Journal of Development Economics
Vol. 59 (1999) 295–318

JOURNAL OF
Development
ECONOMICS

Comparing the welfare costs and initial dynamics of alternative inflation stabilization policies

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Received 1 January 1996; accepted 1 August 1998

Abstract

This paper uses calibrated versions of a sticky-price currency-substitution model to compare the initial dynamics and welfare costs of three types of stabilization program: exchange-rate-based (ERB), money-based (MB), and money-based with initial reliquefication (MBR). ERB and MBR programs are found to induce an initial expansion in real activity, whereas MB programs are initially contractionary. The welfare gains of eliminating high inflation are significant under permanent ERB and MBR programs but small under permanent MB programs. In addition, temporary MB programs are shown to be much more disruptive than temporary ERB or MBR programs. These results provide an explanation for why MB programs are so rarely implemented and suggest that empirical studies that fail to distinguish MB from MBR programs are likely to be biased toward finding that stabilizations are always expansionary regardless of the nominal anchor. © 1999 Elsevier Science B.V. All rights reserved.

JEL classification: F41

Keywords: Inflation stabilization; Nominal anchors; Welfare analysis

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PII: S0304-3878(99)00014-0

1. Introduction

In spite of the large amount of work that has been devoted to understanding the dynamics of inflation stabilization programs, the question of whether there exists a recession-now-versus-recession-later trade-off in choosing between a monetary and an exchange-rate anchor remains controversial. For example, Calvo and Végh (1994a) analyze episodes of inflation stabilization in Latin America and Israel and find evidence in favor of such a trade-off. Specifically, they find that money-based stabilization programs generate an initial recession, whereas exchange-rate-based programs are initially expansionary and generate a recession later. Other authors are skeptical about the empirical validity of the trade-off. Easterly (1996) and Gould (1996), for example, find that stabilizations are always expansionary regardless of the nominal anchor.

In this paper, I argue that unless one departs from the dichotomy of classifying stabilization policies as either exchange-rate-based or money-based, the question is likely to remain unresolved. The reason is that money-based stabilization programs are virtually never implemented. Typically, money-based programs include an initial monetary injection aimed at preventing a liquidity crunch resulting from the public's desire to re-build real balances in response to lower inflation expectations. With this motivation in mind, I analyze the dynamics and welfare consequences of money-based programs with reliquefication (MBR) in addition to exchange-rate-based (ERB) and money-based (MB) programs.

ERB and MB programs can be viewed as polar monetary policies. Under an ERB program, the government fixes the path of the nominal exchange rate, and the money supply is endogenously determined. Under an MB program, the nominal money supply is not allowed to jump; the government fixes the path of the money growth rate and lets the exchange rate be endogenously determined. An MBR program is an MB program coupled with an initial once-and-for-all increase in the money supply that keeps the price level from falling upon announcement. Because in the model economy studied in this paper the price of nontradables is sticky, preventing an initial deflation amounts to preventing the nominal exchange rate—which determines the nominal price of tradables—from appreciating on impact. MBR programs combine elements of both ERB and MB programs. They share with MB programs the government's fixing of the path of the money growth rate and with ERB programs the government's fixing of the initial value of the nominal exchange rate with the initial level of the money supply being endogenously determined.

I compare these three alternative stabilization strategies within the Calvo and Végh (1994b) model of a small open economy with staggered price setting and currency substitution. This model predicts the recession-now-versus-recession-later trade-off: a temporary MB program induces an initial contraction in aggregate demand, whereas a temporary ERB program is initially expansionary and generates a recession that begins around the time the program is expected to be discontinued. I show that, unlike MB programs, MBR programs are initially expansionary. Thus, empirical studies that fail to distinguish between MB and MBR programs may introduce a bias toward finding that stabilizations are initially expansionary regardless of the nominal anchor.

To quantitatively compare the initial dynamics and welfare costs of the different stabilization strategies, I calibrate the model using long-run data relations from high-inflation economies. I find that the initial recession induced by MB programs is much larger than the later recessions induced by ERB or MBR programs. As a result, the welfare costs associated with MB programs are much larger than those associated with any of the other two programs. In addition, ERB and MBR programs produce welfare costs of the same order of magnitude. These results help explain why MB programs are so rarely observed and suggest that, contrary to conventional wisdom, the choice of nominal anchor is more likely to reflect the policymakers' desire to avoid a recession of major proportions than their preference regarding the timing of the contraction.

The remainder of the paper is organized in four sections. Section 2 presents the building blocks of the model, Section 3 compares the initial dynamics of ERB, MB, and MBR programs, Section 4 presents welfare comparisons, and Section 5 concludes.

2. The model

In this section, I outline the theoretical environment, which follows closely Calvo and Végh (1994b), and discuss in some detail computational issues.

2.1. Households

Consider a perfect-foresight economy populated by a large number of identical households with preferences defined over paths of consumption of tradable goods, c_t^*, and nontradable goods, c_t, and described by the utility function

$$\int_0^{\infty} e^{-\beta t}\left[\ln(c_t^*) + \ln(c_t)\right] \mathrm{d}t; \quad \beta > 0. \tag{1}$$

Households are assumed to have access to three financial assets: domestic currency, M_t, foreign currency, f_t, and a foreign-currency-denominated bond, b_t, that pays the constant interest rate $r > 0$ in foreign currency. In addition, households have an income of y_t^* units of tradables and y_t units of nontradables and receive from the government a lump-sum transfer, τ_t, measured in terms of tradables.

I will assume that the law of one price holds for traded goods and that the foreign-currency price of tradables is constant and equal to one. Then the domestic-currency price of tradables must equal the nominal exchange rate, E_t, defined as the price of foreign currency in terms of domestic currency. Letting P_t denote the domestic-currency price of nontradables, $e_t \equiv E_t/P_t$ the real exchange rate defined as the relative price of tradables in terms of nontradables, $m_t \equiv M_t/E_t$ real domestic money balances in terms of tradables, and $\epsilon_t \equiv \dot{E}_t/E_t$ the devaluation rate, the evolution of the household's financial wealth, $b_t + f_t + m_t$, is given by

$$\dot{b}_t + \dot{f}_t + \dot{m}_t = rb_t - \epsilon_t m_t - c_t^* - c_t/e_t + y_t^* + y_t/e_t + \tau_t$$

Households are subject to a no-Ponzi-game borrowing constraint of the form

$$\lim_{t\to\infty} e^{-rt}(b_t + f_t + m_t) \geq 0.$$

The above two expressions are equivalent to the following intertemporal budget constraint:

$$\int_0^\infty e^{-rt}[c_t^* + c_t/e_t + i_t m_t + rf_t]\mathrm{d}t$$
$$= m_0 + f_0 + b_0 + \int_0^\infty e^{-rt}(y_t^* + y_t/e_t + \tau_t)\mathrm{d}t, \tag{2}$$

where i_t denotes the nominal interest rate, which, assuming perfect capital mobility, satisfies

$$i_t = r + \epsilon_t. \tag{3}$$

Purchases of goods are subject to a liquidity-in-advance constraint of the form

$$L(m_t, f_t) \geq \alpha(c_t^* + c_t/e_t); \quad \alpha > 0, \tag{4}$$

where $L(\cdot,\cdot)$ is a liquidity-services production function of the form

$$L(m,f) \equiv [\gamma m^{-\rho} + (1-\gamma)f^{-\rho}]^{-1/\rho}; \quad \rho \geq -1, \quad \gamma \epsilon (0,1].$$

