamic path followed by the economy in the case of a non-linear system is affected by both the turnpike and backroad, with the influence of the backroad dying out more rapidly than that of the turnpike. This implies that the dynamic path of the economy from any initial position off the backroad converges to the steady state in the direction of the turnpike. Essentially, a path off the turnpike and backroad is found by integrating backwards away from the turnpike to find the section of a trajectory along which the backroad-term is influential.

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[7]The parameter values are: σ=3, ρ=0.05, γ=0.25, δ=0.1, N*=100, N=1, ϕ=ϕ*=0.02, ψ=ψ*=0.75, α=α*=0.6, β=β*=0.3. An extensive grid search—varying the technology, preference, and production parameters—was undertaken in order to verify the robustness of the qualitative results. In particular, it was found that varying the model's parameters preserves the positive and negative slopes of the turnpike and backroad, respectively, and the ordering of the corresponding eigenvalues. Results are available from the author.

The backroad and turnpike divide the state space into four quadrants, labeled I-IV in Figure 1. Four representative trajectories—one corresponding to an initial position in each of the four quadrants—are illustrated by the dotted curves in Figure 2. The backroad (turnpike) is the negatively (positively-) sloped solid line, and the steady state equilibrium is given by the origin. One can see that, far from the turnpike, each trajectory mimics the backroad. Another feature common to each trajectory is that one state variable overshoots its steady state level during the transition.

B. Adjustment to the Steady State

Consider now the dynamics along the trajectories originating at A(0) and B(0) in Figure 2. At an initial position in quadrant I, say A(0), $\hbar$ (*relh*) is above (below) its steady state value. Moreover, at A(0), the knowledge gap is greater than in the steady state. Intuitively, at A(0), the home country has less human capital per person than the ROW and its composition of human capital is biased away from imitation, implying a large knowledge gap. Such a configuration of state variables might arise in a country that is emerging from a situation of autarky and, as a consequence, faces a large opportunity for imitation from abroad.[8]

The time paths of the state variables, labor allocations and growth rates for the dynamic adjustment from A(0) are illustrated in Figure 3. Initially, the rates of imitation (ν_I) and total human capital accumulation (ν) exceed their long-run level, while the rate of innovation (ν_O) is below its steady state level. Furthermore, a relatively large amount of labor is allocated to imitation (μ_I), coming at the expense of innovation (μ_O) and current production (μ_x). These adjustments reflect the initially high productivity of imitation—itself a reflection of the knowledge gap—and the high productivity of total human capital accumulation (see equations (27) and (28)). In contrast, since $\hbar$ is relatively large at A(0) (reflecting the initial bias of the autarkic country away from imitation), the productivity of labor in innovation is relatively small, implying that relatively few resources are devoted to this activity and that the stock of innovation human capital grows relatively slowly (see equation (26)). This pattern of growth rates of the state variables implies that, along the initial section of the adjustment path, $\hbar$ declines and *relh* rises, as shown by the dotted curve from A(0) in Figure 2.

Over time, through intensive imitation, the country will acquire more of the foreign stock of original human capital, thereby reducing the knowledge gap and its potential for imitation. As a consequence, the productivity of labor in innovation relative to imitation begins to increase, leading to a reallocation of labor towards innovation and a higher rate of growth of innovation human capital (Figure 3). As the country acquires more human capital, labor productivity in current production increases, leading to a reallocation of labor from investment towards production, which gives rise to a reduction in the growth rate of total human capital and

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[8]Initial positions in quadrant IV of Figure 1 (for example D(0)) also exhibit a large knowledge gap relative to the steady state. As can be seen from Figure 2, the initial stages of the dynamic adjustment are similar from D(0) and A(0).

output. An additional, final, stage of the adjustment involves overshooting of *relh*: this overshooting result reflects the fact that the steady state must be approached in the direction of the turnpike (which is positively sloped) and must not cross the backroad.

The framework developed here is consistent with Maddison's (1982) observation that late-developing countries tend to catch up with the ROW more rapidly than countries that developed earlier. This can be illustrated by considering two small autarkic countries, with identical preferences and technologies, that open their economies at different dates. Assume that, upon opening, each country has the same per capita level and composition of human capital, with $relh < relh^{ss}$ and $\hbar > \hbar^{ss}$. Suppose that the initial position of the early developer is represented by A(0) in Figure 2. The late developer's initial position in the state space will be different from A(0) since, during the interval between the opening up of the two countries, the ROW continues to innovate. However, since both countries have the same preferences and technologies, they will reach the same steady state, with a common level of human capital. The late developer will initially face a larger human capital stock in the ROW (h^*) and, therefore, a smaller $relh = h/h^*$. This is consistent with an initial position for the late developer directly below A(0). Intuitively, the difference in initial conditions between the two countries reflects the continued innovation in the ROW which gives the late developer a relatively large initial knowledge gap and imitation opportunity. As a consequence, the late developer will have a faster rate of imitation and total human capital growth than the early developer at a similar stage of development (measured as the time elapsed from the initial opening up of the economy). This represents an advantage to developing late.[9]

For completeness, consider the dynamics from an initial position in quadrant II of Figure 1, say point B(0) in Figure 2, where $relh > relh^{ss}$ and $\hbar < \hbar^{ss}$. This configuration implies that the knowledge gap is smaller than in the steady state, giving rise to relatively low productivity in imitation and total human-capital accumulation.[10] Such a combination of state variables might occur when a country has subsidized imitation at the expense of innovation and, therefore, has reduced the knowledge gap below its steady state level. As a consequence of this configuration of state variables, along the initial section of the adjustment path, the rate of innovation exceeds its long-run level, and the rates of imitation and total human capital accumulation are lower than in the steady state (Figure 4) . Consistent with these results, a

[9]Measured from the time of opening up, the late developer receives a welfare advantage over the early developer. However, by postponing its integration into the world economy, the late developer foregoes the opportunity of raising its growth rate earlier on and hence improving its welfare.

[10]Initial positions in quadrant III of Figure 1 (for example C(0) in Figure 2) also exhibit a smaller knowledge gap than in the steady state. As can be seen from Figure 2, the initial stages of the dynamic adjustment are similar from C(0) and B(0). Furthermore, the adjustment path for an initial position in quadrant IV is symmetric to the path corresponding to an initial position in quadrant II.

relatively large proportion of labor is devoted to innovation and current production, at the expense of imitation, in the initial stage of the adjustment. This pattern of growth rates implies that $\hbar$ rises and *relh* declines.

Over time, reflecting the past concentration on innovation rather than imitation, the knowledge gap begins to widen. This leads to increased opportunities for imitation and human-capital growth. As a consequence, during this second stage of the adjustment, increasing amounts of (labor) resources are allocated to imitation, at the expense of innovation and production, generating an increase in the rate of imitation and human-capital accumulation. Since the trajectory emanating from B(0) must approach the steady state in the direction of the turnpike, during the final stage of the adjustment, $\hbar$ overshoots its long-run value.

To conclude, the dynamic adjustment to the steady state is determined by the knowledge gap, which depends on the relative size and composition of the country's human capital stock. This knowledge gap determines the return to imitation relative to innovation, and investment relative to current production. If initially the knowledge gap is large (as under autarky), the country will face a large opportunity for investment in imitation human capital. As a result, it will devote a large proportion of its resources to imitation, and human capital growth will exceed the long-run rate. Over time, as the knowledge gap is reduced and the stock of human capital rises, resources will be shifted to innovation and current production, and the growth rate will decline. Finally, the model suggests that late developers grow faster during the initial phase of the transition since they face a large knowledge gap upon opening up; given their slower growth under autarky, however, this is not an argument for postponing integration.

IV. Opening Up and Capital Controls: The Role of Foreign Borrowing

To this point, residents of the small country were assumed to be able to borrow and lend freely in world capital markets at a given rate of interest. If, however, access to capital markets is curtailed, this will affect the pattern and speed of adjustment from any set of initial conditions.[11] This is reflected in Figure 5, which shows the backroad and turnpike in the presence and absence of capital controls. Notice that the backroad is flatter, and the turnpike

[11]As mentioned previously, the steady state is not affected by capital controls. See Appendix II for the steady state conditions for the model with capital controls

steeper, in the absence of capital markets.[12] In addition, the eigenvalues of the linearized system are smaller under capital controls, indicating slower adjustment to the steady state.

