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Anticipated policy and endogenous growth in a small open monetary economy

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Abstract

This paper analyzes the effects of a *preannounced* change in the growth rate of credit in a small *open* economy. The model, based on an endogenous growth model, introduces the adjustment costs for investment and the role of money in the production function and highlights the dynamic behavior of an open economy. We show that an increase in the rate of anticipated credit growth lowers the steady-growth rate of capital, real money balances, and real output. We also find that the rate of depreciation of the domestic currency will rise steadily toward its stationary level. The anticipated domestic credit growth hence exhibits monetary *nonsuperneutrality* in both the rate and the level of output in the intermediate and the long run.

JEL classification: F41; F43; O42

Keywords: Announced credit growth; Endogenous growth; Small open economy

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1. Introduction

The literature on monetary growth models that embody endogenous growth theories has recently expanded and developed at a rapid pace. Easterly (1996) and Fischer et al. (1996) find that disinflation programs have an expansionary effect on economic growth.[1] Braumann (2000) further emphasizes that the factor of open economy plays an important role in the negative relationship between inflation and economic growth. Gylfason and Herbertsson (2001) summarize the empirical findings of the existing literature (their summarized result is stated in Table 1), and conclude that there exists a negative relationship between inflation and economic growth in the long run. However, previous studies including Marquis and Reffett (1991), Wang and Yip (1992), and Van der Ploeg and Alogoskoufis (1994) employ an endogenous growth model, developed by Romer (1986) and Lucas (1988), to analyze the monetary growth policy in a *closed economy*.[2] Evidently, these existing studies cannot provide a plausible framework to illustrate the relevant growth factors of open economies.

The monetary policy of an open growing economy is essentially different from that of a closed growing economy. So far as a developing country is concerned, if capital is the only factor to stimulate growth, then economic growth in a small open economy may be constrained on *the gap between savings and investment and the gap between demand and supply in foreign exchange*. Consequently, monetary policy in a small open economy with a flexible exchange rate will impact the gap between savings and investment and hence affect economic growth. Though monetary policy is important in an open economy, until now very few efforts have been made to analyze the role of monetary policy for an *open economy* in the endogenous growth literature.

The existing endogenous growth studies (for example, Razin and Yuen, 1996; Turnovsky, 1996a, 1996b, 1997; Van der Ploeg, 1996; Eicher and Turnovsky, 1999) that focus on the open economy set up their model from the viewpoints of *real aspects*. Furthermore, their analyses put emphasis on the growth effect of an unanticipated permanent change in fiscal policy. To our knowledge, Palokangas (1997) is the only exception. Palokangas introduces money as an intermediary good that reduces transaction costs, and discusses the impact of an unanticipated permanent change in money growth on an open economy's long-run growth rate. He concludes that the effect of an inflation rate increase on the rate of long-run economic growth depends on the relative strength of both the positive effect on human capital through

[1] In essence, the orthodox disinflation programs include money-based stabilization and exchange-rate-based stabilization. Orthodox money-based programs rely on restrictions on the rate of monetary expansion to provide a nominal anchor for the economy while using the exchange rate to maintain external balance, see Agénor and Montiel (1996, chap. 8).

[2] Related monetary growth work of a closed economy can also be found in Gomme (1993), De Gregorio (1993), Mino and Shibata (1995), Pecorino (1995), Palivos and Yip (1995), Mino (1997), Zou (1998), and Dotsey and Sarte (2000).

Table 1
Inflation and growth: overview of empirical studies

Studies	Countries	Effects of an increase in inflation from 5 to 50 percent a year on growth
Thirlwall and Barton (1971)	51	Not available
Heitger (1985)	115	−0.9 to −4.5
Kormendi and Meguire (1985)	47	Not available
Barro (1990)	117	Insignificant and weak
Fischer (1991)	73	−2.1
Grimes (1991)	21	−5.0
Gylfason (1991)	37	−2.0
De Gregorio (1992, 1993)	12	−0.7
Roubini and Sala-i-Martin (1992)	98	−2.2
Fischer (1993)	80	−1.8
Motley (1994)	78	−1.3 to −4.5
Barro (1995, 1997)	100	−1.0 to −1.5
Sarel (1996)	87	−5.8
Taylor (1996)	US	−11.2
Bruno and Easterly (1998)	97	−1.2
Gylfason (1999)	105	−2.3
Rousseau and Wachtel (2001)	84	−0.14
Gylfason and Herbertsson (2001)	170	−0.6 to −1.3

Source: Adapted from Gylfason and Herbertsson (2001, p. 408).

lower ordinary taxation and the negative effect on human capital through larger transaction costs.

Palokangas (1997) focuses his analysis on the unanticipated policy. An unanticipated policy implies that government action is undertaken immediately. This may not always be possible in the real world of politics. In particular, in high inflation countries the empirical evidence indicates that disinflation programs are often preannounced. Accordingly, to be more realistic, some studies including Sargent and Wallace (1973), Fischer (1979), Gray and Turnovsky (1979), and Wilson (1979), analyze how an *anticipated monetary policy* governs the economy's behavior. Therefore, the purpose of this paper is to examine the effects of an anticipated change in money growth in the long run and the transitional adjustments in the context of a small *open economy* with a flexible exchange rate regime.

In constructing our analytical framework, both the accumulation of capital with adjustment costs and money as an input in the production process are two key features in determining the economy's dynamic patterns following an anticipated monetary policy. The existence of adjustment costs for investment, introduced by Lucas (1967) and Gould (1968), implies that all changes in capital are costly; this avoids some of the counterfactual results from the open-economy version of the Ramsey model (Barro and Sala-i-Martin,1995, chap. 3). Moreover, it is necessary for such models to give rise to non-degenerate dynamics (Turnovsky, 1996a, 2000). The view that real money balances are an input in the production function is developed by Levhari and Patinkin (1968), Friedman (1969), and Fischer (1974). Firms hold money to facilitate production on the grounds that money enables them to economize the use of other inputs, and it spares the cost of running short of cash (Fischer, 1974). Our way is consistent with Wang and Yip (1992) and Pecorino (1995), as well as the transaction costs model constructed by Dornbusch and Frenkel (1973) and Wang and Yip (1991). It is also consistent with King and Levine (1993), Gylfason and Herbertsson (2001), and Gylfason and Zoega (2002), in which the ratio of credit issued to private firms to GDP or the ratio of real money balances to GDP is viewed as a relevance variable for the extent of financial development.[3]

Based on our analysis, it is found that an increase in the rate of domestic credit growth lowers the balanced growth rate of capital, real money balances, and real output. In addition, the depreciation rate of the domestic currency displays an increasing process during the evolutionary adjustment, and the change in the rate of depreciation of the domestic currency is greater than the change in the nominal credit growth rate. This conclusion implies that money-based stabilization has an expansionary effect on economic growth through reducing capital outflows or improving current account.

The rest of the paper proceeds as follows. The structure of a small open economy embodying money and endogenous growth is outlined in Section 2. The economy's dynamic responses to an anticipated monetary growth are examined in Section 3. Finally, Section 4 concludes the major findings.

2. The model

Consider a small open economy consisting of a representative household and a government. The domestic economy produces and consumes a single traded good, the foreign price of which is given in the world market. In the absence of any impediments to trade, purchasing power parity is assumed to hold and is further described by (expressed in percentage change terms):

$$\pi = \pi^* + \varepsilon, \tag{1}$$

where $\pi\,(\equiv \dot{P}/P)$ is the rate of inflation of the good in terms of the domestic currency, π^* is the rate of inflation of the good in terms of foreign currency and assumed to be exogenously given to the small open economy, and $\varepsilon\,(\equiv \dot{E}/E)$ is the rate of depreciation of the domestic currency. Moreover, P is the domestic price level, E is the nominal exchange rate, and the overdot denotes the time derivative.