The household's problem consists in choosing paths for consumption and asset holdings so as to maximize Eq. (1) subject to Eqs. (2) and (4). I will assume for simplicity that the pecuniary and subjective rates of discount are equal, $r = \beta > 0$. Also, throughout the paper, I will study equilibria in which the domestic nominal interest rate is strictly positive. The fact that the opportunity cost of both liquidity-generating assets are assumed to be positive implies that households will always choose to satisfy the liquidity-in-advance constraint with equality. The first-order conditions corresponding to the household's optimization problem are:

$$\frac{f_t}{m_t} = \left[\left(\frac{1-\gamma}{\gamma}\right)\left(\frac{i_t}{r}\right)\right]^{\frac{1}{1+\rho}} \equiv w(i_t), \quad w' > 0, \tag{5}$$

$$\frac{1}{c_t^*} = \lambda\left[1 + \frac{\alpha i_t}{L_m(1, w(i_t))}\right] \equiv \frac{\lambda}{z(i_t)} \quad z' < 0, \tag{6}$$

$$\frac{c_t}{c_t^*} = e_t, \tag{7}$$

$$\int_0^\infty e^{-rt}[c_t^* + c_t/e_t + i_t m_t + rf_t]\mathrm{d}t$$

$$= m_0 + f_0 + b_0 + \int_0^\infty e^{-rt}(y_t^* + y_t/e_t + \tau_t)\mathrm{d}t, \tag{8}$$

and

$$L(m_t, f_t) = \alpha(c_t^* + c_t/e_t), \tag{9}$$

where λ is a Lagrange multiplier associated with the budget constraint (2). Letting $\pi_t \equiv \dot{P}_t/P_t$ denote the inflation rate of nontradables in period t, it follows that

$$\dot{e}_t = (\epsilon_t - \pi_t)e_t. \tag{10}$$

2.2. Aggregate supply

The supply of tradables is assumed to be exogenously given. The supply of nontradables is demand-determined. Following Calvo (1983), the price of nontradables is assumed to be sticky (i.e., a non-jump variable), but the inflation rate is allowed to jump in response to unexpected innovations in the state of the economy. Specifically, the evolution of π_t is assumed to take the form

$$\dot{\pi}_t = -\theta \ln(y_t/\bar{y}), \quad \theta > 0, \tag{11}$$

where $\bar{y}$ denotes the full-employment level of output in the nontraded sector. [1]

2.3. The government

The government uses money creation and the return on its interest-bearing asset holdings to perform lump-sum transfers to the public and to expand its asset holdings. Formally,

$$\mu_t m_t + rb_t^{\mathrm{g}} = \tau_t + \dot{b}_t^{\mathrm{g}}$$

[1] Calvo (1983) assumes that $\dot{\pi}_t$ is proportional to the difference rather than the log-difference between potential and current output. This slight departure from Calvo's original formulation allows for a closed-form solution of the equilibrium dynamics and welfare costs of both permanent and temporary exchange-rate-based stabilization program, without violating any of the model's microfoundations. Specifically, the derivation of an expression of the form $\dot{\pi}_t = -\theta D_t$, where D_t is some measure of aggregate excess demand, is independent of the particular form assumed for D_t (see Calvo, 1983, pp. 385–387).

where b_t^{g} denotes the stock foreign-currency-denominated bonds held by the government and $\mu_t \equiv \dot{M}_t / M_t$ the money growth rate, which by definition satisfies

$$\dot{m}_t = (\mu_t - \epsilon_t) m_t. \tag{12}$$

The government is also assumed to satisfy a borrowing constraint of the form

$$\lim_{t \to \infty} e^{-rt} (b_t^{\mathrm{g}} - m_t) = 0$$

The last three conditions are equivalent to the following present-value budget constraint:

$$b_0^{\mathrm{g}} - m_0 = \int_0^{\infty} e^{-rt} [\tau_t - i_t m_t] \mathrm{d}t \tag{13}$$

2.4. Equilibrium

In equilibrium, the nontraded goods market must clear, that is,

$$y_t = c_t. \tag{14}$$

Combining Eqs. (8), (13) and (14) yields the resource constraint

$$\int_0^{\infty} e^{-rt} (c_t^* + r f_t) \mathrm{d}t = \frac{y_0^{\mathrm{p}}}{r}, \tag{15}$$

where

$$y_0^{\mathrm{p}} \equiv r(b_0 + b_0^{\mathrm{g}} + f_0) + r \int_0^{\infty} e^{-rt} y_t^* \mathrm{d}t$$

denotes permanent income of tradables in period zero. A perfect-foresight equilibrium consists of a positive scalar λ and a set of sequences $\{c_t^*, c_t, y_t, m_t, f_t, e_t, \epsilon_t, \pi_t, \mu_t, i_t\}_{t=0}^{\infty}$ satisfying Eqs. (3), (5)–(12), and Eqs. (14) and (15), given y_0^{p}, P_0, and a specification of the monetary/exchange-rate regime to be provided below.

3. Inflation stabilization and nominal anchors

Prior to time zero, the economy is assumed to be in a steady state in which the devaluation rate (ϵ^{H}) and the money growth rate (μ^{H}) are constant and equal to each other. It then follows from the equilibrium conditions that before period zero, consumption, the real exchange rate, the nominal interest rate, and real asset holdings are all constant. We are now ready to provide a formal description of the three types of inflation stabilization program whose welfare effects and initial dynamics are to be compared: exchange-rate-based programs and money-based programs with and without reliquefication. All programs are assumed to be announced unexpectedly in period zero.

A permanent ERB stabilization program is defined as a permanent and credible reduction in the devaluation rate from ϵ^{H} to $\epsilon^{\mathrm{L}} < \epsilon^{\mathrm{H}}$, with the initial nominal exchange rate, E_0, fixed at the value prevailing immediately before the announcement, which will be denoted by E_{-}. Formally,

$$\epsilon_t = \epsilon^{\mathrm{L}} \quad t \geq 0 \tag{16}$$

$$E_0 = E_{-}. \tag{17}$$

In addition, the government ensures free convertibility of the domestic currency, so that M_t is endogenously determined.

A permanent MB program is a permanent and credible reduction in the money growth rate from μ^{H} to $\mu^{\mathrm{L}} < \mu^{\mathrm{H}}$, keeping the initial stock of money, M_0, fixed at the level prevailing immediately before the announcement, M_{-}. Formally,

$$\mu_t = \mu^{\mathrm{L}} \quad t \geq 0 \tag{18}$$

$$M_0 = M_{-}. \tag{19}$$

Under this type of stabilization program, the government lets the nominal exchange rate float freely.

A permanent MBR program is a permanent and credible reduction in the money growth rate from μ^{H} to μ^{L} coupled with a once-and-for-all increase in the stock of money that prevents the nominal exchange rate from jumping in period zero. Formally, this program is described by Eqs. (17) and (18). [2]

A temporary ERB stabilization program is defined as a reduction in the devaluation rate from ϵ^{H} to ϵ^{L} that lasts, and is expected to last, for a finite period of time, $T > 0$. Formally, a temporary ERB program is described by Eq. (17) and

$$\epsilon_t = \begin{cases} \epsilon^{\mathrm{L}} & \text{for } 0 \leq t < T \\ \epsilon^{\mathrm{H}} & \text{for } t \geq T \end{cases} \tag{20}$$

Similarly, a temporary MB stabilization program is a reduction in the money growth rate from μ^{H} to μ^{L} for a finite period of time T and is formally described by Eq. (19) and

$$\mu_t = \begin{cases} \mu^{\mathrm{L}} & \text{for } 0 \leq t < T \\ \mu^{\mathrm{H}} & \text{for } t \geq T \end{cases} \tag{21}$$

Finally, a temporary MBR program consists of a temporary reduction in the money growth rate coupled with an initial once-and-for-all change in the stock of

[2] Because in this model the interest earned by the central bank on its international reserves is returned to the public in a lump-sum fashion, the dynamics of the variables of interest are unaffected by whether the initial monetary injection is carried out through purchases of foreign currency or through a helicopter-type transfer. Of course, these two methods are different from the standpoint of the policymaker because they imply different paths for the primary fiscal deficit and the stock of international reserves held at the central bank.