To see the effect of capital controls on the transition, consider an initial position such as A(0) in Figure 6, consistent with high imitation and growth potential. The paths to the steady state in the presence and absence of capital controls are denoted by a dashed and solid line, respectively. Under perfect capital mobility, as shown in the previous section, adjustment to the steady state from such a position initially involves a large investment of labor in the accumulation of imitation human capital, generating rapid growth in total human capital and output. Consumption grows at the constant world growth rate, which is slower than output growth. In order to satisfy the intertemporal budget constraint, consumption must initially exceed production, with foreign borrowing making up the difference.

With capital controls, consumption is constrained to equal current production, and the domestic interest rate adjusts to satisfy the marginal condition governing consumption. With the domestic interest rate higher than in the unconstrained regime, investment in human capital is reduced, thereby lowering growth and slowing adjustment to the steady state, while additional labor resources are diverted to current production. Although output is initially higher in the presence of capital controls, this relationship is subsequently reversed as human capital growth is below the level under capital mobility. Moreover, the present value of output (and consumption) is necessarily lower under capital controls. As regards consumption, both the substitution and wealth effects contribute to an initial fall relative to the perfect capital mobility case. This consumption profile generates a welfare loss of more than two hundred times the corresponding loss in the present value of output, or wealth.[13]

For completeness, consider the effect of capital controls on the dynamic adjustment from B(0) in Figure 7, which lies in the region of low relative imitation and growth opportunities. Paths to the steady state in the presence and absence of capital markets are depicted by dashed and

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[12]To understand the effect of capital controls on the shape of the backroad, consider a point on the backroad in the region where $\hbar > \hbar^{ss}$ and $relh < relh^{ss}$, consistent with a large opportunity for human capital growth. With capital mobility, an individual devotes a relatively large share of labor to investment—reflecting the high return to investment relative to the fixed world interest rate—and borrows abroad the difference between his desired consumption and output. When borrowing is precluded, however, the domestic interest rate will exceed the world rate, so time allocated to investment falls and growth accordingly slows. Hence, during the transition, a given decline in $\hbar$ will be associated with a smaller increase in human capital and *relh* under capital controls, implying that the backroad is flatter than when capital mobility is unrestricted. A similar argument establishes that the turnpike is steeper under capital controls.

[13]Both the absolute reduction in welfare and wealth arising from capital controls increase with the distance between the initial condition and the steady state.

solid lines, respectively. Under perfect capital mobility, an individual would devote a large share of labor to production and the growth rate of output would fall short of the rate in the rest of the world. As before, the level of consumption, which is determined by the present value of output, increases at the world rate of output growth. Since the home country's growth rate is lower than that in the rest of the world, output initially exceeds consumption, and the residual is lent abroad at the world rate of interest. When intertemporal trade is prohibited, however, consumption smoothing is effected through production smoothing. Under capital controls, the domestic interest rate will be below the world rate, inducing a reduction in the amount of resources allocated to production. As a result, relative to the perfect capital mobility case, output initially declines, while the growth rate of human capital increases. The lower interest rate at B(0) induces an initial rise in consumption, but this is reversed in the future, and the resulting welfare loss is thirty times greater than the corresponding loss in wealth.

Therefore, when borrowing is restricted during the transition to the steady state, output is raised while consumption and growth are reduced along the initial section of the adjustment path. In contrast, when lending restrictions are binding, production is lowered while consumption and growth are increased. In both cases, however, adjustment to the steady state is slowed, and welfare and the present value of output are reduced.

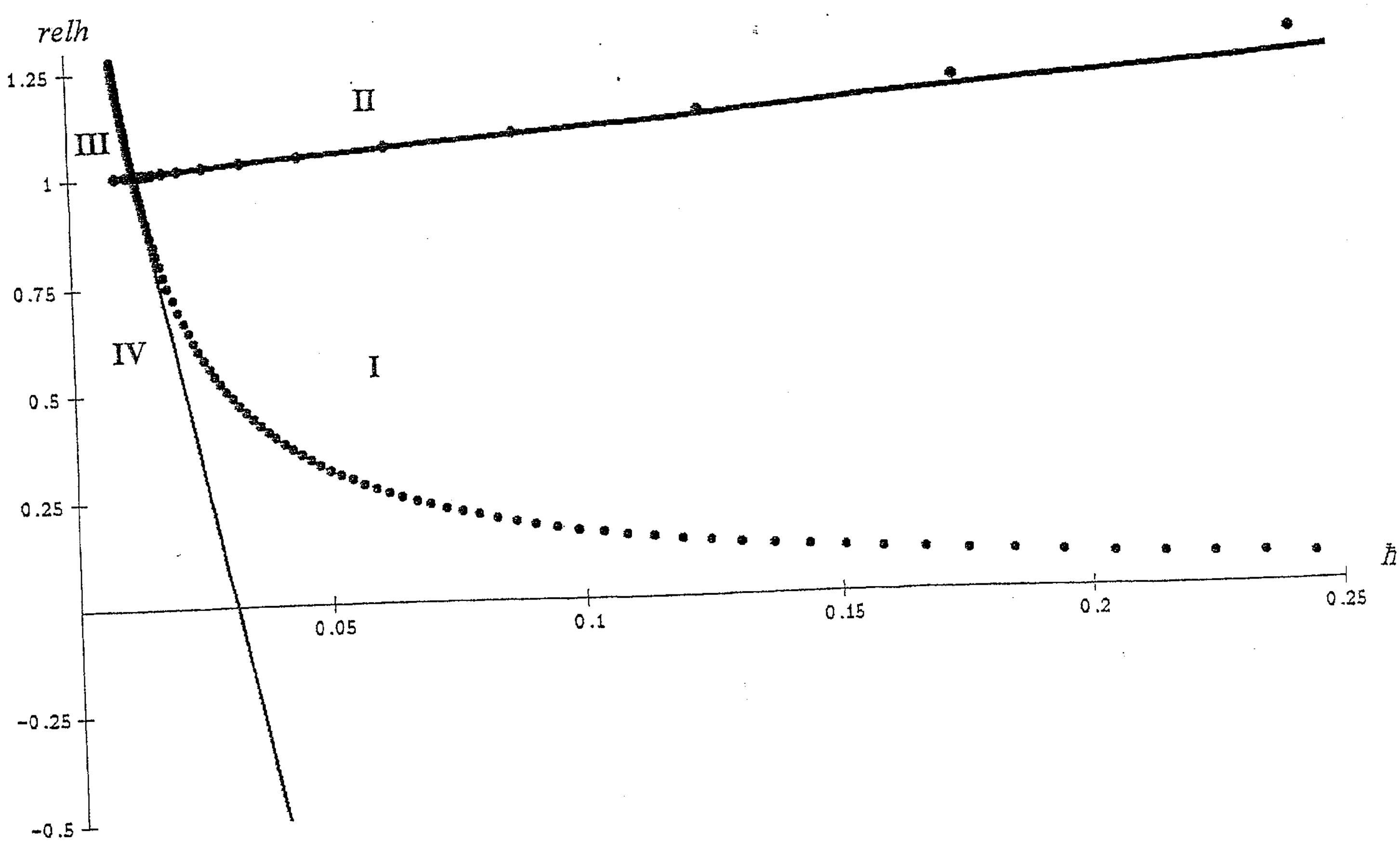
V. Conclusion

This paper has analyzed the transitional and steady state effects on growth resulting from the integration of an autarkic country into the world economy, focusing in particular on the roles of imitation of foreign ideas and technologies and indigenous innovation in the process of human capital accumulation. Since the cost of imitation is negatively related to the size of the knowledge gap between the autarkic country and the rest of the world, countries which are further from the world technology frontier will have relatively large imitation opportunities, relatively small catch-up costs, and relatively high initial growth rates upon opening up. During the initial stages of integration, countries will tend to concentrate their human capital accumulation on imitation while subsequently, as more of the imitation potential is acquired and the stock of human capital rises, indigenous innovation will play a greater role.