The representative household is assumed to have an infinite planning horizon, faces perfect world capital markets, and has perfect foresight. Moreover, the labor supply of a representative household is fixed inelastically. The household is postulated to choose his private level of consumption, c, the level of investment, i, physical capital, k, real money balances, $m\,(\equiv M/P)$, and holdings of the real traded

[3] Moreover, many empirical studies also support a positive relationship between production and real money balances; see, for example, the survey of Odedokun (1999).

bond, $b^*(\equiv EB^*/P)$, in order to maximize the discounted sum of future instantaneous utilities:

$$\int_0^{\infty} \frac{c^{1-\theta}-1}{1-\theta}\, \mathrm{e}^{-\rho t}\, \mathrm{d}t, \quad \theta > 0,\ \rho > 0, \tag{2}$$

where M is the nominal money stock, B^* is the stock of traded bonds, ρ is the constant rate of time preference, and θ is the inverse of the elasticity of intertemporal substitution which measures the utility function's curvature. The instantaneous utility function is equivalent to a logarithmic utility function, $\ln c$, if $\theta = 1$.

Following Levhari and Patinkin (1968), Friedman (1969), and Fischer (1974), the domestic output y is produced using two factors of production, physical capital k and real money balances m. Firms hold money to facilitate production on the grounds that money enables them to economize the use of other inputs and money holding spares the cost of running short of cash (Fischer, 1974). Furthermore, we specify the technologies as Cobb–Douglas form:

$$y = Ak^{\alpha}m^{1-\alpha}, \quad A > 0,\ 1 > \alpha > 0. \tag{3a}$$

The specification that money is an input in the production process is consistent with that of Wang and Yip (1992) and Pecorino (1995). It is also consistent with the viewpoint proposed by Dornbusch and Frenkel (1973) that involves transaction costs.[4] Several empirical studies including Sinai and Stokes (1972), Simos (1981), Nguyen (1986), and Hasan and Mahmud (1993) also support money in the production function.

It is worth mentioning that money in Eq. (3a) can also be justified to be related to the extent of financial development, and hence is consistent with the argument of Goldsmith (1969) and Roubini and Sala-i-Martin (1992).[5] To be more specific, the Cobb–Douglas function in Eq. (3a) can be derived by an Ak technology with a financial intermediation system. To clarify this, we follow Goldsmith (1969), Greenwood and Jovanovic (1990), King and Levine (1993), and Roubini and Sala-i-Martin (1995) on the argument that more financial development (or a smaller degree of financial repression) stimulates economic growth by improving the efficiency of capital allocation. Then, in line with Pagano (1993) and Roubini and Sala-i-Martin (1995), we assume that a fraction ϕ of real output is 'lost' in the process of financial intermediation as commissions, bank reserves, and so on. Moreover, Roubini and Sala-i-Martin (1992, 1995) assert that ϕ is affected by financial development (or

[4] Dornbusch and Frenkel (1973) postulate that money facilitates transactions necessary to produce output and not just consume it, see Orphanides and Solow (1990, pp. 251–254). Based on liquidity costs and one-period production lag, Foley (1992) further sets up the fundamental of real liquidity in production function.

[5] Goldsmith (1969) argues that policies of financial repression affect the process of economic growth by affecting the efficiency of capital, see Roubini and Sala-i-Martin (1992) and Pagano (1993).

financial repression). As a result, with the Ak production technology, *net* output $\mathbf{y}$ is given by:

$$\mathbf{y} = Ak - \phi(F)Ak = [1 - \phi(F)]Ak, \tag{3b}$$

where F is the indicator of financial development and $0 \le F \le 1$. The function ϕ possesses the following properties: $\phi' < 0$, $\phi'' \ge 0$, $\lim_{F \to 0} \phi(F) = 1$, and $\lim_{F \to 1} \phi(F) = \bar{\phi} < 1$, indicating that the more developed (or the less repressed) the financial system, the more resources would be allocated from financial intermediaries to production sector. Among the literature, King and Levine (1993) suggest that the ratio of credit issued to private firms to GDP is an appropriate indicator to reflect the extent of financial development. According to multiple deposit creation, a decrease in the banking system's reserves leads to a multiple increase in deposits, which are a component of the money supply. Consequently, in line with Gylfason and Herbertsson (2001) and Gylfason and Zoega (2002), it is clear that the real money balances–GDP ratio can serve as a plausible indicator of financial development. With such an understanding, we set:

$$F = m/Ak. \tag{3c}$$

Then Eq. (3b) can be rewritten as:

$$\mathbf{y} = [1 - \phi(m/Ak)]Ak. \tag{3d}$$

An example of function ϕ satisfying the properties described above is $\phi(m/Ak) = 1 - \phi_0 (m/Ak)^{1-\alpha}$ with $0 < \phi_0 < 1$ and $0 < \alpha \le 1$. Given such a specification, the net production function can be rewritten as $\mathbf{y}(k,m) = A^{\alpha}\phi_0 k^{\alpha} m^{1-\alpha}$, which is equivalent to the specification of production function in Eq. (3a).

The representative household accumulates physical capital involving adjustment costs (installation costs) with the quadratic convex function. This formulation of the installation function follows the original specification developed by Lucas (1967) and Gould (1968). Following Hayashi (1982), Abel and Blanchard (1983), and Turnovsky (1996a), the installation function is specified as follows:

$$\Phi(i,k) = i\left(1 + \frac{h}{2}\frac{i}{k}\right), \quad h > 0,$$

where h is a constant parameter of adjustment costs, expressing the sensitivity of the adjustment costs. Adjustment costs depending upon investment relative to capital stock can be justified by learning-by-doing in the installation process. As addressed by Feichtinger et al. (2001, p. 255), "if capital stock is large, a lot of machines have been installed in the past so that this firm has a lot of experience, implying that it is more efficient in installing new machines." The existence of adjustment costs implies finite convergence speeds even when credit markets are perfect. Thus, the presence of adjustment costs for investment can avoid some of the counterfactual results from the open-economy version of the Ramsey model. It is worth mentioning here that a lowerbound for h is imposed in our analysis, which will be explained in Section 3.

Moreover, the linear homogeneity of this function is necessary to give rise to non-degenerate dynamics and to be sustained if a steady equilibrium exhibits ongoing growth (Turnovsky, 2000).

At each instant of time, the representative household is bound by a flow constraint linking wealth accumulation to any difference between its gross income and its expenditure. The household's flow budget constraint is thus described by:

$$\dot{m}+\dot{b}^* = Ak^{\alpha}m^{1-\alpha} - c - i\left(1+\frac{h}{2}\frac{i}{k}\right) + (r^*+\varepsilon-\pi)b^* - \pi m + \tau, \tag{4}$$

where r^* is the world nominal interest rate on foreign bonds, and τ is real transfers from government. For simplicity, we assume that the capital stock does not depreciate, so that the representative household faces the physical capital accumulation constraint:

$$\dot{k}=i. \tag{5}$$

The current-value Hamiltonian for the agent's optimization is given by:

$$H=\frac{c^{1-\theta}-1}{1-\theta}+\lambda\left[Ak^{\alpha}m^{1-\alpha} - c - i\left(1+\frac{h}{2}\frac{i}{k}\right) + (r^*+\varepsilon-\pi)b^* - \pi m + \tau - u\right] + q'i + \nu u,$$

where λ is the shadow value (marginal utility) of foreign bonds, q' is the shadow value of the agent's capital stock, and ν is a costate variable associated with the slack variable identity, $u=\dot{m}$. Let the shadow value of foreign bonds be the numéraire. Consequently, $q \equiv q'/\lambda$ is defined to be the market value of capital in terms of the (unitary) price of foreign bonds.