Table 1
Calibration

Parameter	Value	Description
T	12	Duration of temporary programs (quarters)
$\epsilon^{\mathrm{H}} = \mu^{\mathrm{H}}$	35%	Quarterly pre-stabilization and post-collapse (if applicable) devaluation and money growth rates
$\epsilon^{\mathrm{L}} = \mu^{\mathrm{L}}$	0	Devaluation and money growth rates during transition
$(1+\rho)^{-1}$	1.0	Elasticity of currency substitution
γ	0.5	Share of domestic currency in CES liquidity function
α	0.4	Liquidity to consumption ratio
θ	0.48	Speed of price adjustment (half life = 1 quarter)
r	1.6%	Quarterly international real interest rate
β	1.6%	Subjective discount factor
y_0^{p}	1.0	Permanent income of tradables
$\bar{y}$	1.0	Full employment output in the nontraded sector

money aimed at preventing the nominal exchange rate from jumping upon announcement. It is described by Eqs. (17) and (21).

This completes the description of the economic environment. A description of the methods applied to compute equilibrium dynamics is in Appendix A.

3.1. Calibration

To quantitatively compare the effects of the alternative stabilization policies, I assign numerical values to the parameters of the model. The baseline calibration is summarized in Table 1. The time unit is meant to be a quarter. Based on the evidence provided by Calvo and Végh (1994a) and Reinhart and Végh (1995) on episodes of inflation stabilization in Latin America and Israel over the past three decades, I assume that stabilization programs are designed to eliminate an inflation rate of 35% per quarter and that temporary programs last three years. That is, I set $\epsilon^{\mathrm{H}} = \mu^{\mathrm{H}} = 0.35$, $\epsilon^{\mathrm{L}} = \mu^{\mathrm{L}} = 0$, and $T = 12$. The elasticity of currency substitution, $1/(1+\rho)$, is set at one and the share of domestic currency in the CES liquidity function, γ, at 0.5. These values fall within the range of estimates reported by Bufman and Leiderman (1993). [3] The liquidity-to-consumption ratio, α, was set at 0.4 to make the pre-stabilization levels of seigniorage revenue and inflation consistent with those observed in Israel over the two years leading to the Israeli

[3] Based on data for Israel, their estimates of $1/(1+\rho)$ range from 0.83 to 3.33, and the ones of γ are clustered around 0.5. As in most empirical studies of currency substitution, their measure of foreign currency consists of dollar-denominated time deposits. Ideally, foreign currency should be measured as the sum of foreign-currency-denominated checkable deposits and foreign currency in circulation in the nonbanking private sector. Unfortunately, data availability problems make the construction of such a measure virtually impossible.

program of mid 1985 (see Bufman and Leiderman, 1993; Table 4). The baseline value of θ is 0.48 and implies a half-life of π_t of one quarter. [4] This value was arbitrarily chosen because of scarce empirical evidence on the degree of price stickiness in high-inflation economies. It is meant to reflect the fact that in such economies firms face strong incentives to adjust prices frequently. The international real interest rate, r, and the subjective discount factor, β, were set at 1.6% per quarter, a value that corresponds to the average real rate of return on US equity between 1948 and 1981 (King et al., 1988). The full-employment level of output in the nontraded sector, $\bar{y}$, as well as the permanent income of tradables in period zero, y_0^{p}, were set at one.

Finally, for analytical and computational simplicity, throughout the paper I maintain a log–linear specification for the instant utility index. This specification is certainly restrictive, for empirical estimates of the elasticity of intertemporal substitution for developing countries are typically below one (Reinhart and Végh, 1993; Giovannini et al., 1985; Eckstein and Leiderman, 1992). [5]

3.2. Permanent stabilization programs

It can be shown that permanent ERB and MBR programs induce identical dynamics and that under permanent ERB, MB, and MBR programs, the nominal interest rate and consumption of tradables jump to their new steady states at $t=0$ (see Appendix A). Fig. 1 displays the initial dynamics of permanent ERB, MB, and MBR programs. The increase in consumption of tradables is of about 5%. It is driven by a positive wealth effect stemming from the fact that as the nominal interest rate falls, the public substitutes domestic currency, which has a social opportunity cost of zero, for foreign currency, which has a social opportunity cost equal to the international real interest rate. As shown in the upper right panel of the figure, the MB program generates an initial contraction in the nontraded sector of more than 80%. This severe adverse effect is caused by the liquidity crunch generated by the increase in money demand (induced by lower inflation expectations) that cannot be accommodated by either the money supply (which by assumption is not allowed to jump in period zero) or the price level (because of its inflexibility). Interestingly, the liquidity crunch is not reflected in a high nominal interest rate. Under ERB and MBR programs, a liquidity crunch does not occur because the money supply is demand determined. In fact, consumption of nontradables experiences an initial boom that is proportional to the initial increase in

[4] In the absence of expected changes in policy, π_t converges to its steady-state value at the rate $\sqrt{\theta}$ (see Appendix A). Therefore, its half-life is $-\ln(1/2)/\sqrt{\theta}$ quarters.

[5] It should be noted, however, that estimates of the intertemporal elasticity of substitution are highly sensitive to factors such as the empirical definition of consumption and the choice of instruments. For example, the estimates reported by Eckstein and Leiderman range from 0.15 to 1.3.

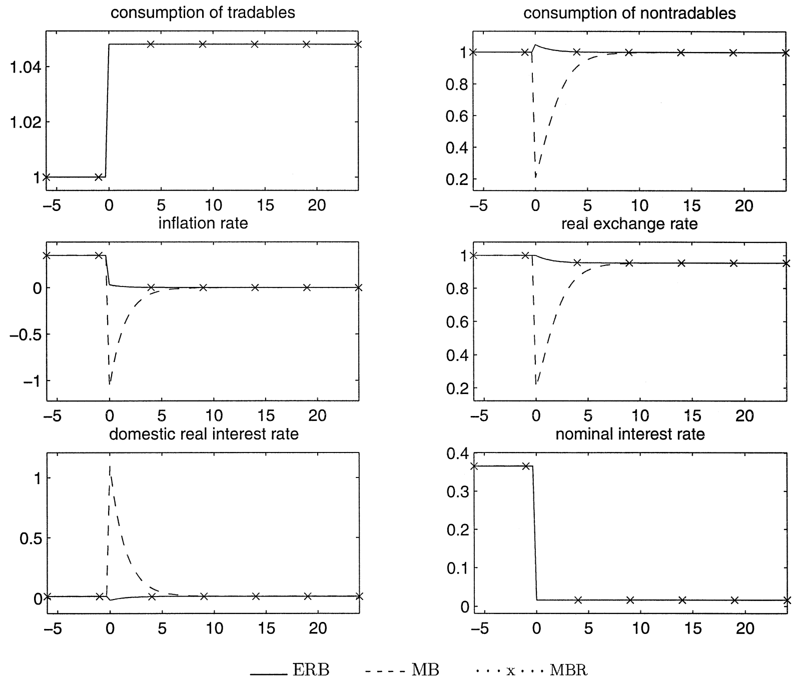

Fig. 1. Permanent inflation stabilization and nominal anchors. Under the exchange-rate-based (ERB) program, the devaluation rate is permanently reduced from 35% per quarter to 0. Under money-based (MB) program and the money-based program with initial reliquefication (MBR), the money growth rate is permanently reduced from 35% per quarter to 0. All other parameter values are as described in Table 1. The response of consumption of tradables was scaled so that its pre-stabilization value equals one.

consumption of tradables. [6] Under all three stabilization programs, after the initial impact, c_t, e_t, and π_t converge monotonically to their respective steady states at the constant rate $\sqrt{\theta}$ (see Appendix A for a proof).