Late developing countries tend to catch up more rapidly than countries that developed earlier, reflecting the fact that late developers face a larger imitation opportunity from abroad—and, therefore, a lower cost of imitation—than earlier developed countries. As a result, during the initial stages of adjustment, the late developer will have a faster rate of imitation and total human capital accumulation than a country that developed earlier.

Capital controls reduce the speed of adjustment to the steady state and affect the time profiles of the main macroeconomic variables from any set of initial conditions. Specifically, with an initially large knowledge gap, restrictions on foreign borrowing depress both growth and consumption relative to perfect capital mobility. The welfare loss, moreover, is many times larger than the reduction in wealth associated with restrictions on foreign borrowing.

Figure 1. Eigenvectors, Turnpike, and Backroad for a Small Open Economy[1/]



1/ Eigenvectors are shown as solid lines. Actual trajectories are represented as dots.

Figure 2. Trajectories in Quadrants I to IV

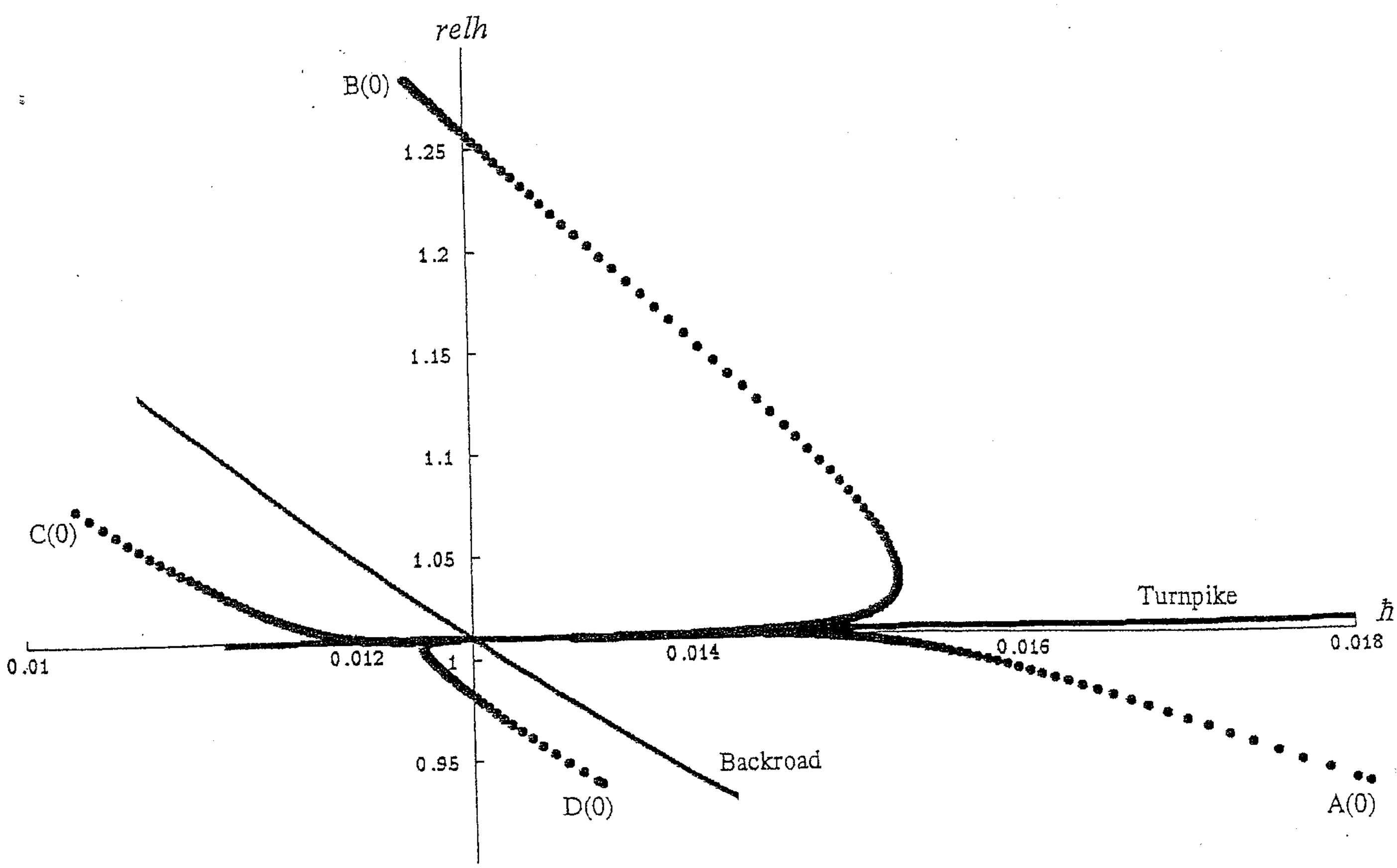


Figure 3. Time Paths from Initial Position A(0)

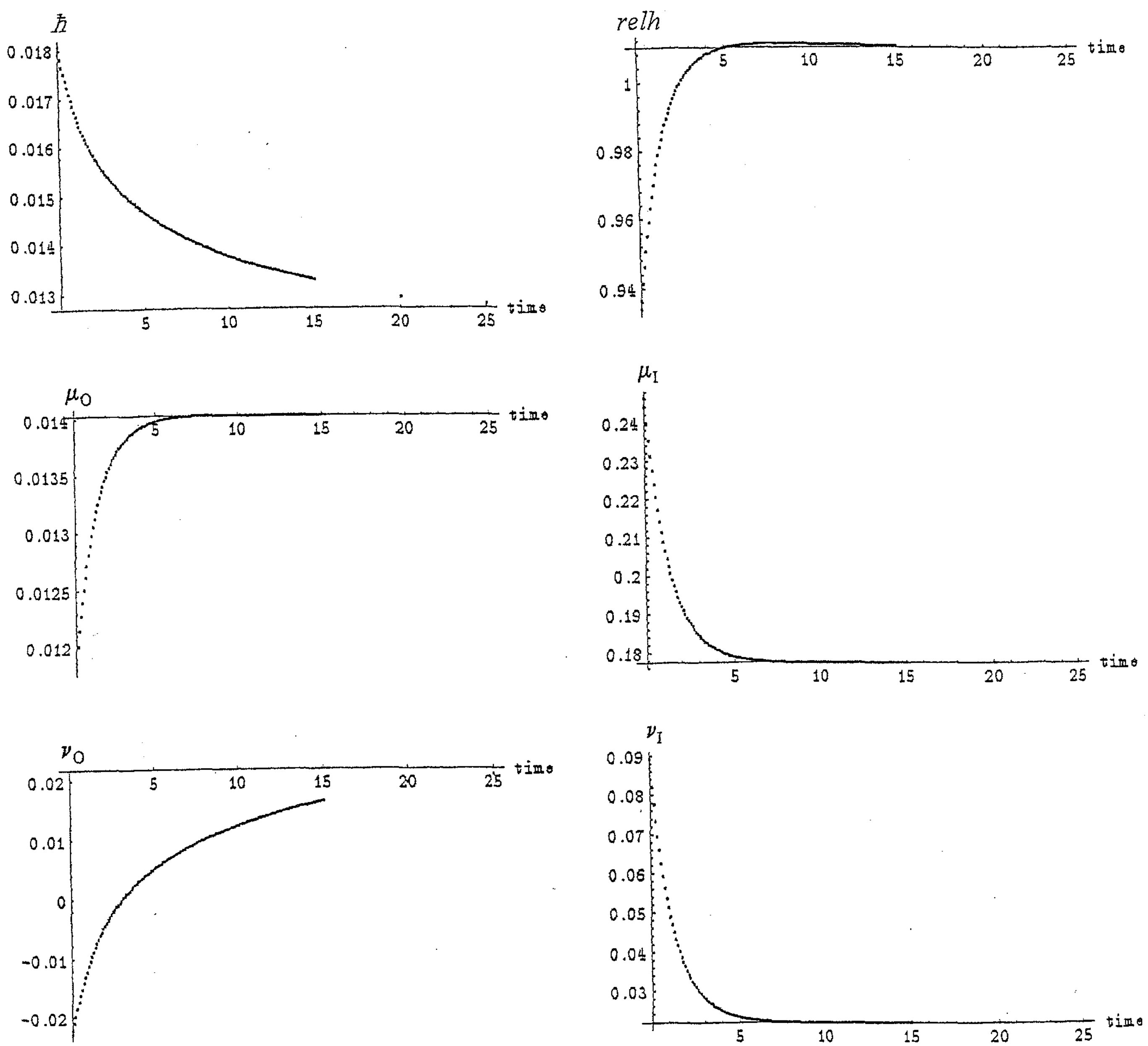


Figure 3. Time Paths from Initial Position A(0) (concluded)