The optimum conditions necessary for the representative household hence are:

$$c^{-\theta}=\lambda, \tag{6}$$

$$\frac{i}{k}=\frac{(q'/\lambda)-1}{h}\equiv\frac{q-1}{h}, \tag{7}$$

$$\lambda=\nu, \tag{8}$$

$$\dot{\lambda}/\lambda=\rho-(r^*+\varepsilon-\pi), \tag{9}$$

$$\frac{\dot{q}}{q}=r^*+\varepsilon-\pi-\frac{1}{q}\left[\alpha A(m/k)^{1-\alpha}+\frac{h}{2}\left(\frac{i}{k}\right)^2\right], \tag{10}$$

$$\dot{\nu}/\nu=\rho-\left[(1-\alpha)A(m/k)^{-\alpha}-\pi\right], \tag{11}$$

together with Eqs. (4), (5), and the transversality conditions of b^*, m, and k:

$$\lim_{t\to\infty} \lambda b^* \mathrm{e}^{-\rho t} = 0, \tag{12a}$$

$$\lim_{t\to\infty} \nu m \,\mathrm{e}^{-\rho t} = 0, \tag{12b}$$

$$\lim_{t\to\infty} q' k \,\mathrm{e}^{-\rho t} = \lim_{t\to\infty} \lambda q k \,\mathrm{e}^{-\rho t} = 0. \tag{12c}$$

Under a regime of flexible exchange rates, foreign reserves are constant and the credit growth rate is predetermined. For simplicity, following Agénor and Montiel (1996, pp. 323–326), set the constant level of reserves to be equal to zero. Changes in the real money balances are thus equal to changes in the real credit stock, that is:

$$\dot{m}/m = \dot{d}/d = \mu - \pi, \tag{13}$$

where $d\,(\equiv D/P)$ is the real domestic credit, D is the nominal stock of domestic credit, and $\mu\,(\equiv \dot{D}/D)$ is the growth rate of the nominal credit stock. We assume that the government forgoes the issuance of domestic bonds to finance its deficit, and finances its budget deficit by borrowing from the central bank. That is, the government keeps the money growth rate at a constant rate μ and distributes seigniorage to the representative household as a transfer payment in a lump-sum manner. Thus, the flow budget constraint of the government can be written as:

$$\dot{m} = \tau - \pi m. \tag{14}$$

Combining Eq. (4) with Eq. (14) implies that the economy's net accumulation of foreign bonds is the current account balance, which in turn equals the balance of trade plus the net interest income earned on the foreign bonds:

$$\dot{b}^* = Ak^{\alpha}m^{1-\alpha} - c - i\left(1 + \frac{h}{2}\frac{i}{k}\right) + (r^* + \varepsilon - \pi)b^*. \tag{15}$$

3. Anticipated inflation and transitional dynamics

We now examine the effects of an *anticipated* permanent increase in the credit growth rate on the economy's evolution. This announcement effect is a central theme of perfect foresight models pioneered by Sargent and Wallace (1973), Gray and Turnovsky (1979), and Wilson (1979), but is overlooked in the literature of a small open economy with endogenous growth.

From Eqs. (8), (9), and (11), the currency depreciation rate is endogenously determined by:

$$(1-\alpha)A(m/k)^{-\alpha} = r^* + \varepsilon. \tag{16}$$

Eq. (16) essentially is the interest rate parity. It equates the marginal product of real money balances to the world interest rate plus the currency depreciation rate. Differentiating Eq. (6) with respect to time and using Eqs. (1) and (9), the optimal change in consumption is given by:

$$\dot{c}/c = (r^* - \pi^* - \rho)/\theta \equiv \psi. \tag{17}$$

Substituting Eq. (5) into Eq. (7), Eqs. (1) and (7) into Eq. (10), and Eqs. (1) and (16) into Eq. (13), the evolution of physical capital k, market value of capital q, and real money balances m can be rewritten as:

$$\frac{\dot{k}}{k} = \frac{i}{k} = \frac{q-1}{h} \equiv \phi, \tag{18}$$

$$\frac{\dot{q}}{q} + \frac{1}{q}\left[\alpha A(m/k)^{1-\alpha} + \frac{(q-1)^2}{2h}\right] = r^* - \pi^*, \tag{19}$$

$$\frac{\dot{m}}{m} = \mu - \pi = \mu - (1-\alpha)A(m/k)^{-\alpha} + r^* - \pi^*. \tag{20}$$

Eq. (18) is essentially a 'Tobin q' theory of investment. Eq. (19) states that the real rate of return from investing in the domestic capital should equal the real rate of return from investing abroad, $r^* - \pi^*$. The former is composed of expected capital gains, $\dot{q}/q$, the value of the marginal product of capital, and the value of marginal savings on installation costs.

Solving Eqs. (9) and (18) implies $\lambda(t) = \lambda_0 \exp[\rho t - (r^* - \pi^*)t]$ and $k(t) = k_0 \exp\left[\int_0^t \phi(\xi)\mathrm{d}\xi\right]$, where λ_0 is the endogenously determined initial marginal utility and k_0 is the given initial stock of domestic capital. Eq. (12c) then can be rewritten as:

$$\lim_{t\to\infty} \lambda q k\, \mathrm{e}^{-\rho t} = \lambda_0 k_0 \tilde{q} \lim_{t\to\infty} \exp\left[\int_0^t (\phi(\xi) - r^* + \pi^*)\mathrm{d}\xi\right], \tag{12c$'$}$$

where $\tilde{q}$ is the stationary value of q determined below. In order to ensure that the household's intertemporal budget constraint is met, given that q approaches $\tilde{q}$ exponentially along the transitional adjustment path, Eq. (12c′) will be met if and only if

$$\tilde{\phi} \equiv (\tilde{q} - 1)/h < r^* - \pi^*. \tag{21}$$

Eq. (21) states that the rate of growth of domestic capital is less than the real rate of interest on foreign bonds. With the equilibrium being one in which real money balances grow at the same rate as capital, this also ensures that Eq. (12b) is met.

Following Turnovsky (1996a), combining Eq. (17) with $\theta\dot{c}/c = -\dot{\lambda}/\lambda$ gives the no-Ponzi-game condition that $\lim_{t\to\infty} b^* \exp[-(r^* - \pi^*)t] = 0$ is satisfied. Thus, following Turnovsky (1996a, 1997), the transversality condition (12a) must be satisfied and it will be held if and only if[6]:

$$c_0 = (r^* - \pi^* - \psi)\left[b_0^* + k_0 \frac{A' - [(\tilde{q}_0^2 - 1)/2h]}{r^* - \pi^* - \tilde{\phi}_0}\right], \tag{22a}$$

$$r^* - \pi^* > \psi, \tag{22b}$$

$$r^* - \pi^* > \phi, \tag{22c}$$

where A' is defined as $A(m_0/k_0)^{1-\alpha}$. Eq. (22a) determines the feasible initial level of real consumption. Eq. (22b) imposes an upper bound on the growth rate of consumption, while Eq. (22c) is equivalent to Eq. (21).

We then deal with the transitional dynamics of the economy. Following Futagami et al. (1993), Barro and Sala-i-Martin (1995) and Turnovsky (1997), define $s \equiv m/k$. From Eqs. (18)–(20), the dynamic system in terms of the transformed variable s and the market value of capital q can be expressed as follows:

$$\frac{\dot{q}}{q} = r^* - \pi^* - \frac{1}{q}\left[\alpha A s^{1-\alpha} + \frac{(q-1)^2}{2h}\right], \tag{23a}$$

$$\frac{\dot{s}}{s} = \frac{\dot{m}}{m} - \frac{\dot{k}}{k} = \mu - (1-\alpha)A s^{-\alpha} + r^* - \pi^* - \frac{q-1}{h}. \tag{23b}$$

At steady-growth equilibrium, the economy is characterized by $\dot{q} = \dot{s} = 0$ and q and s are at their stationary values, namely $\tilde{q}$ and $\tilde{s}$. Based on Eqs. (23a) and (23b), the corresponding steady-state values of q and s are determined by:

$$(r^* - \pi^*)\tilde{q} - \alpha A \tilde{s}^{1-\alpha} - \frac{(\tilde{q}-1)^2}{2h} = 0, \tag{24a}$$

$$\left[\mu - (1-\alpha)A\tilde{s}^{-\alpha} + r^* - \pi^* - \frac{\tilde{q}-1}{h}\right]\tilde{s} = 0. \tag{24b}$$

Furthermore, given that the economy is characterized by $\dot{q} = \dot{s} = 0$ at the steady-growth equilibrium, it is quite clear from Eqs. (3a) and (23b) that $\tilde{\gamma}_y = \tilde{\gamma}_m = \tilde{\gamma}_k$ should hold. Consequently, from Eqs. (17) and (18) in the steady-growth equilibrium we have[7]:

$$\tilde{\gamma}_y = \tilde{\gamma}_m = \tilde{\gamma}_k \equiv \tilde{\phi} = (\tilde{q} - 1)/h,$$

[6] See Appendix.