Fig. 1 captures the main result of this paper. Namely, that because MB programs are rare, empirical studies that classify stabilization episodes as either ERB or MB, without distinguishing between MB and MBR programs, will wrongly tend to conclude that ERB and MB programs are expansionary.

Although illustrative, the exercise conducted in this section is highly unrealistic. Permanent stabilization programs are the exception rather than the rule. If the theoretical argument against the validity of empirical studies based on a di-

[6] To see this, recall that $c_t = e_t\, c_t^*$ and that under both ERB and MBR programs e_t cannot jump at $t = 0$.

chotomic classification of programs is to be relevant, it must hold in the context of temporary, imperfectly credible stabilization.

3.3. Temporary stabilization programs

Fig. 2 displays the initial dynamics of key macroeconomic variables under temporary ERB, MB, and MBR stabilization programs. Under policy temporariness, both ERB and MB programs induce a recession at some point of the transition. In the MB program, the recession takes place right after the announcement, whereas in the ERB program it occurs around the time the policy is expected to be abandoned. However, the recession induced by the MB program is more than twice as severe as the one induced by the ERB program (65% vs. 25%). Thus, although there is a clear trade-off regarding the timing of the contraction, quantitatively MB programs appear to be more disruptive than ERB programs.

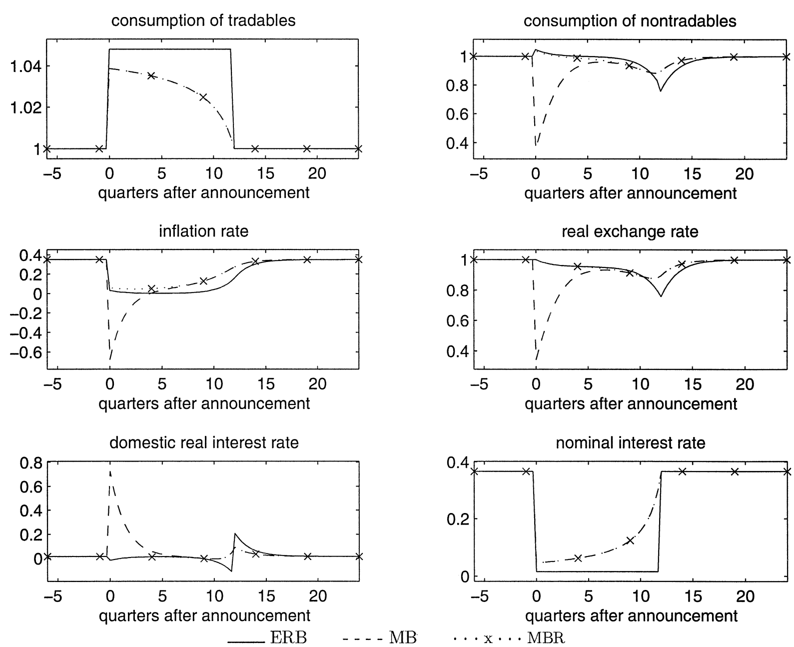

Fig. 2. Temporary inflation stabilization and nominal anchors. Under the exchange-rate-based (ERB) program, the devaluation rate is reduced from 35% per quarter to 0 for 12 quarters and then increased back to 35% per quarter forever. Under the money-based (MB) program and the money-based program with initial reliquefication (MBR), the money growth rate is reduced from 35% per quarter to 0 for 12 quarters and then increased back to 35% per quarter forever. All other parameter values are as described in Table 1.

This conclusion is confirmed by the sensitivity and welfare analyzes performed below. [7]

The liquidity crunch that is at the root of the initial recession in the MB program disappears when the program is coupled with an initial once-and-for-all increase in the stock of money. In fact, under the MBR program consumption of nontradables displays an initial boom that is similar in magnitude to the one induced by the ERB program. Unlike permanent ERB and MBR programs, however, temporary ERB and MBR programs do not induce identical dynamics. Under a temporary ERB program, the nominal interest rate experiences a discrete increase at time T as the devaluation rate jumps from ϵ^{L} to ϵ^{H}. As a result, c_t^*, c_t, and m_t also jump at time T (see conditions (5)–(9)). Under a temporary MBR program, a jump in the nominal interest rate at time T is impossible. Such a pattern would imply a discrete increase in m_t, which, given the continuity of M_t at $t = T$, would require a discrete depreciation of the domestic currency (i.e., a discrete increase in E_t at time T). But an anticipated jump in the nominal exchange rate is not possible in equilibrium. Thus, the nominal interest rate is continuous at $t = T$, as are consumption and real balances. As the MBR program approaches the time of collapse, the path of c_t departs from the one corresponding to the ERB program and joins the one associated with the MB program.

Finally, as shown in the bottom right panel of Fig. 2, MB and MBR programs induce the same response in the nominal interest rate (see Appendix A for a proof). Thus, the nominal interest rate is not a good indicator of whether the monetary authority is providing enough liquidity in the initial phase of money-based programs. The middle panel of Fig. 2 suggests that better signals are provided by the nominal exchange rate, the rate of inflation, or the domestic ex-post real interest rate.

3.3.1. Sensitivity analysis

Fig. 3 displays the initial dynamics of consumption of tradables and nontradables, the real exchange rate, and the rate of inflation of nontradables under temporary ERB, MB, and MBR programs for different values of key parameters of the model: the share of domestic currency in the CES liquidity function, γ; the elasticity of currency substitution, $(1+\rho)^{-1}$; the speed of adjustment of nominal prices, θ; and the liquidity-to-consumption ratio, α. Panel (a) reproduces the dynamics of the model for the baseline calibration (see Table 1).

Panel (b) depicts the case in which domestic currency is the only means of payment available to the public ($\gamma = 1$). In this case, an MB program does not

[7] Reinhart and Végh (1995) argue that the ERB programs typically end in financial and/or banking crises. To the extent that this empirical regularity does not apply to MB programs–an issue that to my knowledge has not yet been empirically investigated—the model studied in this paper would conceivably underestimate the magnitude of the late recession induced by ERB programs.