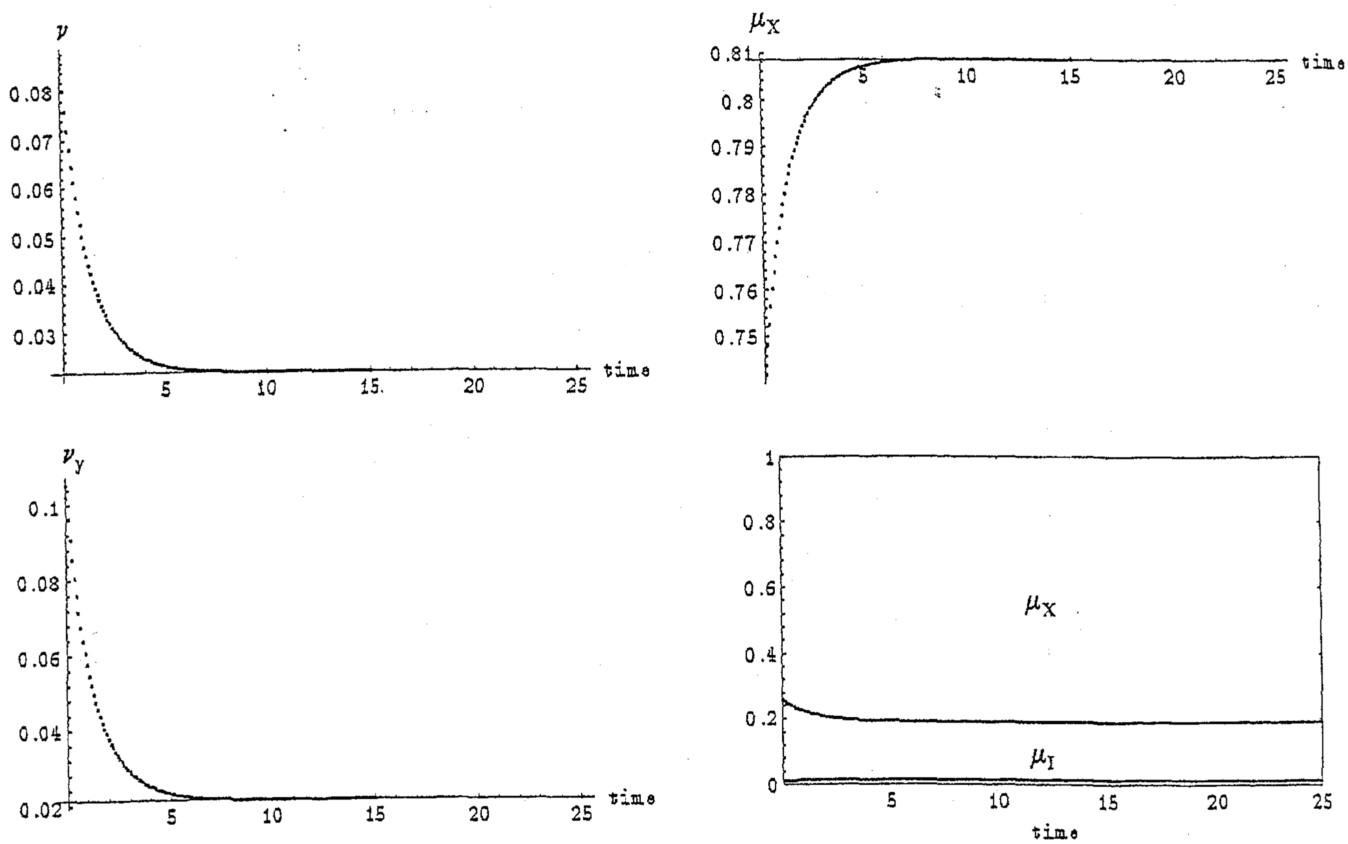


Figure 4. Time Paths from Initial Position B(0)

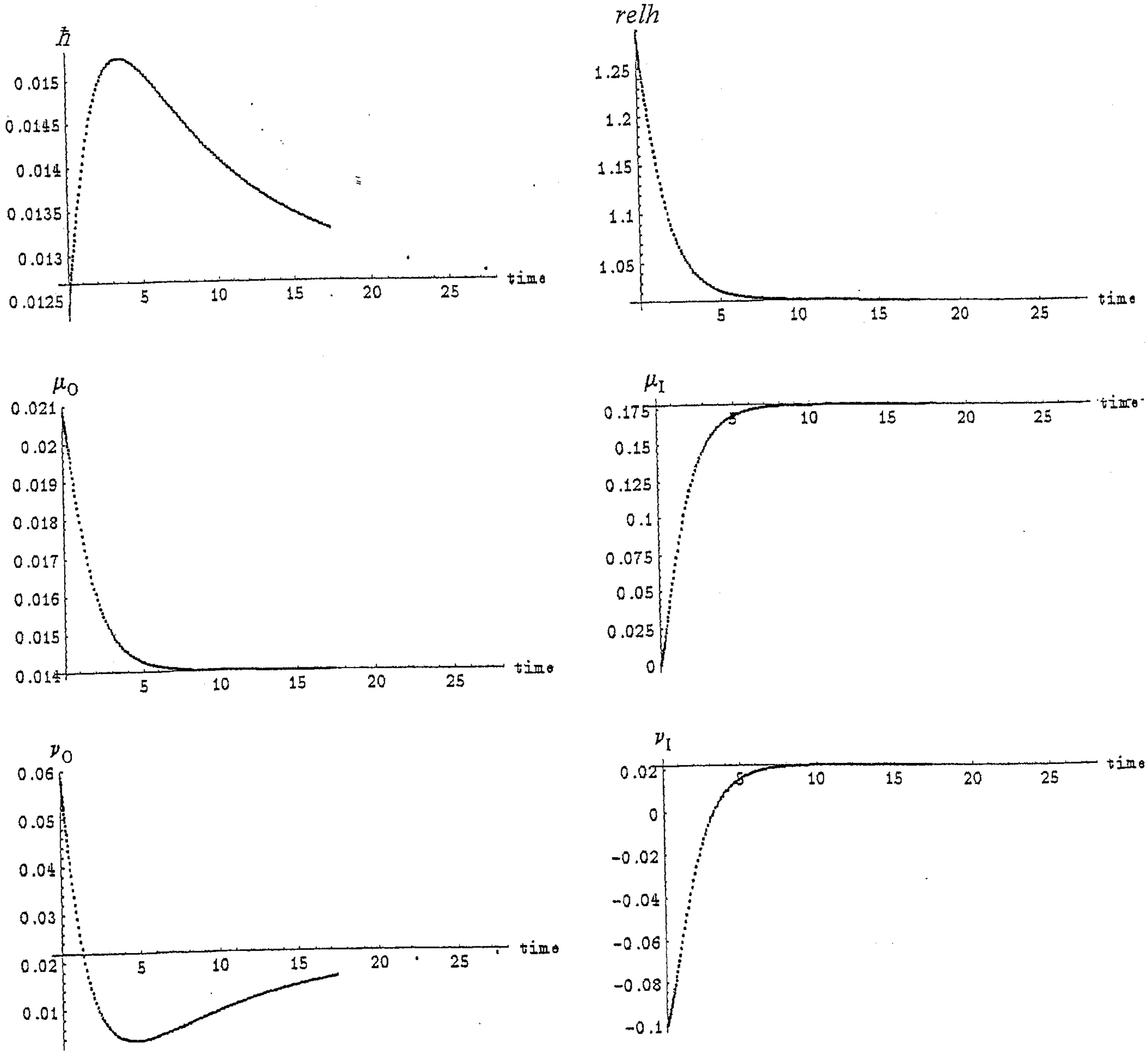


Figure 4. Time Paths from Initial Position B(0) (concluded)