[7] On the other hand, the rate of growth of real foreign bonds converges asymptotically to $\max(\phi, \psi)$. This result is analogous to Turnovsky (1996a).

$$\tilde{\gamma}_c \equiv \psi = (r^* - \pi^* - \rho)/\theta.$$

We can now trace the economy's evolution following an anticipated inflation. The experiment we conduct is that, at $t=0$, the monetary authorities announce that the monetary growth rate will increase from μ_0 to μ_1 at a specific date $t=T$ in the future. Meanwhile, we assume that, prior to the policy change's announcement, the economy is in its steady-growth equilibrium with $\mu=\mu_0$. Linearizing the dynamic system (23a) and (23b) around its steady state stated in Eqs. (24a) and (24b), the local dynamics can be described by:

$$\begin{bmatrix} \dot{q} \\ \dot{s} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} q - \tilde{q} \\ s - \tilde{s} \end{bmatrix} + \begin{bmatrix} 0 \\ \tilde{s} \end{bmatrix} (\mu - \mu_0), \tag{25a}$$

where $a_{11} = r^* - \pi^* - \tilde{\phi}$, $a_{12} = -\alpha(1-\alpha)A\tilde{s}^{-\alpha}$, $a_{21} = -\tilde{s}/h$, and $a_{22} = \alpha(1-\alpha)A\tilde{s}^{-\alpha}$.

Let δ_1 and δ_2 be the two characteristic roots of the dynamic system. We then have:

$$\delta_1\delta_2 = \Delta = \alpha(1-\alpha)A\tilde{s}^{-\alpha}\left[r^* - \pi^* - \tilde{\phi} - \tilde{s}/h\right], \tag{25b}$$

$$\delta_1 + \delta_2 = r^* - \pi^* - \tilde{\phi} + \alpha(1-\alpha)A\tilde{s}^{-\alpha} > 0. \tag{25c}$$

Note that in a small open economy with the flexible exchange rate regime, the exchange rate E is freely adjusting to maintain the foreign exchange market in equilibrium. As a result, the exchange rate E, and hence real money balances ($m \equiv M/EP^*$), is a jump variable (see, for example, Obstfeld, 1981; Turnovsky, 1985).[8] Moreover, the market price of capital q possesses a forward-looking feature, and is also a jump variable (see, for example, Blanchard and Fischer, 1989, pp. 58–69; Sen and Turnovsky, 1990; Nielsen and Sorensen, 1991; Turnovsky, 1996a).

According to Eqs. (25b) and (25c), the two real roots are either all positive or of opposite signs.[9] As claimed in the literature of dynamic rational expectation models (for example, Burmeister, 1980; Buiter, 1984; Turnovsky, 1995), if the number of unstable roots equals the number of jump variables, then there exists a unique perfect foresight equilibrium solution. Since the dynamic system reported in Eq. (25a) has two jump variables, q and s, in what follows we impose $\Delta > 0$ to assure that both roots of the system are positive evaluated at the steady state. More specifically, a unique perfect foresight equilibrium is ensured when we examine the dynamic

[8] In the monetary endogenous growth studies of a closed economy, including Van der Ploeg and Alogoskoufis (1994), Mino and Shibata (1995), Hon and Yip (2001), and Palivos and Yip (2001), m is treated as a jump variable.

[9] From Eqs. (25b) and (25c) we have $(a_{11}+a_{22})^2 - 4(a_{11}a_{22} - a_{12}a_{21}) = (a_{11} - a_{22})^2 + 4a_{12}a_{21} > 0$, thus δ_1 and δ_2 are real roots.

responses to an anticipated inflation.[10] Given $\Delta > 0$, it further implies that the condition $r^* - \pi^* - \tilde{\phi} > \tilde{s}/h$ should be satisfied. Accordingly, the dynamic system is locally unstable.

We now turn to deal with the lowerbound for h. First, from Eq. (21) we have the constraint on h, $h > (\tilde{q} - 1)/(r^* - \pi^*)$, where $\tilde{q}$ is an initial steady-state value determined by Eqs. (24a) and (24b). Second, from Eq. (25b) we obtain another constraint on h, $h > (\tilde{q} - 1 + \tilde{s})/(r^* - \pi^*)$, where $\tilde{s}$ is an initial steady-state value determined by Eqs. (24a) and (24b). With these two constraints we can easily obtain the lowerbound for h, that is $h > (\tilde{q} - 1 + \tilde{s})/(r^* - \pi^*)$. Given that the presence of adjustment costs reduces the speed of convergence, the lowerbound constraint on h implies an upperbound speed of convergence.

For expository convenience, we assume that $\delta_1 > \delta_2 > 0$. It follows from Eq. (25a) that the general solution for q and s can be expressed as:

$$q(t) = \tilde{q}(\mu, r^*) + \Gamma_1 \mathrm{e}^{\delta_1 t} + \Gamma_2 \mathrm{e}^{\delta_2 t}, \tag{26a}$$

$$s(t) = \tilde{s}(\mu, r^*) + \frac{\delta_1 - a_{11}}{a_{12}} \Gamma_1 \mathrm{e}^{\delta_1 t} + \frac{\delta_2 - a_{11}}{a_{12}} \Gamma_2 \mathrm{e}^{\delta_2 t}, \tag{26b}$$

where Γ_1 and Γ_2 are unknown parameters.

The transitional behavior of q and s can be clearly illustrated by a graphical presentation. From Eq. (25a) the slopes of loci $\dot{q} = 0$ and $\dot{s} = 0$ are:

$$\left.\frac{\partial s}{\partial q}\right|_{\dot{q}=0} = -\frac{a_{11}}{a_{12}} = \frac{r^* - \pi^* - \tilde{\phi}}{\alpha(1-\alpha)A\tilde{s}^{-\alpha}} > 0, \tag{27a}$$

$$\left.\frac{\partial s}{\partial q}\right|_{\dot{s}=0} = -\frac{a_{21}}{a_{22}} = \frac{\tilde{s}/h}{\alpha(1-\alpha)A\tilde{s}^{-\alpha}} > 0. \tag{27b}$$

Equipped with the information of the direction of arrows in Fig. 1, we can sketch all possible trajectories. In the phase space plane, the unstable branches UU and UU^* are associated with $\Gamma_1 = 0$ and $\Gamma_2 = 0$ in Eqs. (26a) and (26b), respectively. In addition, all other unstable trajectories correspond to the values with $\Gamma_1 \neq 0$ and $\Gamma_2 \neq 0$ in Eqs. (26a) and (26b). The common feature of these divergent trajectories is that they start from the unstable node Q_0 with the slope of UU, and their slope approaches asymptotically to that of the UU^* locus.[11]

Let us begin to study the economy's evolution in response to an anticipated credit growth. In the right panel of Fig. 2, the initial equilibrium, where $\dot{s} = 0(\mu_0)$ intersects

[10] This implies that we are only confined ourselves on the situation of local determinacy. For a detailed discussion on (in)determinacy, see Arnold (2000).

[11] The slopes of loci UU and UU^* from Eqs. (26a) and (26b) with $\Gamma_1 = 0$ and $\Gamma_2 = 0$ are $\partial s/\partial q|_{UU} = (\delta_2 - a_{11})/a_{12} = -a_{21}/(a_{22} - \delta_2)$ and $\partial s/\partial q|_{UU^*} = (\delta_1 - a_{11})/a_{12} = -a_{21}/(a_{22} - \delta_1)$, respectively. It is clear from Eqs. (26a) and (26b) that $\lim_{t \to -\infty} (\dot{s}/\dot{q}) = (\delta_2 - a_{11})/a_{12}$ and $\lim_{t \to \infty} (\dot{s}/\dot{q}) = (\delta_1 - a_{11})/a_{12}$ are true.