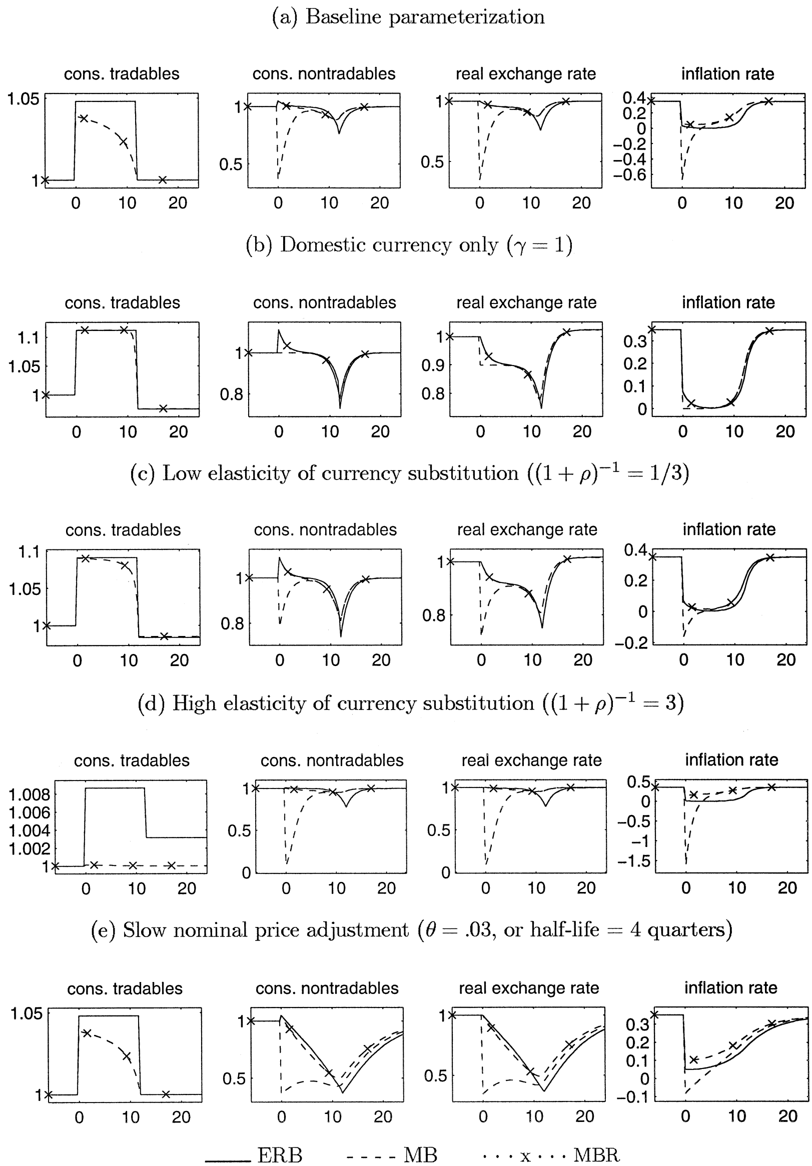

Fig. 3. Sensitivity analysis. See description at the bottom of Fig. 2.

generate an early recession. To see why, note that when γ equals one, the liquidity-in-advance constraint (9) becomes a standard cash-in-advance constraint of the form $m_t = \alpha(c_t^* + c_t/e_t)$, which, using Eq. (7) and setting $t = 0$, can be written as $M_0/P_0 = 2\alpha c_0$. Since both M_0 and P_0 are pre-determined at $t=0$, c_t cannot jump when the plan is announced. Under all three types of program, the boom in consumption of tradables is more than twice as large when γ equals one than when it takes the baseline value of $1/2$. This is also the case for consumption of nontradables under ERB and MBR programs.

In panels (c) and (d) the elasticity of currency substitution takes the values $1/3$ and 3, respectively. [8] For all three of the stabilization programs considered, the size of the initial boom in consumption of tradables is decreasing in this elasticity. [9] The same is true for consumption of nontradables under ERB and MBR programs. Under MB programs, the magnitude of the initial recession in the nontraded goods sector increases with the degree of currency substitution. This is because the larger the elasticity of currency substitution, the larger the liquidity crunch associated with a given decline in expected inflation.

Finally, in panel (e) the parameter θ is set at a value such that the half-life of π_t is one year, four times longer than in the baseline parameterization. As shown in Appendix A, θ does not affect the determination of consumption of tradables, the nominal interest rate, or the impact effect on consumption of nontradables under any of the three stabilization programs. However, it plays an important role in shaping the transitional dynamics of consumption of nontradables. Fig. 3 shows that as the degree of nominal rigidity increases, both the initial recession associated with MB programs and the late recession associated with ERB and MBR programs deepen considerably and become more persistent.

4. Welfare comparisons

The welfare cost of a stabilization program is defined as the percentage reduction in the pre-stabilization steady-state stream of consumption that makes households indifferent between the resulting constant stream of consumption and the sequence of consumption associated with the stabilization program. Formally, let ξ denote the welfare cost, c_-^* and c_- the pre-stabilization steady-state levels of

[8] The implied log-log money demand elasticities evaluated at the pre-stabilization nominal interest rate are -0.1 and -3.0, respectively.

[9] For high values of the elasticity of currency substitution (as in panel (d)), the post-collapse level of consumption of tradables under ERB programs is larger than the pre-stabilization level. Two factors are behind this effect. First, under currency substitution, a decline in expected inflation—even if temporary—generates a permanent income effect as households substitute domestic for foreign currency in producing liquidity. Second, the higher the elasticity of currency substitution, the weaker the public's incentive to reallocate consumption across time in response to a temporary decline in expected inflation.

consumption of tradables and nontradables, respectively, and $\{c_t^*,\ c_t\}_{t=0}^{\infty}$ the consumption streams induced by the stabilization program. Then ξ solves

$$\ln(c_-^*) + \ln(c_-^*) + 2\ln(1 - \xi/100) = r\int_0^{\infty} e^{-rt}[\ln(c_t^*) + \ln(c_t)]\,\mathrm{d}t$$

Positive values of ξ correspond to welfare-decreasing programs.

4.1. Permanent stabilization programs

As shown in the previous section, permanent ERB and MBR programs induce identical paths for consumption of tradables and nontradables. Consequently, they generate identical welfare effects. Furthermore, the paths of consumption of tradables and nontradables induced by these programs are always at or above their respective pre-stabilization levels. Therefore, permanent ERB and MBR programs are not welfare decreasing. On the other hand, MB programs induce the same response in consumption of tradables as ERB and MBR programs but generate an initial contraction in consumption of nontradables. As a result, permanent MB programs may be welfare increasing or decreasing depending on parameter values. For the baseline calibration, the three programs are welfare enhancing. The gain from implementing permanent ERB or MBR programs that reduce the long-run inflation rate from 35% per quarter to zero is substantial—2.4%. The gain resulting from a permanent MB program that achieves the same goal with respect to inflation is also significant but considerably lower—0.5%. [10]

Fig. 4 displays the welfare costs of permanent ERB, MB, and MBR stabilization programs as a function of key parameters of the model. In each panel, all parameters except for the one being varied are set at their baseline values. The welfare costs of MB programs appear to be highly sensitive to the degree of price stickiness (upper left panel). As the half-life of inflation increases from one to two quarters, the welfare cost increases from -0.5% (a gain) to 1.1%. Although almost imperceptible from the figure, in the case of ERB and MBR programs, a higher degree of price stickiness is welfare increasing because it makes the initial boom in consumption of nontradables more persistent.

The welfare costs of permanent stabilization programs are also fairly sensitive to changes in the parameters defining the liquidity-services technology—ρ, γ, and

[10] Other studies have estimated even larger welfare gains. For example, Eckstein and Leiderman (1992) using data for Israel estimate the structural parameters of a Sidrauski-type model of a small open economy and find that in the case of logarithmic preferences, the welfare cost of a permanent reduction of the inflation rate from 32% per quarter to zero generates a welfare gain of 7.5% of GNP. The difference between this number and the ones obtained in this paper is explained mainly by two factors. First, Eckstein and Leiderman's calculations do not take into account transitional dynamics. Second, in their model money enters in the representative agent's utility, thus a reduction in inflation increases welfare not only through its effect on consumption but also through remonetization.