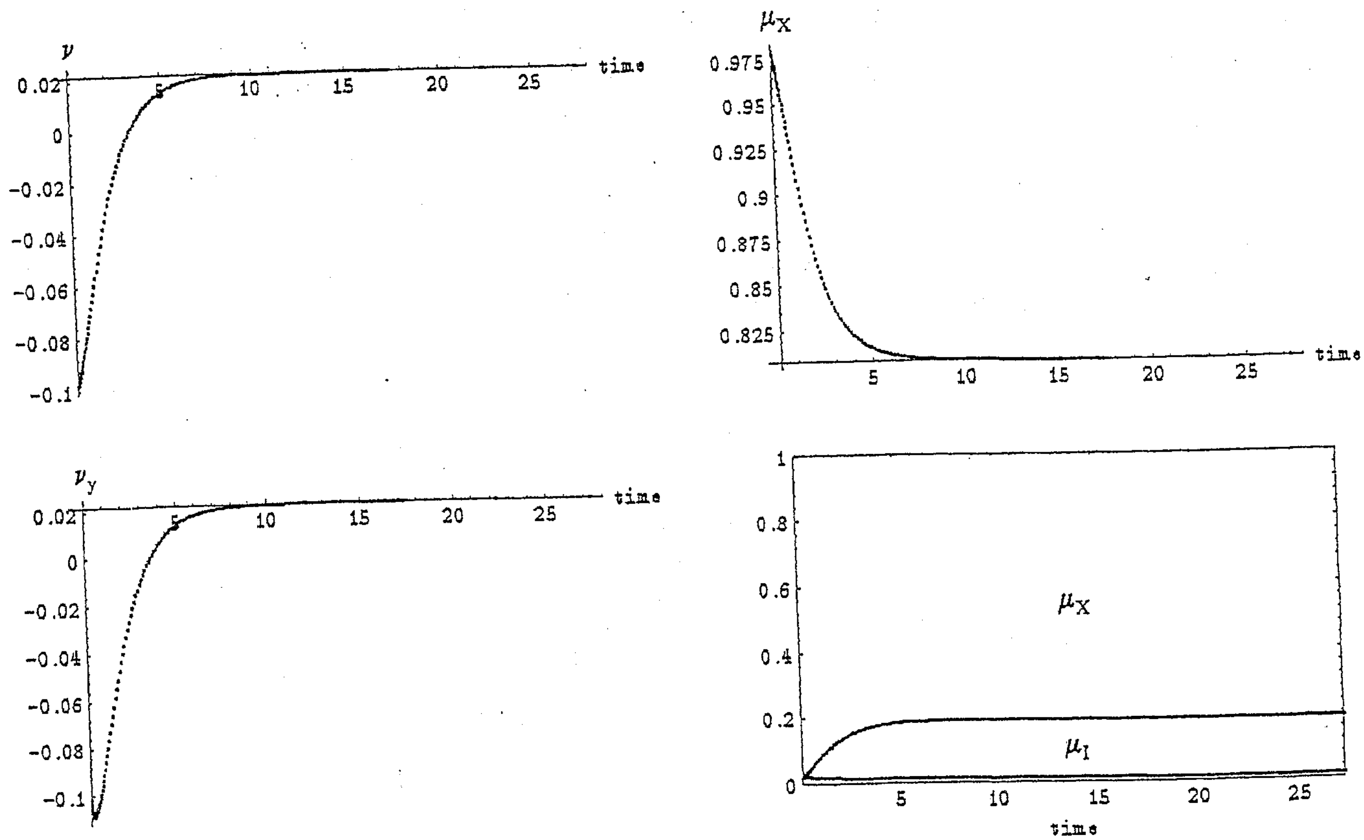
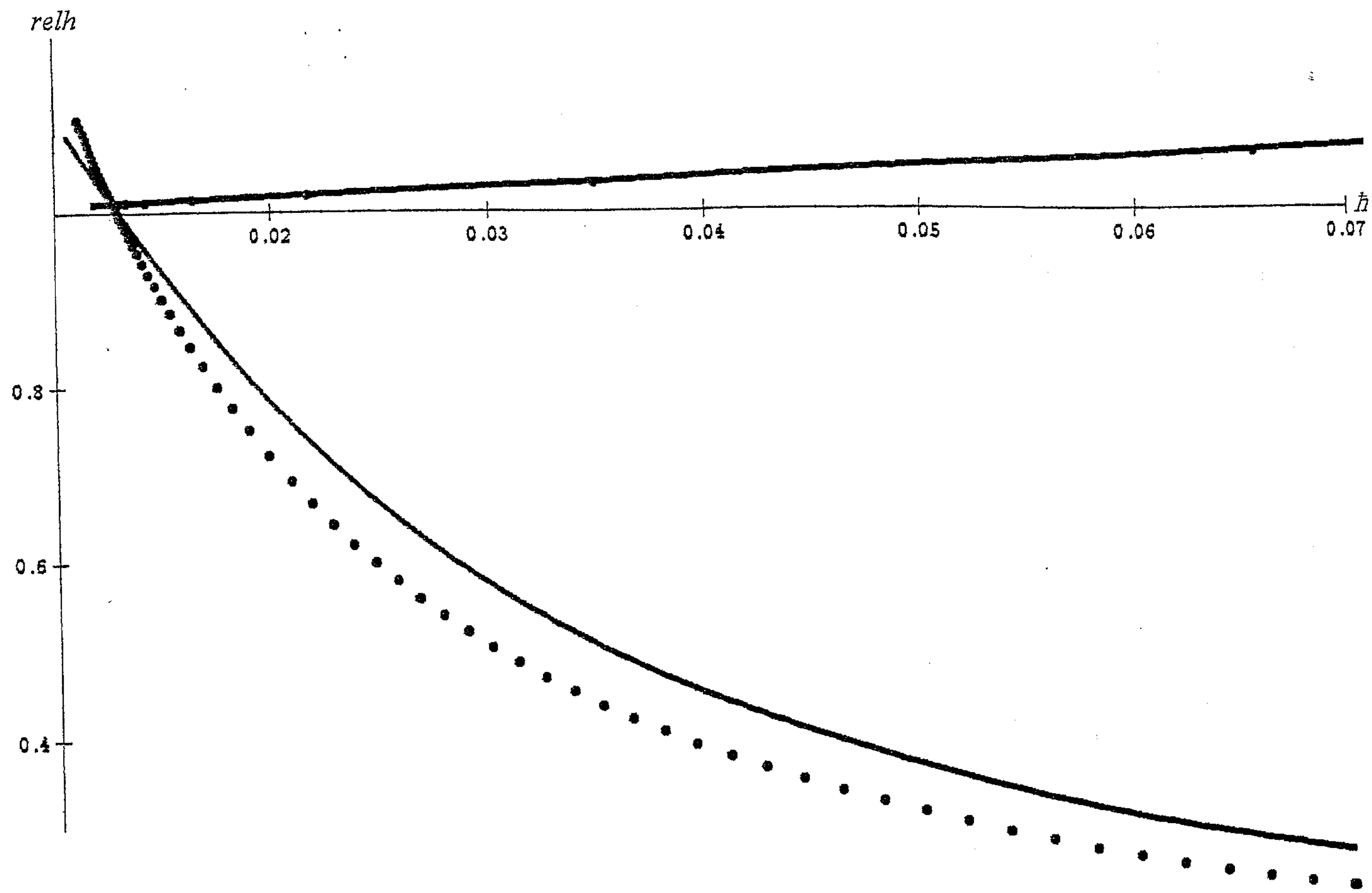
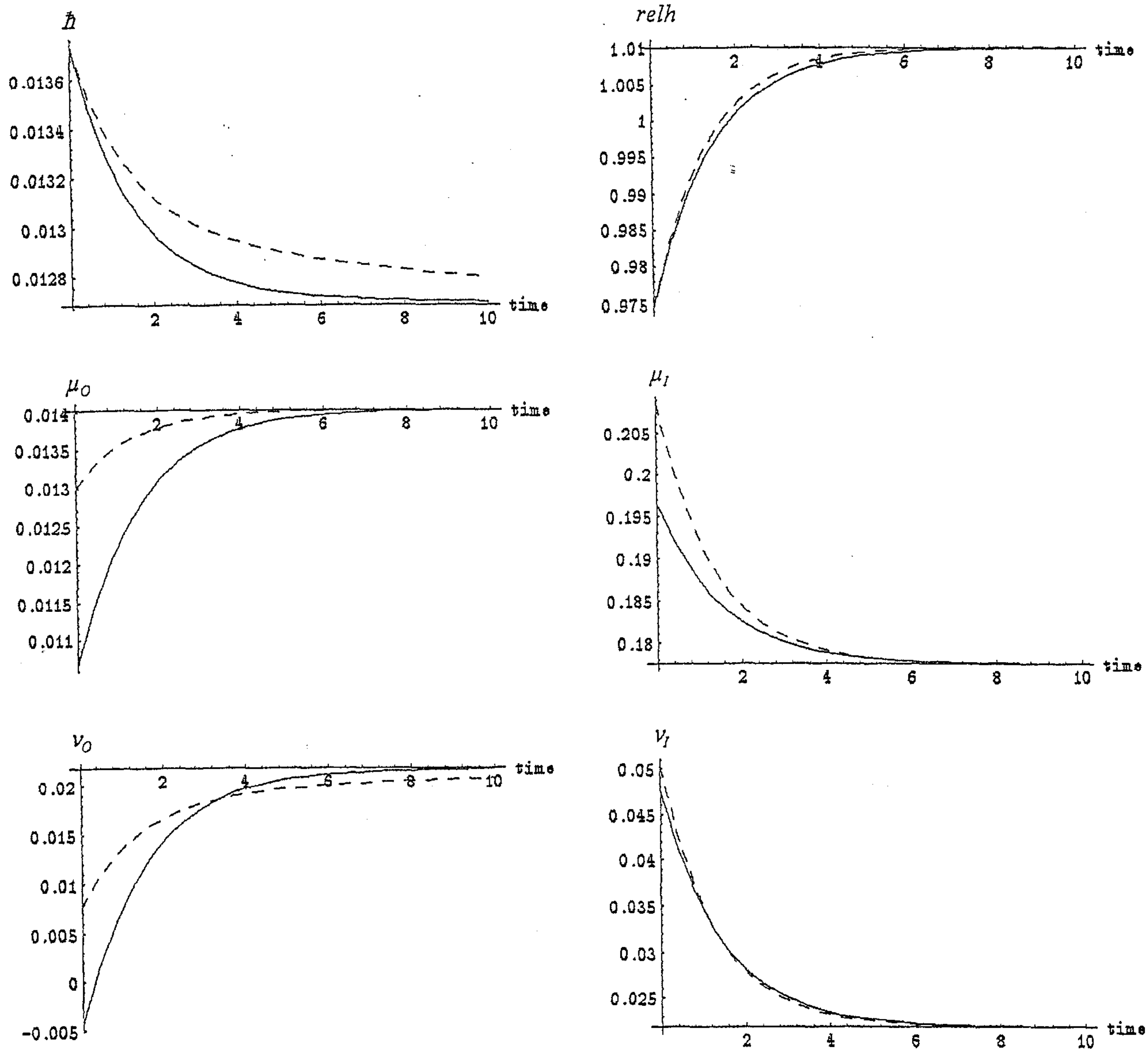