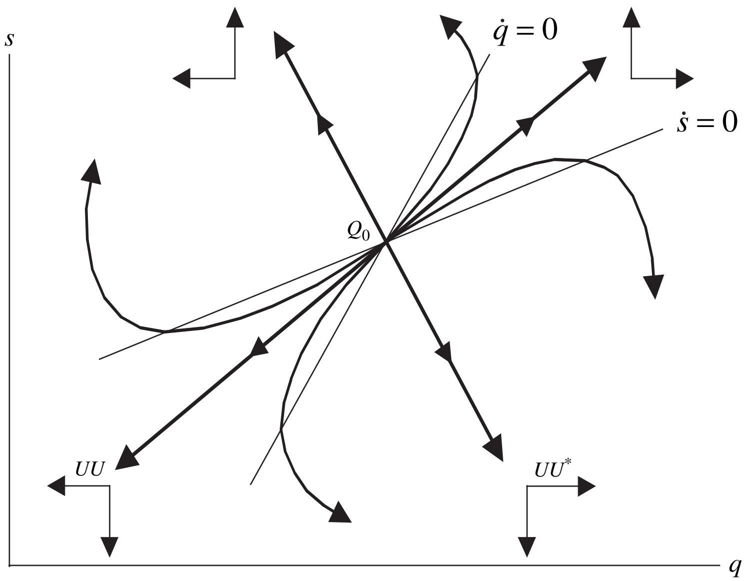

Fig. 1. Phase diagram.

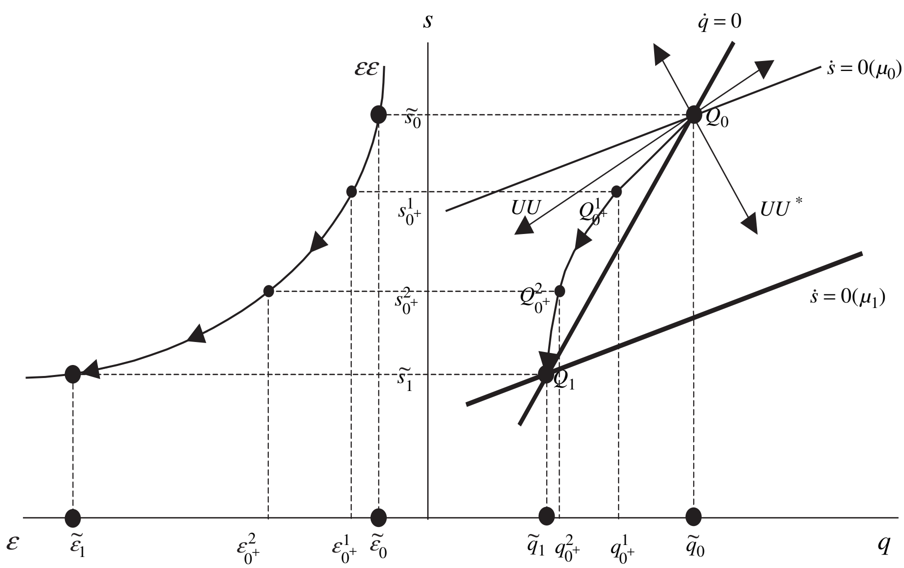

Fig. 2. Dynamics of the market value of capital, the currency depreciation rate, and the real money balances–capital ratio following an anticipated domestic credit growth.

$\dot{q}=0$, is established at Q_0; the initial real money balances–capital ratio and market value of capital are $\tilde{s}_0$ and $\tilde{q}_0$, respectively. In the left panel of Fig. 2, the $\varepsilon\varepsilon$ locus traces all combinations of ε and s that satisfy Eq. (16). As is evident, the initial the rate of depreciation of the domestic currency is $\tilde{\varepsilon}_0$. Upon a permanent monetary growth shock, $\dot{s}=0(\mu_0)$ shifts downward to $\dot{s}=0(\mu_1)$, while both $\dot{q}=0$ and $\varepsilon\varepsilon$ remain intact.[12] The new steady-growth equilibrium is at point Q_1, with s and q being $\tilde{s}_1$ and $\tilde{q}_1$, respectively. Comparing point Q_1 with Q_0, the result is that the stationary value of the real money balances–capital ratio reduces from $\tilde{s}_0$ to $\tilde{s}_1$, and the stationary value of capital's market value falls from $\tilde{q}_0$ to $\tilde{q}_1$. The rationale for this result is that a rise in μ lowers the marginal product of capital. In the left panel, the new steady-state value of the depreciation rate of the domestic currency rises from $\tilde{\varepsilon}_0$ to $\tilde{\varepsilon}_1$.

Three points should be addressed before proceeding to study the dynamic adjustment. First, for expository convenience, in what follows 0^+ denotes the instant after the announcement is made by the central bank, and T^- and T^+ denote the instant before and after policy implementation, respectively. Second, as the rate of monetary growth increases from μ_0 to μ_1 at the moment of time T^+, the transversality condition requires that the economy should reach exactly the point of new steady-growth equilibrium Q_1, because the system is characterized by global instability. Third, during the dates between 0^+ and T^-, the credit growth rate has not increased yet and thus point Q_0 should be treated as the reference point to govern the dynamic adjustment of s and q. Based on this information, as is evident in Fig. 2, only the dynamic path linking points Q_0, $Q^1_{0^+}$, $Q^2_{0^+}$, and Q_1 will reach the new steady-state Q_1 at the instant of monetary implementation.

Upon the shock of an anticipated increase in the credit growth rate, in the right panel of Fig. 2 the economy will instantaneously jump to different points on this dynamic path between Q_0 and Q_1 in response to different values of T. If the value of T is smaller, the economy will jump to a point closer to Q_1; otherwise, the economy will jump to a point closer to Q_0. As a consequence, at the instant 0^+, the economy will instantly jump from Q_0 to a point like Q_{0^+} and both s and q correspondingly fall from $\tilde{s}_0$ to s_{0^+} and $\tilde{q}_0$ to q_{0^+}, respectively. During the dates between 0^+ and T^-, as the arrows indicate, the economy will move from Q_{0^+} to the new steady-state point Q_1 in which both s and q continue to decrease. At time T^+ the economy will go to its new stationary point Q_1. Thereafter, from T^+ onward, the economy stays put forever at its stationary point Q_1.

In the left panel of Fig. 2, at time 0^+ the depreciation rate of the domestic currency will immediately rise from $\tilde{\varepsilon}_0$ to ε_{0^+}. During the period following the announcement, but prior to the expansion of the monetary growth rate, ε continues to increase. From T^+ onward, ε remains intact at its stationary level $\tilde{\varepsilon}_1$. Obviously, the economy's impact response to news arrival has a common feature that both the real money balances–capital ratio and market value of capital will at once decrease regardless of the value of lead-time T, while the depreciation rate of the domestic currency will at once increase.

[12] From Eq. (25a), we have $\partial s/\partial\mu|_{\dot{s}=0} = -1/[\alpha(1-\alpha)A\tilde{s}^{-\alpha-1}] < 0$ and $\partial s/\partial\mu|_{\dot{q}=0} = 0$.

It is now important for us to know what the transitional behavior of the growth rate for economic variables is in response to an anticipated increase in credit growth. From Eqs. (16), (18), (20), and (3a) with $s \equiv m/k$, we have:

$$\gamma_k = \dot{k}/k = (q-1)/h, \tag{28a}$$

$$\dot{\gamma}_k = \dot{q}/h = \left[a_{11}(q-\tilde{q}) + a_{12}(s-\tilde{s})\right]/h, \tag{28b}$$

$$\gamma_m = \dot{m}/m = \mu - (1-\alpha)As^{-\alpha} + r^* - \pi^*, \tag{29a}$$

$$\dot{\gamma}_m = \alpha(1-\alpha)As^{-\alpha-1}\dot{s} = \alpha(1-\alpha)As^{-\alpha-1}\left[a_{21}(q-\tilde{q}) + a_{22}(s-\tilde{s}) + b_2(\mu-\mu_0)\right], \tag{29b}$$

$$\varepsilon = (1-\alpha)As^{-\alpha} - r^*, \tag{30a}$$

$$\dot{\varepsilon} = -\alpha(1-\alpha)As^{-\alpha-1}\dot{s}, \tag{30b}$$

$$\gamma_y = \dot{y}/y = \alpha(q-1)/h + (1-\alpha)\left[\mu - (1-\alpha)As^{-\alpha} + r^* - \pi^*\right], \tag{31a}$$

$$\dot{\gamma}_y = \alpha\dot{\gamma}_k + (1-\alpha)\dot{\gamma}_m = \alpha(1-\alpha)^2 As^{-\alpha-1}\left[\dot{s}/\dot{q} - \partial s/\partial q\big|_{\gamma_y}\right]\dot{q}. \tag{31b}$$