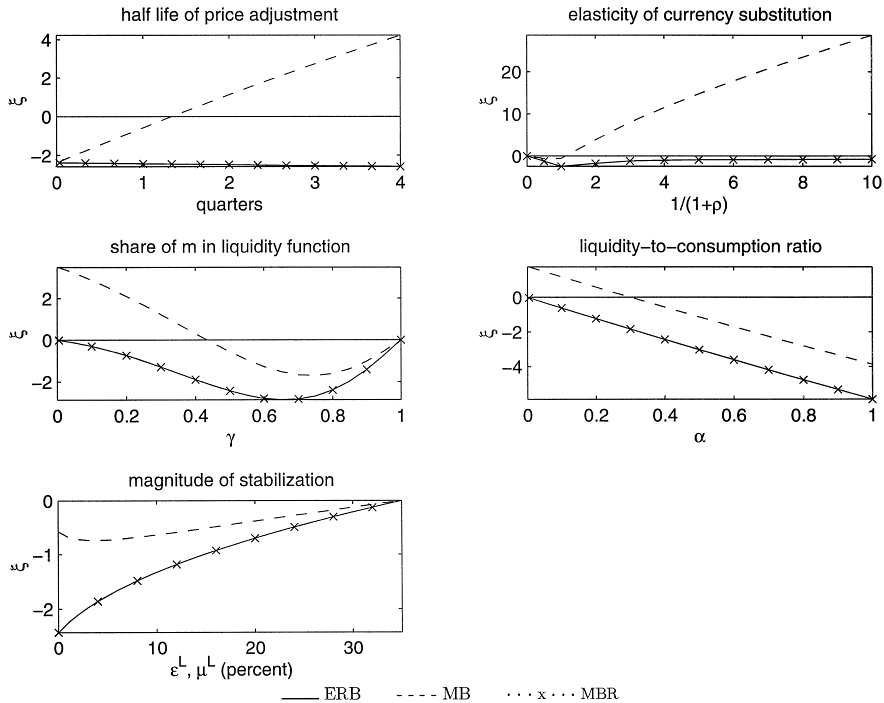

Fig. 4. Welfare costs: permanent programs. In each subplot, the vertical axis measures the welfare cost, ξ, as a percentage of the pre-stabilization steady-state stream of consumption, and the horizontal axis measures the values taken by the parameter considered. All other parameters are set at their baseline values (see Table 1).

α. Among these parameters, one that has received much theoretical and empirical attention, particularly in high-inflation economies, is the elasticity of currency substitution, $(1+\rho)^{-1}$. The top right panel shows that as this elasticity increases from one to six—two values that are within the range of estimates reported by Bufman and Leiderman (1993)—the welfare cost of a permanent MB program increases from -0.5% to more than 17%. This dramatic decline in welfare stems mainly from the fact that, as noted earlier, an increase in the degree of currency substitution exacerbates the liquidity crunch associated with a given decline in nominal interest rates. On the other hand, under ERB or MBR programs the welfare costs are much less sensitive to changes in the elasticity of currency substitution because the endogeneity of the money supply prevents the initial liquidity crunch.

Finally, consider the question of whether a stabilization program that targets a positive long-run rate of inflation could be preferable to one consistent with zero long-run inflation. It is straightforward to show that for permanent ERB and MBR programs the answer to this question is no. For permanent MB programs, the answer depends on parameter values. As the bottom panel of Fig. 4 shows, for the baseline calibration, the maximum welfare gain is attained when the money growth rate is reduced to around 4% per quarter.

4.2. Temporary stabilization programs

Unlike permanent ERB and MBR programs, temporary ERB and MBR programs can be welfare-decreasing. Also, temporary MB programs cause substantially higher welfare costs than temporary ERB or MBR programs. For the baseline parameter values, the welfare costs of MB, ERB, and MBR programs are 1.35, 0.02, and 0.15%, respectively. These figures imply that in the presence of credibility problems a benevolent policymaker would be better off keeping the status quo (that is, no stabilization of any kind).

Another contrast between permanent ERB and MBR programs and temporary ones is that temporary ERB and MBR programs are more costly the higher the degree of nominal rigidity (top left panel of Fig. 5). This is because when ERB or MBR programs are temporary, an increase in price stickiness makes the initial boom in nontradables shorter and the later recession deeper (Fig. 3).

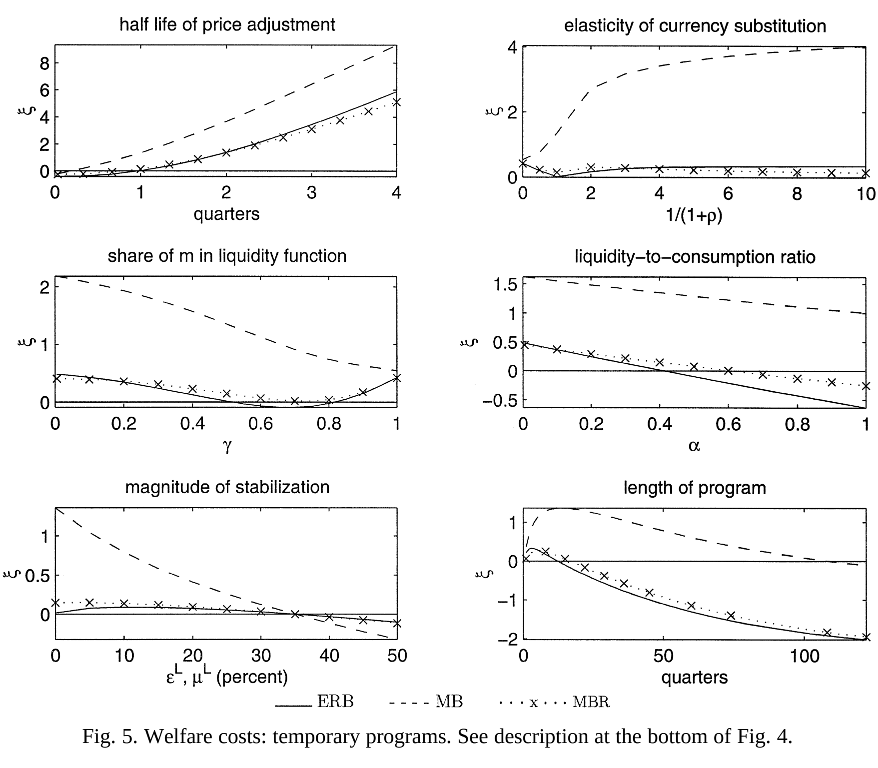

Fig. 5. Welfare costs: temporary programs. See description at the bottom of Fig. 4.

The bottom left panel of Fig. 5 shows that under the baseline parameterization, a temporary increase in the devaluation or money growth rates, with or without reliquefication, is welfare increasing. Such policies can be interpreted, following Calvo et al. (1995), as an attempt by the government to temporarily target a more depreciated real exchange rate. Finally, the bottom right panel of Fig. 5 displays the welfare costs as a function of the duration of the program. At long enough horizons, all programs become welfare increasing. However, the minimum duration necessary for a program to be welfare increasing is much greater under MB programs (more than 25 years) than under ERB or MBR programs (3 and 4 years, respectively). It has been argued that in situations in which the anti-inflation policy is expected to be short lived, MB programs may be preferable to ERB programs because the latter tend to induce wider fluctuations in consumption (Calvo and Végh, 1994a, p. 44). The figure shows that for the benchmark calibration, this is not the case. MB programs are more disruptive than ERB programs at all horizons, even at very short ones. This result also holds in the absence of currency substitution (this case is not shown in the figure).