Figure 5. Backroad and Turnpike in the Presence and Absence of Capital Markets[1/]



1/ Trajectories denoted by (—) refer to the absence of capital markets.

Figure 6. Time Paths in the Presence and Absence of Capital Markets for an Initial Condition in Quadrant I[1/]



1/ Time paths with complete capital controls are denoted by a solid line. Time paths with perfect capital markets are denoted by a broken line. The initial foreign stock of human capital is normalized to unity.

2/ Difference in discounted output = $[y_{no\ access} - y_{access}]e^{-rt}$.

3/ Difference in consumption = $c_{no\ access} - c_{access}$.

4/ Difference in discounted utility = $[U(c_{no\ access}) - U(c_{access})]e^{-\rho t}$.

Figure 6. Time Paths in the Presence and Absence of Capital Markets for an Initial Condition in Quadrant I (concluded)

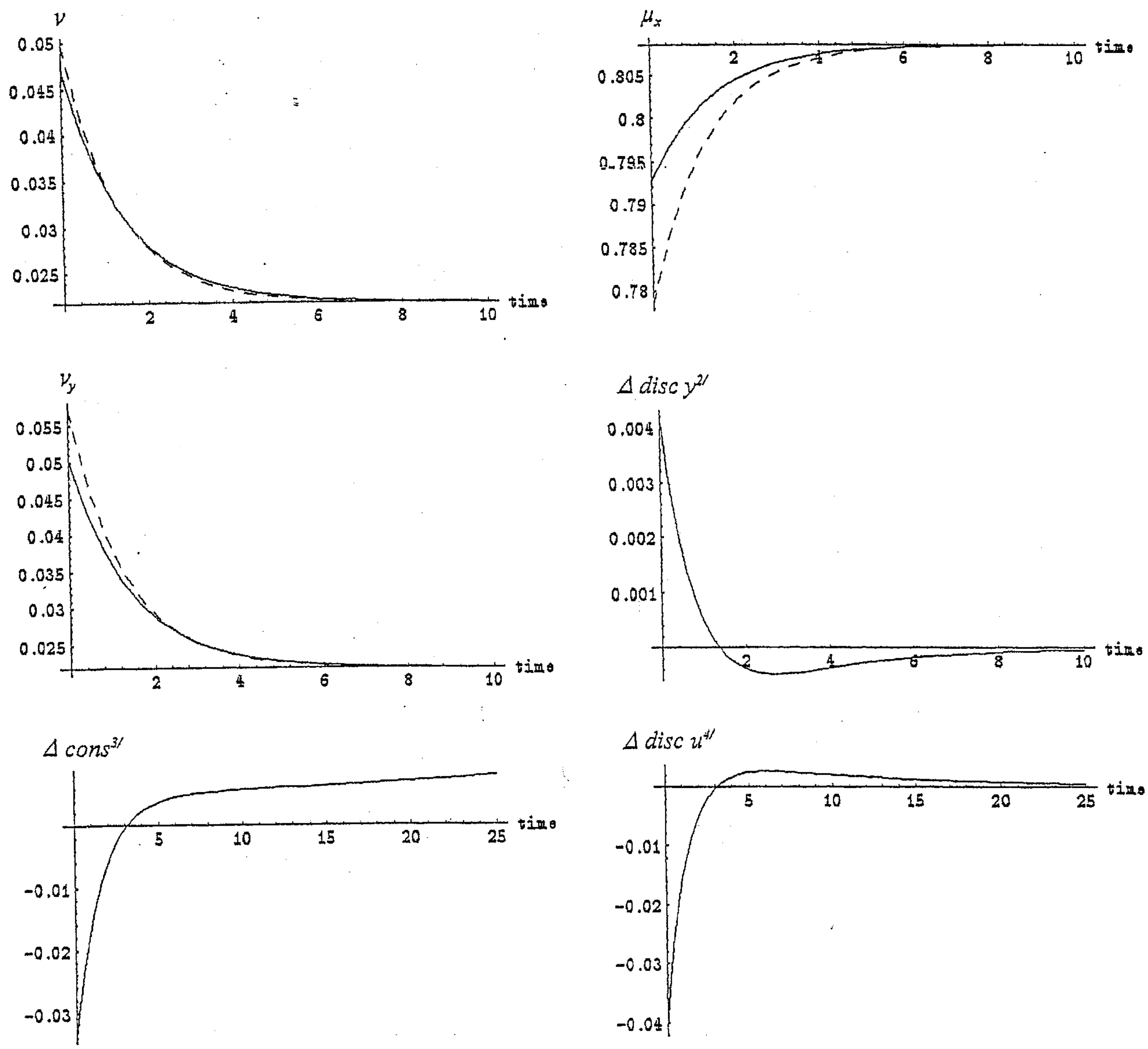
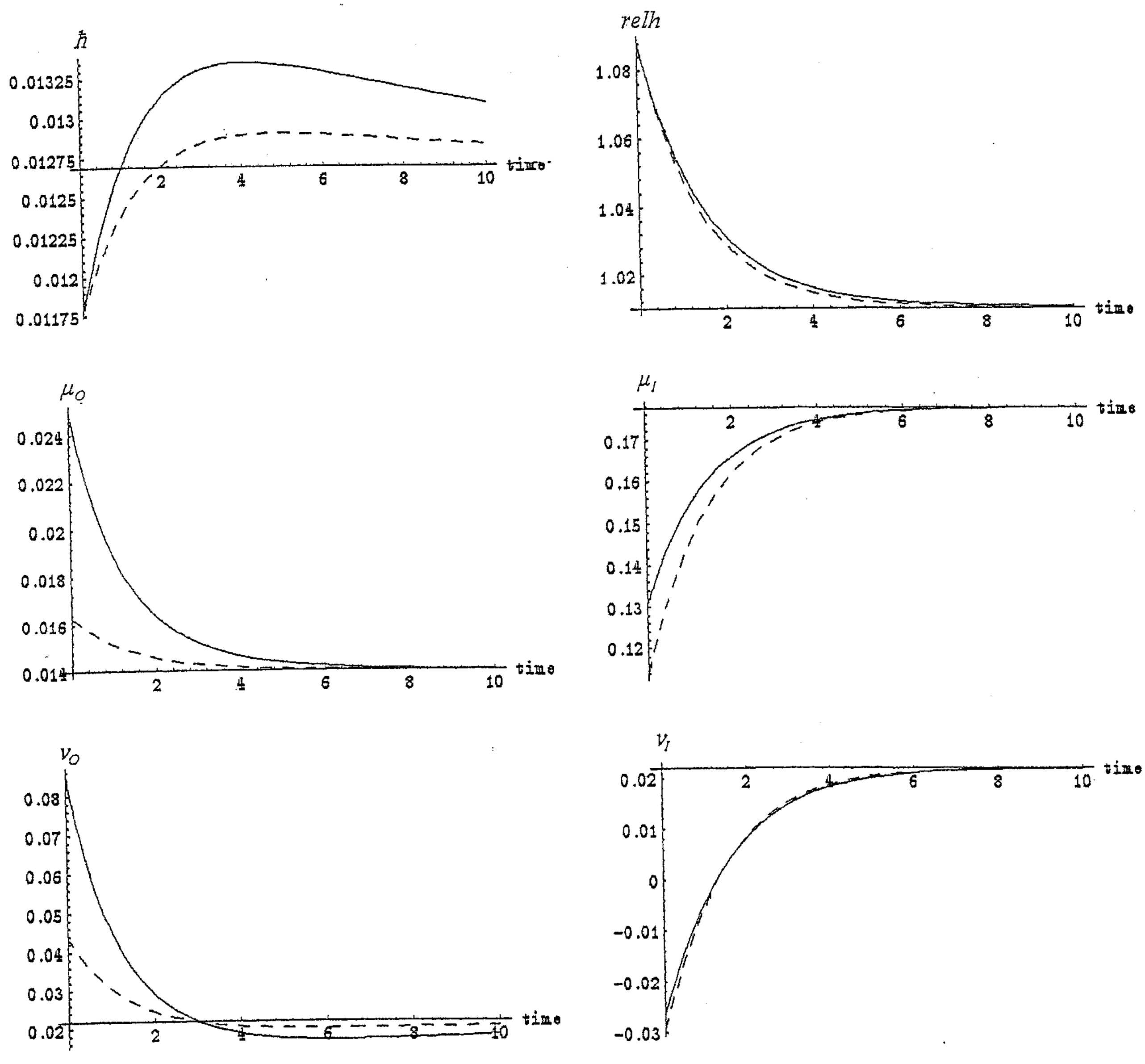
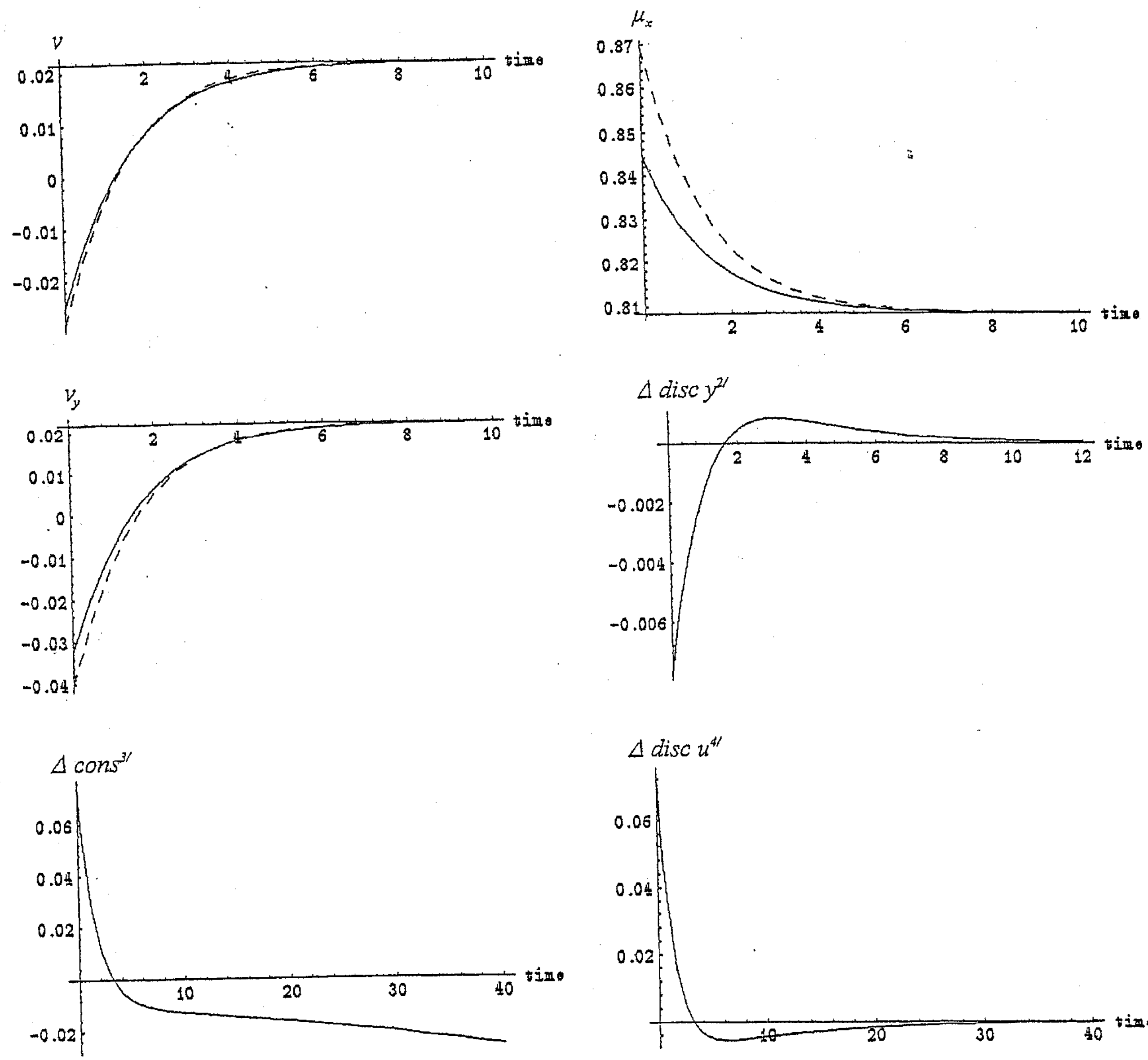


Figure 7. Time Paths in the Presence and Absence of Capital Markets for an Initial Condition in Quadrant II[1/]



1/ Time paths with complete capital controls are denoted by a solid line. Time paths with perfect capital markets are denoted by a broken line. The initial foreign stock of human capital is normalized to unity.
2/ Difference in discounted output = $[y_{no\ access} - y_{access}]e^{-rt}$.
3/ Difference in consumption = $c_{no\ access} - c_{access}$.
4/ Difference in discounted utility = $[U(c_{no\ access}) - U(c_{access})]e^{-\rho t}$.