Based on the results reported in the above equations, we can sketch the behavior of γ_k, γ_m, ε, and γ_y by referring to the dynamic adjustment of q, s, and ε exhibited in Fig. 2. We first illustrate, for clarity of exposition, the isogrowth lines of γ_k. Fig. 3 provides a graphical illustration to the determination of γ_k. First, we reproduce the $Q_0Q_{0+}^1Q_{0+}^2Q_1$ trajectory from the right panel of Fig. 2 and use Eq. (28a) to construct isogrowth lines of γ_k, that is, the loci for q and s that correspond to the constant values of γ_k. Eq. (28a) indicates that γ_k is positively related to q in the vicinity of the steady state. Hence, Fig. 3 depicts several isogrowth lines, where those that lie further to the left – with lower values of q – correspond to lower values of γ_k. Moreover, the $\dot{\gamma}_k = 0$ curve is also displayed in Fig. 3. Eq. (28b) indicates that $\dot{\gamma}_k$ is positively related to $\dot{q}$ and thus any point (q, s) off and to the left (right) of $\dot{\gamma}_k = 0$ will have a negative (positive) value of $\dot{\gamma}_k$ since $a_{11} > 0$ in Eq. (28b).

Equipped with this inference, it is possible to identify the transitional dynamics in γ_k following an anticipated rise in the credit growth rate. As is clear from Fig. 2, in Fig. 3, in response to a different value of T, the economy will instantaneously jump to different points on the dynamic path between points Q_0 and Q_1. If the value of T is smaller, then the economy will jump to a point closer to Q_1; otherwise, the economy will jump to a point closer to Q_0. Furthermore, we can find a critical value of T,

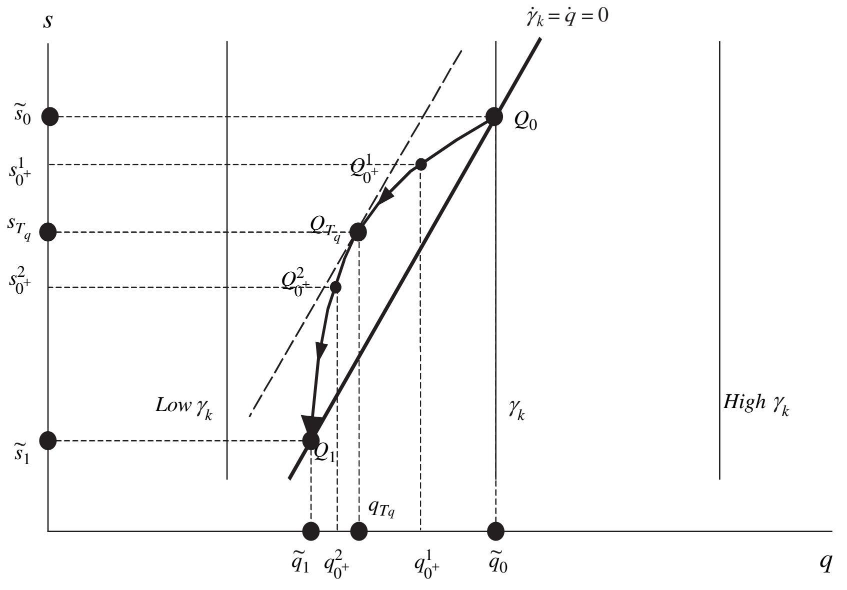

Fig. 3. Determination of the growth rate of domestic capital.

namely T_q, which is characterized by the feature that the slope of $Q_0Q^1_{0^+}Q^2_{0^+}Q_1$ trajectory equals the slope of $\dot{q}=0$, as depicted by the point Q_{T_q} in Fig. 3.

We now take two points $Q^1_{0^+}$ and $Q^2_{0^+}$ as examples to illustrate how the value of T will govern the transitional dynamics of γ_k. If the value of T, namely T_1, is larger than T_q, then the economy will jump to point $Q^1_{0^+}$. As shown in Fig. 3, q falls on impact, implying γ_k decreases on impact from Eq. (28a). Subsequently, q continues to decrease as the economy moves from $Q^1_{0^+}$ to the new steady-state Q_1 throughout the time interval between 0^+ and T_1. Moreover, from Fig. 3 the value of $\dot{q}$ continues to decrease from $Q^1_{0^+}$ to Q_{T_q}; this implies from Eq. (28b) that γ_k falls at an increasing rate. Sequentially, the value of $\dot{q}$ continues to rise from Q_{T_q} to Q_1, meaning that γ_k turns to fall at a decreasing rate. The entire adjustment of γ_k corresponding to the value of T_1 would therefore look like path (a) in Fig. 5. If the value of T, namely T_2, is smaller than T_q, then the economy will jump to a point $Q^2_{0^+}$. Similarly, from Fig. 3 q falls on impact, implying γ_k decreases on impact, and q continues to decrease as the economy moves from $Q^2_{0^+}$ to the new steady-state Q_1 throughout the time interval between 0^+ and T_2. Moreover, the value of $\dot{q}$ continues to rise from $Q^2_{0^+}$ to Q_1; this implies that γ_k turns to fall at a decreasing rate. The adjustment of γ_k corresponding to the value of T_2 would therefore look like path (b) in Fig. 5.

We next examine the dynamic behavior of the growth rate of real money balances, γ_m, and the rate of depreciation of the domestic currency, ε. In Fig. 4 we similarly use Eq. (29a) to construct the isogrowth lines of γ_m and reproduce the Q_0Q_1 trajectory from the right panel of Fig. 2. Eq. (29a) indicates that γ_m is positively related to s in the vicinity of the steady state. Moreover, Eq. (29b) expresses that $\dot{\gamma}_m$ is positively

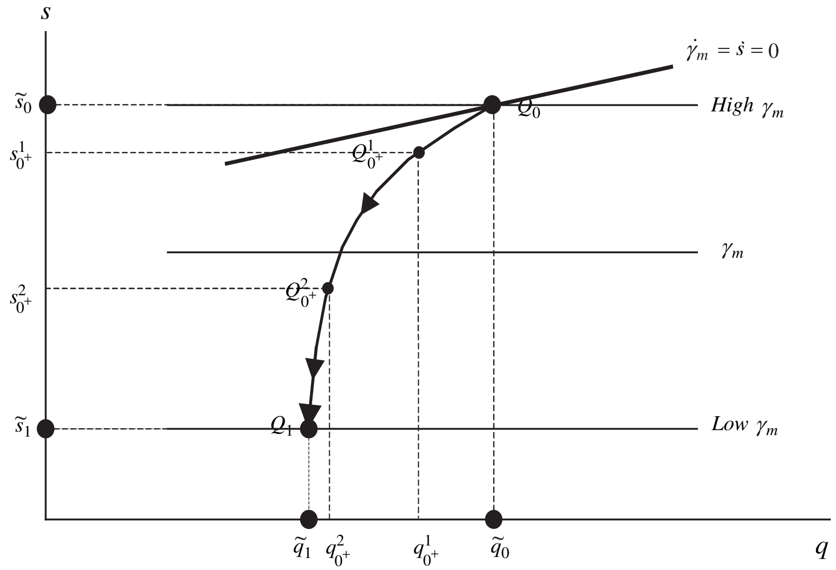

Fig. 4. Determination of the growth rate of real money balances.

related to $\dot{s}$. These statements imply that any point (q, s) off and to the underside (upside) of $\dot{\gamma}_m = 0$ is associated with a negative (a positive) value of $\dot{\gamma}_m$. As exhibited in Fig. 4, based on Eq. (29a) a fall in s on impact implies a decrease in γ_m. Subsequently, s continues to decrease as the economy moves from $Q^1_{0^+}$ (or $Q^2_{0^+}$) to the new steady-state Q_1 throughout the time interval between 0^+ and T_1 (or T_2). Given that in Eq. (29a) γ_m is positively related to μ, as shown in Fig. 6, at the instant T^+, γ_m will jump from $\gamma_{m_{T-}}$ to $\gamma_{m_{T+}}$. Moreover, $\dot{s}$ continues to decrease as the economy moves from $Q^1_{0^+}$ (or $Q^2_{0^+}$) to its new steady state. From Eq. (29b) this implies that γ_m falls monotonically at an increasing rate towards $\gamma_{m_{T-}}$ regardless of the size of T. The time paths of γ_m corresponding to distinct values of T are exhibited path (a) and path (b) in Fig. 6.