5. Concluding remarks

The welfare comparison performed in this paper shows that substantial welfare gains can arise from eliminating high inflation. More important, these welfare gains depend a great deal upon the choice of nominal anchor. For example, under the baseline parameterization of the model, the welfare gain associated with eliminating an inflation rate of 35% per quarter through either a permanent exchange-rate-based program or a permanent money-based program with initial reliquefication is five times larger than the welfare gain of achieving the same goal through a permanent money-based program.

The second main conclusion is that lack of credibility is costly. For example, an exchange-rate-based stabilization program that reduces the devaluation rate from 35% per quarter to zero and is expected to last forever generates a welfare gain of around 2% of permanent income. However, if the program is expected to be discontinued after three years, the gain turns into a cost.

A number of policy implications arise from the analysis performed in the paper. First, a monetary anchor is in general dominated by an exchange rate anchor or by a monetary anchor coupled with initial reliquefication, especially in highly dollarized economies. Second, measures conducive to increasing the perceived viability of the program—such as structural fiscal reforms—should be implemented in the early stage or even before the announcement of the program. Third, lack of credibility is particularly disruptive in economies with a high degree of nominal rigidity. Thus, the elimination of regulations that introduce this type of rigidity—such as mandatory wage indexation or minimum labor contract lengths—tend to lessen the cost of the transition toward low inflation. Finally, in the model studied in this paper, money-based programs and money-based programs coupled with initial reliquefication induce an identical response in the nominal interest rate. As a result, the nominal interest rate is not a good indicator of whether the monetary authority is providing enough liquidity in the initial phase of money-based programs. Better indicators are the nominal exchange rate, the inflation rate, or the ex-post domestic real interest rate.

The model could be extended to incorporate a number of important aspects of real economies that can affect the quantitative results. For example, supply-side effects stemming from capital accumulation and labor supply (Lahiri, 1995; Roldós, 1995; Uribe, 1997a,c), irreversibility, or hysteresis, in currency substitution (Guidotti and Rodríguez, 1992; Uribe, 1997b), and policy uncertainty (Mendoza and Uribe, 1996, 1998). Also, welfare comparisons are restricted to the case of log-linear utility. A more realistic analysis should be based on preferences that imply an intertemporal elasticity of substitution significantly less than one.

Acknowledgements

I would like to thank Guillermo Mondino, Jorge Roldós, Thomas Sargent, Stephanie Schmitt-Grohé, Charlie Végh, Mike Woodford, and an anonymous referee for helpful comments.

Appendix A. Computing equilibrium dynamics

This appendix shows how to compute the equilibrium dynamics of the model under each of the stabilization policies considered in the paper. It derives closed-form solutions under permanent ERB, MB, and MBR and temporary ERB stabilization programs, and shows how to compute exact numerical solutions for temporary MB and MBR programs.

Combining Eqs. (5)–(9), f_t can be written as

$$f_t = \lambda^{-1} \frac{2\alpha w(i_t) z(i_t)}{L(1,w(i_t))} \tag{22}$$

Combining Eqs. (6) and (2) yields

$$c_t^* + rf_t = \lambda^{-1} z(i_t)\left[1 + \frac{2r\alpha w(i_t)}{L(1,w(i_t))}\right] \equiv \lambda^{-1} z(i_t) x(i_t) \tag{23}$$

where $x'(i_t) \geq 0$. Using Eq. (23) and the economy's resource constraint (15), one can express λ as

$$\lambda = \frac{r}{y_0^{\mathrm{p}}} \int_0^{\infty} e^{-rt} z(i_t) x(i_t) \mathrm{d}t \tag{24}$$

A.1. ERB stabilization plans

Because permanent stabilization programs are a particular case of temporary ones, I first consider temporary programs. It follows from Eqs. (3) and (20) that under a temporary ERB plan, the evolution of the nominal interest rate is given by

$$i_t = \begin{cases} i^{\mathrm{L}} \equiv \epsilon^{\mathrm{L}} + r & \text{for } 0 \leq t < T \\ i^{\mathrm{H}} \equiv \epsilon^{\mathrm{H}} + r & \text{for } t \geq T \end{cases} \tag{25}$$

substituting this expression into Eq. (24), yields the following expression for λ,

$$\lambda = \frac{1}{y_0^{\mathrm{p}}} \left[(1 - e^{-rT}) z(i^{\mathrm{L}}) x(i^{\mathrm{L}}) + e^{-rT} z(i^{\mathrm{H}}) x(i^{\mathrm{H}}) \right]$$

The time path of tradables is a step function of the form

$$c_t^* = \begin{cases} \lambda^{-1} z(i^{\mathrm{L}}) & \text{for } 0 \leq t < T \\ \lambda^{-1} z(i^{\mathrm{H}}) & \text{for } t \geq T \end{cases} \tag{26}$$

A.2. Steady state

Consider a long-run state of the economy in which all real variables, as well as the rates of devaluation, inflation and monetary expansion are constant. I will denote steady-state values by dropping time subscripts. It is clear from Eq. (25) that the steady-state level of consumption of tradables is reached at $t = T$,

$$c^* = c_T^*$$

From Eqs. (11) and (14), in turn, the steady-state value of consumption of home goods is given by

$$c = \bar{y}$$

Using Eq. (7), one can express the long-run value of the real exchange rate as

$$e = \bar{y}/c_T^*$$

From Eqs. (10), (20) and (25), the steady states of the devaluation rate, the nominal interest rate, and the inflation rate are

$$\epsilon = \epsilon^{\mathrm{H}}$$
$$\pi = \epsilon^{\mathrm{H}}$$
$$i = \epsilon^{\mathrm{H}} + r$$

A.3. Dynamics

It will prove convenient to define, $\Delta e_t \equiv \ln(e_t/e)$, $\Delta c_t \equiv \ln(c_t/c)$, $\Delta c_t^* \equiv \ln(c_t^*/c^*)$ $\Delta \pi_t \equiv \pi_t - \pi$, and $\Delta \epsilon_t \equiv \epsilon_t - \epsilon$. Write Δc_t^* and $\Delta \epsilon_t$ in the following way,

$$\Delta c_t^* = \Delta c_0^* (1 - u_T(t))$$
$$\Delta \epsilon_t = \Delta \epsilon_0 (1 - u_T(t))$$

where $u_t(t)$ denotes the unit step function, defined as,

$$u_T(t) = \begin{cases} 0 & \text{for } 0 \leq t < T \\ 1 & \text{for } t \geq T \end{cases}$$

Using Eq. (7), one can express Eqs. (11) and (10) as a system of two linear differential equations in $\Delta\pi_t$ and Δe_t,

$$\begin{bmatrix} \Delta\dot{\pi}_t \\ \Delta\dot{e}_t \end{bmatrix} = \begin{bmatrix} 0 & -\phi^2 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} \Delta\pi_t \\ \Delta e_t \end{bmatrix} + \begin{bmatrix} -\phi^2 \Delta c_0^* \\ \Delta\epsilon_0 \end{bmatrix} (1 - u_T(t)), \tag{27}$$

where $\phi \equiv \sqrt{\theta}$. The initial condition (17) implies that Δe_0 is predetermined and equal to

$$\Delta e_0 = \ln(e_-/e), \tag{28}$$

where $e_- \equiv E_-/P_0$. In addition, $\Delta\pi_0$ is determined in such a way that $\Delta\pi_t$ is continuous and satisfies [11]

$$\lim_{t\to\infty} \Delta\pi_t = 0. \tag{29}$$

The system (27)–(29) can be solved analytically.