Figure 7. Time Paths in the Presence and Absence of Capital Markets for an Initial Condition in Quadrant II (concluded)



THE STEADY STATE OF THE REST OF THE WORLD AND THE SMALL OPEN ECONOMY

The set of equations that characterizes the closed-economy steady state of the ROW is:

$$-\sigma v^* = \rho + \delta - f^* - \frac{\mu_x}{\gamma} f^{*\prime} \tag{I-1}$$

$$v^* = \frac{f^*}{\hbar^*} - \delta \tag{I-2}$$

$$f^*(1-\hbar^*) = (N^*\hbar^*-1)\hbar^* g^* \tag{I-3}$$

$$1 = \mu_x^* + \mu_O^* + \mu_I^* \tag{I-4}$$

$$\left[\frac{\mu_x^*}{\gamma} + \frac{f^*}{f^{*\prime}}\right] N^*\hbar^* g^{*\prime} = g^* + f^* + \frac{\mu_x^*}{\gamma}(f^{*\prime} + g^{*\prime}) + \frac{f^* g^*}{f^{*\prime}} \tag{I-5}$$

The set of equations that characterizes the steady state of the small open economy is:

$$v^* = \frac{f}{\hbar} - \delta \tag{I-6}$$

$$v^* = r^* + \frac{(1-\hbar)}{\hbar} f - \frac{\mu_x}{\gamma} f' \tag{I-7}$$

$$f(1-\hbar) = \left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right] \hbar g \tag{I-8}$$

$$\left[\frac{\mu_x}{\gamma} + \frac{f}{f'}\right] \hbar N g' = g + f + \frac{\mu_x}{\gamma} f' + \left[\frac{\mu_x}{\gamma} + \frac{f}{f'}\right]\left[1 - \frac{N^*\hbar^*}{relh}\right] g' \tag{I-9}$$

$$1 = \mu_x + \mu_O + \mu_I \tag{I-10}$$

where v^*, $r^* = \rho + \sigma v^*$ and $\hbar^*$ are determined by the ROW.

With the benchmark parameter values used throughout the paper ($\sigma = 3$; $\rho = 0.05$; $\gamma = 0.25$; δ=0.1; N = 100; $\phi = 0.02$; ψ= 0.75; α=0.6; β=0.3), the closed-economy steady state solutions are: $\mu_x^{ss} = 0.808$; $\mu_O^{ss} = 0.014$; μ_I^{ss} =0.177; $\hbar^{ss} = 0.0127$; $v^{ss} = 0.0218$. For N* = 100 and N = 1, *relh* = 1.0101 in the steady state. The level of human capital in the small country exceeds that in the ROW in the long run since, due to the small-country assumption, the ROW does not imitate the stock of original knowledge developed by the small country. All other endogenous variables of the small country have the same values as in the ROW.

The Small Open Economy in the Absence of Consumption Loans

In the case where the small country does not have access to international capital markets, the competitive problem for the representative agent is:

$$\max_{\mu_x, \mu_O, \mu_I} \int_0^{\infty} U(c(t))\, e^{-\rho t}\, dt$$

$$\begin{aligned} s.t. \quad c(t) &= \mu_x(t)^{\gamma} h(t) \\ h(t) &= h_O(t) + h_I(t) \\ \dot{h}_O &= f(\mu_O(t))h(t) - \delta h_O(t) \\ \dot{h}_I &= g(\mu_I(t))\left[\overline{H}(t) - h_I(t)\right] - \delta h_I(t) \\ 1 &= \mu_x(t) + \mu_O(t) + \mu_I(t) \\ &\{\overline{H}(t)\}_{t=0}^{\infty} \end{aligned}$$

The first order conditions and co-state equations are:

$$\gamma \mu_x^{\gamma(1-\sigma)-1} h^{(1-\sigma)} = \theta h f' = \lambda\left[\overline{H} - h_I\right] g' \tag{II-1}$$

$$\frac{\dot{\lambda}}{\lambda} = \rho + \delta + g - \left[\frac{\mu_x}{\gamma} + \frac{f}{f'}\right]\left[\frac{N^* \hbar^*}{relh} + N\hbar - 1\right] g' \tag{II-2}$$

$$\frac{\dot{\theta}}{\theta} = \rho + \delta - f - \frac{\mu_x}{\gamma} f'. \tag{II-3}$$

In the steady state:

$$\nu^* = \frac{f}{\hbar} - \delta \tag{II-4}$$

$$-\sigma\nu^* = \rho + \delta - f - \frac{\mu_x}{\gamma}f' \tag{II-5}$$

$$f(1-\hbar) = \left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right]\hbar g \tag{II-6}$$

$$\left[\frac{\mu_x}{\gamma} + \frac{f}{f'}\right]\hbar N g' = g + f + \frac{\mu_x}{\gamma}f' + \left[\frac{\mu_x}{\gamma} + \frac{f}{f'}\right]\left[1 - \frac{N^*\hbar^*}{relh}\right]g' \tag{II-7}$$

$$1 = \mu_x + \mu_O + \mu_I \tag{II-8}$$

where ν^* and $\hbar^*$ are determined by the ROW. Notice that (A-7) is replaced with (B-5) in the presence of capital controls. However, the steady state solution to the endogenous variables is unchanged from the perfect capital mobility case. This result is due to identical preferences in the small country and in the ROW and, therefore, to the equality of the world interest rate and the domestic interest rate in the small country without access to international capital markets. In addition, since long-run *relh* is the same with or without consumption loans, the level of human capital will also be equal.

The out-of-steady state dynamics in the absence of international capital markets are described by:

$$\dot{relh} = relh\left[\hbar v_O + (1-\hbar)v_I - v^*\right] \tag{II-9}$$

$$\dot{\hbar} = \hbar(1-\hbar)(v_O - v_I) \tag{II-10}$$

$$\dot{\mu}_O = \mu_O\left\{(1-\alpha) - [\gamma(1-\sigma)-1]\left[\frac{\mu_O}{\mu_x} + \left(\frac{\alpha-1}{\beta-1}\right)\frac{\mu_I}{\mu_x}\right]\right\}^{-1} * \tag{II-11}$$

$$\left\{\frac{\dot{\theta}}{\theta} + \sigma v + \frac{[\gamma(1-\sigma)-1]}{(\beta-1)}\frac{\mu_I}{\mu_x}\left[\frac{\dot{\theta}}{\theta} - \frac{\dot{\lambda}}{\lambda} - \frac{\left[N\hbar\frac{\dot{\hbar}}{\hbar} - \frac{N^*\hbar^*}{relh}\frac{\dot{relh}}{relh}\right]}{\left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right]}\right]\right\}$$

$$\dot{\mu}_I = \frac{\mu_I}{(\beta-1)}\left\{\frac{\dot{\theta}}{\theta} - \frac{\dot{\lambda}}{\lambda} + (\alpha-1)\frac{\dot{\mu}_O}{\mu_O} - \frac{\left[N\hbar\frac{\dot{\hbar}}{\hbar} - \frac{N^*\hbar^*}{relh}\frac{\dot{relh}}{relh}\right]}{\left[\frac{N^*\hbar^*}{relh} + N\hbar - 1\right]}\right\}. \tag{II-12}$$

(II-12)[14]

[14]The eigenvalues from the linearized system in the presence and absence of consumption loans under the benchmark parameters are {-0.7416, -0.1200} and {-0.6804, -0.1178), respectively, indicating that adjustment to the steady state is slower under capital controls.

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