Given the relation $\varepsilon = (1-\alpha)As^{-\alpha} - r^*$ in Eq. (30a), at the instant 0^+ the decline of s on impact implies that ε rises discretely. Subsequently, ε continues to increase as the economy moves from point Q_{0^+} to the new steady-state Q_1. As shown in Fig. 4, $\dot{s}$ continues to decrease as the economy moves from $Q^1_{0^+}$ (or $Q^2_{0^+}$) to its new steady state. This implies that, from Eq. (30b), ε rises at an increasing rate towards its steady- state $\tilde{\varepsilon}$. The time paths of ε corresponding to different values of T are named path (a) and path (b) in Fig. 7. Note that the change in the depreciation rate of the domestic currency is greater than the change in the credit growth rate, thereby leading to an accelerating depreciation.[13] This consequence mainly stems from the presence of adjustment costs and money as augment input.

[13] From Eq. (16), we have $\partial\varepsilon/\partial\mu = (r^* - \pi^* - \tilde{\phi})/(r^* - \pi^* - \tilde{\phi} - \tilde{s}/h) > 1$.

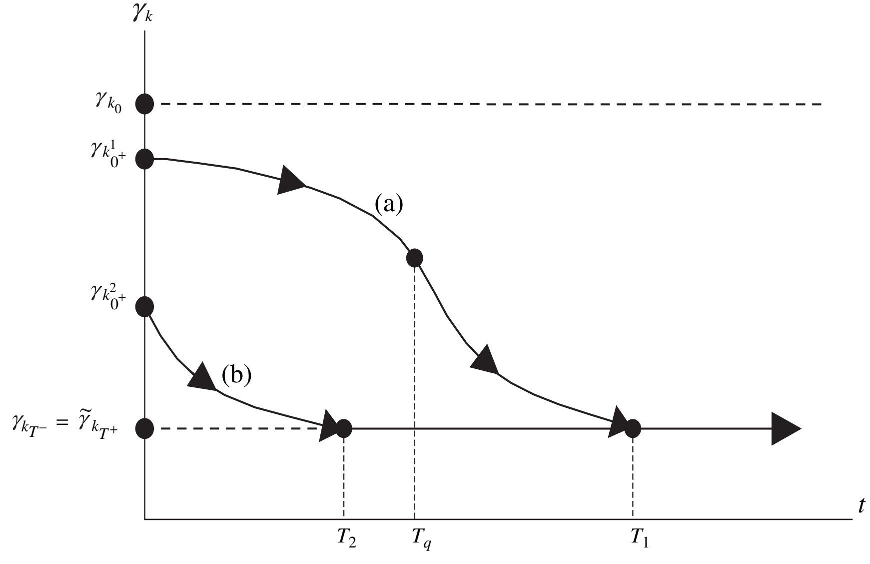

Fig. 5. Dynamic behavior of the growth rate of domestic capital following an anticipated domestic credit growth.

The result above can be intuitively explained as follows. An increase in the domestic credit growth rate raises the nominal interest rate and the rate of depreciation of the domestic currency from Eq. (16). This implies that the opportunity cost of the holdings of real money balances will rise. On the other hand, from Eq. (19) an increase in the domestic credit growth rate will lower the marginal product of physical capital and the real interest rate, and thereby discourage investment. Therefore, when an increase in nominal credit growth is anticipated, rational agents will shift their money holdings to foreign bonds before the imposition of the inflation tax. Moreover, the disinvestment still requires a positive cost. As a result, monetary superneutrality is not held in the intermediate and the long run. The channels we propose are different from those of Palokangas (1997), in which money is an intermediary good that reduces transaction costs.

We finally study the dynamic behavior of the rate of output growth, γ_y. Given that the relationship reported in Eq. (31a) γ_y is a weighted average of γ_k and γ_m, i.e., $\gamma_y = \alpha\gamma_k + (1-\alpha)\gamma_m$, we thus can infer the dynamic path of γ_y by observing the evolutionary process of γ_k and γ_m.[14] To save space, we only show the time path of γ_y in Fig. 9, but do not explicate the possible paths of γ_y here.

We can analyze the economy's responses to an unanticipated permanent rise in credit growth as $T=0$. When the shock of a permanent rise in the credit growth rate

[14] It is clear in Fig. 8 that $\dot{s}/\dot{q} > 0$ along the trajectory and the isogrowth lines of γ_y are downward sloping, that is $\partial s/\partial q|_{\gamma_y} = -1/[h(1-\alpha)^2 A s^{-\alpha-1}] < 0$. The sign of $\dot{\gamma}_y$ thus relies on the sign of $\dot{q}$ in Eq. (31b). Equipped with this information, we can infer that the transitional behavior of γ_y is similar to that of γ_k.

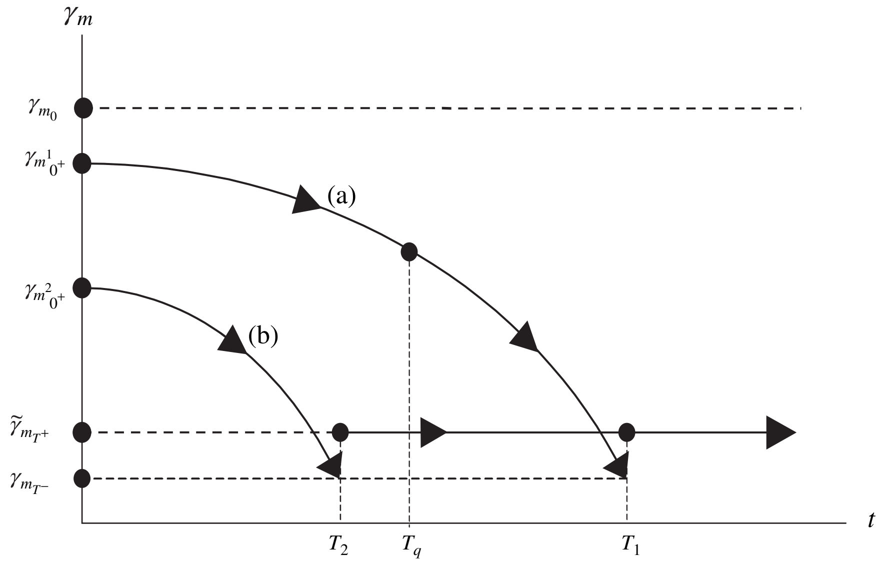

Fig. 6. Dynamic behavior of the growth rate of real money balances following an anticipated domestic credit growth.

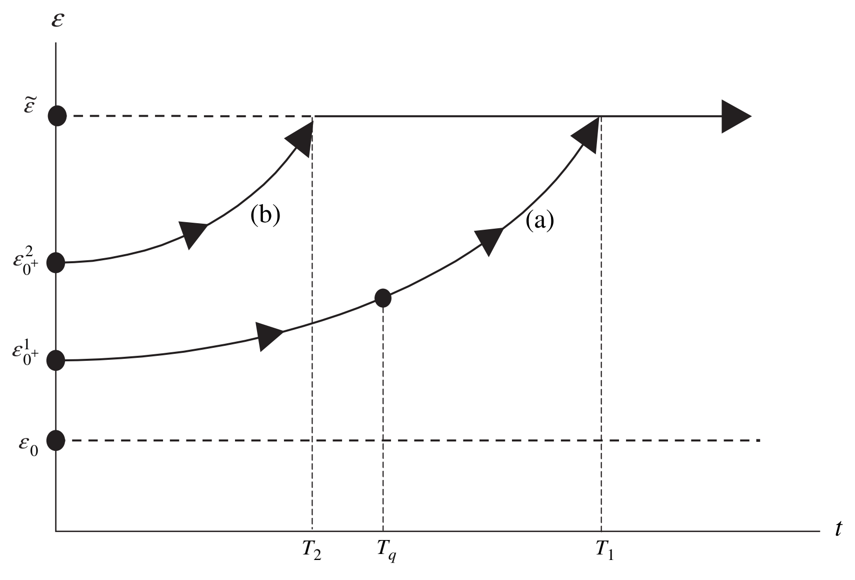

Fig. 7. Dynamic behavior of the currency depreciation rate following an anticipated domestic credit growth.