Consider now permanent ERB programs. It follows from Eqs. (3) and (6) that in this case i_t and c_t^* are constant for all $t \geq 0$ and equal to i^{L} and $\lambda^{-1} z(i^{\mathrm{L}})$, respectively. Thus, $\Delta\epsilon_t = \Delta c_t^* = 0$ for all $t > 0$, and $\Delta\pi_t$ and Δe_t solve

$$\begin{bmatrix} \Delta\dot{\pi}_t \\ \Delta\dot{e}_t \end{bmatrix} = \begin{bmatrix} 0 & -\phi^2 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} \Delta\pi_t \\ \Delta e_t \end{bmatrix} \tag{30}$$

given the initial and boundary conditions (28) and (29).

A.4. MB and MBR stabilization plans

Let us first derive the time paths of the nominal interest rate and domestic real balances under temporary MB and MBR programs. Using Eqs. (5)–(9) m_t can be written as

$$m_t = \lambda^{-1} \frac{2\alpha z(i_t)}{L(1,w(i_t))} \equiv \lambda^{-1} v(i_t) \tag{31}$$

where $v'(i_t) < 0$. Using this expression together with Eq. (3), one can write Eq. (12) as,

$$\dot{i}_t = -\frac{v(i_t)}{v'(i_t)} (i_t - r - \mu_t). \tag{32}$$

[11] The continuity of π_t follows directly from the way in which Eq. (11) is derived in the Calvo (1983) sticky-price model.

Since $-v(i)/v'(i)$ is always positive, it follows from this expression and Eq. (21), that the unique non-explosive solution for $t \geq T$ is the steady state, that is

$$i_t = r + \mu^{\mathrm{H}} \text{ for } t \geq T$$

For $0 \leq t < T$, the time path of i_t can be found by transforming the above equation into an initial-value problem. Let $g_t \equiv i_{T-t}$; then the evolution of g_t is governed by the following differential equation: [12]

$$\dot{g}_t = \frac{v(g_t)}{v'(g_t)}\left(g_t - r - \mu^{\mathrm{L}}\right)$$

with $g(0) = r + \mu^{\mathrm{H}}$. This equation can be solved numerically. Using Eq. (24), the equilibrium value of λ is given by

$$\lambda = \frac{r}{y_0^{\mathrm{p}}} \int_0^t e^{-rT} z(i_t)\, x(i_t) \mathrm{d}t + \frac{e^{-rT}}{y_0^{\mathrm{p}}} z\left(r + \mu^{\mathrm{H}}\right) x\left(r + \mu^{\mathrm{H}}\right)$$

The first term on the right hand side can be evaluated numerically. Once λ and the path of i_t are computed, it is straightforward to obtain the paths of c_t^* from Eq. (6), f_t from Eq. (24), m_t from Eq. (31), and ϵ_t from Eq. (3). Because these variables depend only on λ and i_t, they all reach their steady states at $t = T$. The dynamics of the real exchange rate and the inflation rate are determined by a system similar to Eq. (27)

$$\begin{bmatrix} \Delta\dot{\pi}_t \\ \Delta\dot{e}_t \end{bmatrix} = \begin{bmatrix} 0 & -\phi_2 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} \Delta\pi_t \\ \Delta e_t \end{bmatrix} + \begin{bmatrix} -\phi^2 \Delta c_t^* \\ \Delta\epsilon_t \end{bmatrix} \tag{33}$$

The difference between this system and Eq. (27) is that in this system the forcing term is not a step function. Using condition (19), which defines the initial condition e_0, and the fact that the steady-state level of the real exchange rate is given by $e = \bar{y}/c^{\mathrm{T}}$, it follows that under an MB program, the initial condition Δe_0 is given by

$$\Delta e_0 = \ln\left(\frac{m_- c_T^* e_-}{\bar{y} m_0}\right), \tag{34}$$

where $m^- \equiv M_-/E_-$. Under an MBR program, Δe_0 results from combining Eq. (17) and $e \equiv y/c_t^*$,

$$\Delta e_0 = \ln\left(\frac{c_T^* e_-}{\bar{y}}\right) \tag{35}$$

To calculate the initial value $\Delta\pi_0 \equiv \pi_0 - (r + \mu^{\mathrm{H}})$, it is convenient to define the following variable,

$$h_t \equiv \Delta\pi_t - \phi\Delta e_t$$

[12] As argued in Section 3.3, the nominal interest rate must be continuous at time T.

From Eq. (33) it follows that the evolution of h_t is given by the following differential equation,

$$\dot{h}_t = \phi h_t - \phi(\Delta\epsilon_t + \phi\Delta c_t^*) \tag{36}$$

Because $\Delta c_t^* = \Delta\epsilon_t = 0$ for $t \geq T$, and because $\phi > 0$, the unique non-explosive solution to this equation is $h_t = 0$ for $t \geq T$, or

$$\Delta\pi_t = \phi\Delta e_t \text{ for } t \geq T \tag{37}$$

The condition $h_T = 0$ can then be used to write Eq. (36) as an initial-value problem (as was done to solve Eq. (32)). The solution to this problem gives h_0, which in turn determines $\Delta\pi_0 = h_0 + \phi\Delta e_0$. Given $\Delta\pi_0$ and Δe_0, Eq. (33) becomes an initial-value problem which can be solved numerically for $\Delta\pi_t$ and Δe_t for $0 \leq t \leq T$. [13] Condition (37) and the second equation in Eq. (33) then give the solution for $t \geq T$,

$$\Delta e_t = \Delta e_T e^{-\phi(t-T)}$$

$$\Delta\pi_t = \phi\Delta e_T e^{-\phi(t-T)}$$

Finally, consider the dynamics of permanent MB and MBR programs. Under these types of program, $\mu_t = \mu^{\mathrm{L}}$ $\forall t$. It is straightforward to see that the constant sequences $i_t = r + \mu^{\mathrm{L}}$, $\epsilon_t = \mu^{\mathrm{L}}$, and $m_t = \lambda^{-1}\ \upsilon(r + \mu^{\mathrm{L}})\ \forall\ t$ and the scalar $\lambda = z(r + \mu^{\mathrm{L}})\ x(r + \mu^{\mathrm{L}})$ solve Eqs. (3), (6), (12) and (32). Thus, consumption of tradables is also constant and given by $c_t^* = \lambda^{-1}\ z(r + \mu^{\mathrm{L}})\ \forall\ t$. This implies that if $\mu^{\mathrm{L}} = \epsilon^{\mathrm{L}}$, then permanent ERB, MB, and MBR programs generate the same response in consumption of tradables, real balances, the nominal interest rate, and the devaluation rate. Because under permanent MB and MBR programs both consumption of tradables and the devaluation rate are constant, it follows that $\Delta c_t^* = \Delta\epsilon_t = 0$. Substituting this into Eq. (33), yields a system identical to Eq. (27), which governs the dynamics of π_t and e_t under permanent ERB programs. Note that because e_0 is the same under ERB and MBR programs, permanent ERB and MBR programs generate identical paths for e_t and π_t.

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[13] One can also calculate the path of Δe_t by solving the single-equation, initial-value problem, $\Delta\dot{e}_t = \phi\Delta e_t - h_t + \Delta e_t$.

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