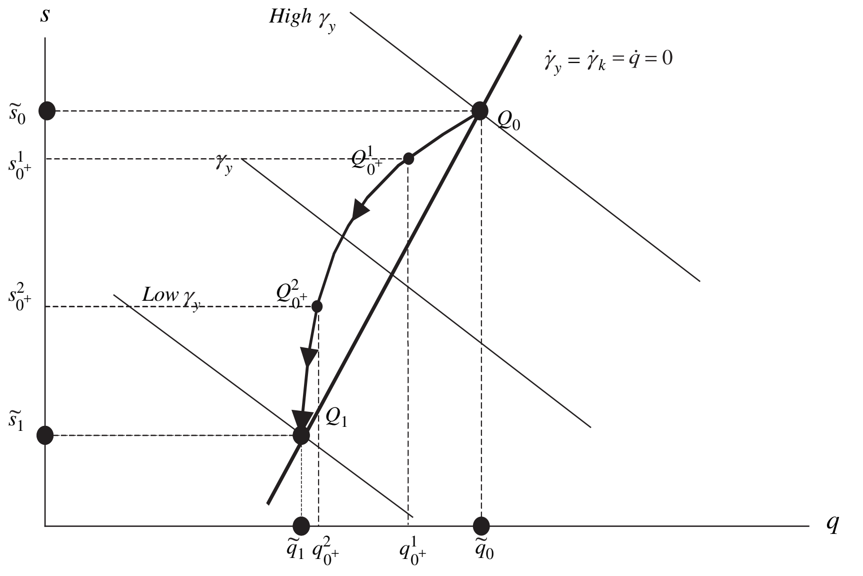

Fig. 8. Determination of the growth rate of domestic output.

is unanticipated, at the instant 0^+, both q and s immediately decrease to their new stationary value. Hence, the economy at once jumps from the initial equilibrium Q_0 to the new steady-state Q_1 in Fig. 2, so as to satisfy the transversality condition that the system is characterized by the global instability. Moreover, at the instant 0^+, the growth rate of physical capital and real money balances immediately decreases to a new stationary value in Figs. 3 and 4. This result is consistent with the conclusion of Pecorino (1995) and Mino (1997) that unanticipated monetary growth is harmful to the stationary economic growth rate though their analyses deal with a closed economy. Comparing with the empirical literature, our result is also consistent with most studies in Table 1.[15] Moreover, the depreciation rate of the domestic currency immediately rises to its new stationary value in Fig. 7 and the change in the depreciation rate of the domestic currency is larger than the change in monetary growth. Hence, money superneutrality is not valid in the long run.

4. Concluding remarks

This paper sets up an endogenous growth model of a small open economy with a flexible exchange rate regime. The model introduces money into the

[15] Table 1 is adopted from Gylfason and Herbertsson (2001), and the detailed references in it are not cited in this paper.

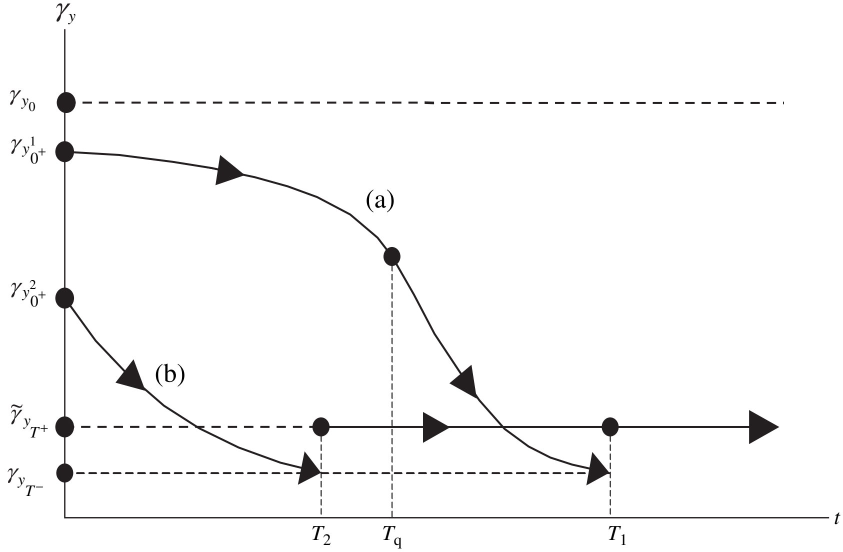

Fig. 9. Dynamic behavior of the growth rate of domestic output following an anticipated domestic credit growth.

production function and incorporates adjustment costs for investment. Embodying these two features, we analyze the effect of a preannounced monetary growth policy on the rate of sustained growth and the transitional behavior of the economy.

We have found that an increase in the domestic credit growth rate stimulates the nominal interest rate and hence lowers the holding of real money balances. To be specific, when an increase in nominal credit growth is anticipated, rational agents will shift their money holdings to foreign bonds before the imposition of the inflation tax. Meanwhile, it lowers the marginal product of physical capital and incurs a positive adjustment cost to reduce investment. Hence, a rise in the growth rate of domestic credit leads to a decrease in transitional behavior of the market value of capital and the growth rate of capital, real money balances, and real output. Furthermore, an increase in the growth rate of the domestic credit lowers the stationary-market value of capital and the sustained-growth rate of capital, real money balances, and real output, while both the transitional dynamics and the steady-growth rate of real consumption remain unchanged. Moreover, the rate of depreciation of the domestic currency displays an increasing process during the evolutionary adjustment and the change in the rate of depreciation of the domestic currency is greater than the change in the credit growth rate. Consequently, money nonsuperneutrality is exhibited in the intermediate and the long run. The conclusion of this paper is therefore consistent with the empirical evidence found by Easterly (1996) and Fischer et al. (1996) in which disinflation programs are found to have an expansionary effect on economic growth.

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Appendix

The growth rate of domestic output y is the same as k, because m and k will grow forever on the balanced growth path. Substituting the expressions for $c(t)$ from Eq. (17), and i and $k(t)$ from Eq. (18) into (15), the accumulation Eq. (15) can be written in the form:

$$\dot{b}^*(t)=(r^*-\pi^*)b^*+y_0\,\mathrm{e}^{\phi t}-c_0\,\mathrm{e}^{\psi t}-\phi\left(1+\frac{h}{2}\phi\right)k_0\,\mathrm{e}^{\phi t}, \tag{A1}$$

where y_0 is defined as $A(m_0/k_0)^{1-\alpha}$, and ψ and ϕ are as defined in Eq. (17) and Eq. (18), respectively. Solving Eq. (A1) implies:

$$b^*(t)=\mathrm{e}^{(r^*-\pi^*)t}\left\{b_0^*+\int_0^t\left[\left(A'-\frac{q^2-1}{2h}\right)k_0\,\mathrm{e}^{\phi\xi}-c_0\mathrm{e}^{\psi\xi}\right]\mathrm{e}^{-(r^*-\pi^*)\xi}\,\mathrm{d}\xi\right\}, \tag{A2}$$

where A' is defined as $A(m_0/k_0)^{1-\alpha}$. Furthermore, the transversality condition $\lim_{t\to\infty}\lambda b^*\,\mathrm{e}^{-\rho t}=\lim_{t\to\infty}\lambda_0 b^*\,\mathrm{e}^{-(r^*-\pi^*)t}=0$ can be rewritten as:

$$\lambda_0\left\{b_0^*+\frac{k_0[A'-((q^2-1)/2h)]}{\phi-(r^*-\pi^*)}\mathrm{e}^{[\phi-(r^*-\pi^*)]t}\Big|_0^\infty-\frac{c_0}{\psi-(r^*-\pi^*)}\mathrm{e}^{[\psi-(r^*-\pi^*)]t}\Big|_0^\infty\right\}=0.$$

Thus, in order to ensure national intertemporal solvency, Eq. (12a) must be satisfied and this will hold if and only if Eqs. (22a)–(22c) are satisfied.

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