Board of Governors of the Federal Reserve System

International Finance Discussion Papers

Number 598

December 1997

HABIT FORMATION AND THE COMOVEMENT OF PRICES AND CONSUMPTION DURING EXCHANGE-RATE-BASED STABILIZATION PROGRAMS

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Habit Formation and the Comovement of Prices and Consumption During Exchange-Rate-Based Stabilization Programs

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Abstract

A defining stylized fact associated with exchange-rate-based (ERB) stabilization programs is that their initial phase is characterized by several years of expansion in private consumption and a gradual appreciation of the real exchange rate. In this paper, I argue that standard optimizing models are unable to account for this empirical regularity, as they predict that, except for the date of announcement of the program, an appreciation of the real exchange rate must necessarily be accompanied by a decline in consumption. I show that this price-consumption problem can be resolved by relaxing the assumption of time separability in preferences. Specifically, under habit formation a permanent ERB program generates a smooth boom in consumption and gradual real exchange rate appreciation. A temporary program induces, in addition, a smooth boom-recession cycle with the recession beginning before the abandonment of the program.

Keywords: Inflation Stabilization, Fixed Exchange Rates, Habit Formation, Durability

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1 Introduction

In the last twenty-five years, high-inflation countries, especially in Latin America, have recurrently used the exchange rate as a nominal anchor to stabilize prices. One defining empirical regularity associated with exchange-rate-based (ERB) stabilization programs is that their initial phase is characterized by several years of expansion in private consumption and a gradual appreciation of the real exchange rate, defined as the relative price of nontradables in terms of tradables (Kiguel and Liviatan, 1992; Végh, 1992). This stylized fact, to which I will refer as the price-consumption regularity, motivated a large theoretical and empirical literature as it defies the traditional notion that disinflation policies must be contractionary.

In this paper, I argue that the comovement of consumption and the real exchange rate implied by existing optimizing models of ERB stabilization is inconsistent with the price-consumption regularity. Specifically, models with time-separable preferences, no uncertainty, and no borrowing constraints imply that after the period of announcement of the program, consumption and the real exchange rate must move in opposite directions. I refer to this counterfactual implication as the price-consumption problem.

The price-consumption problem is present in a large number of optimizing models of ERB stabilization that can be broadly classified into three groups: The temporariness hypothesis, developed by Calvo (1986), stresses the role of intertemporal substitution effects stemming from the public's expectation that the program will be abandoned after a finite period of time. In a second group of models, intertemporal substitution effects arise from expected future fiscal adjustment (Drazen and Helpman, 1987; Helpman and Razin, 1987; Rebelo, 1994). More recently, the supply side hypothesis emphasizes the role of inflation as a tax on domestic factors of production (Lahiri, 1995; Roldós, 1995; Uribe, 1997a,b).[1]

These explanations capture important aspects of the price-consumption regularity. In particular, most of the models predict an increase in consumption and a real exchange rate appreciation at the moment the program is announced. Some of them—like the supply-side models and the temporariness model with sticky prices due to Calvo and Végh (1993)—are further able to replicate the gradual appreciation of the real exchange rate. However, in all of these models, a pattern in which the real exchange rate is gradually appreciating must necessarily be accompanied by a declining path of consumption.

In this paper, I propose a solution to the price-consumption problem that consists in departing from the assumption of time separability in preferences. Specifically, I consider a class of preferences in which the single-period utility function depends on a linear combination of present and past consumption. As is well-known, this class of preferences encompasses the cases of habit formation and consumption durability. I show that under habit formation, the dynamics of ERB stabilization programs are consistent with the price-consumption regularity.

To highlight the role played by the assumption of habit formation in resolving the price-

[1] See Rebelo and Végh (1995) for a survey of these theories.

consumption problem, I first embed this type of preferences in a simple aggregative model of a small open, monetary, endowment economy. The demand for money is motivated à la Kimbrough (1986) by assuming that purchases of goods are subject to transaction costs that are increasing in money velocity. In such a model, the effective cost of consumption is an increasing function of the nominal interest rate. Thus, a permanent decline in the nominal interest rate generates a pure, positive wealth effect as agents build up real balances thereby spending less resources on transaction costs. On the other hand, a temporary decline in the nominal interest rate induces agents to substitute current for future consumption as current consumption becomes cheaper relative to future consumption.

I model a permanent ERB stabilization program as a permanent reduction in the devaluation rate. Under perfect foresight and perfect capital mobility, the uncovered interest parity condition must hold. Thus, a permanent ERB program generates a permanent decline in the nominal interest rate. Under time separable preferences, the resulting positive wealth effect induces a once-and-for-all increase in consumption. Given the supply of nontradables, the jump in aggregate spending produces a corresponding once-and-for-all appreciation of the real exchange rate. The implied comovement between consumption and the real exchange rate *after* the date of announcement of the program is clearly at odds with the price-consumption regularity. By contrast, under habit formation, a once-and-for-all increase in consumption is not optimal because the expected future increase in the stock of habit that results from the higher level of consumption would increase the future marginal utility of consumption relative to its current value, inducing agents to shift present consumption into the future. Thus, habit-forming agents rationally choose a gradually increasing path of consumption. This gradual expansion in aggregate spending causes a sluggish appreciation of the real exchange rate.

As Calvo and Végh (1993, p. 5) point out , "[a]s a general rule, stabilization programmes are not fully credible at the time they are being launched". Accordingly, I study ERB programs under lack of credibility, or temporariness, à la Calvo (1986). Under this type of program, the public is assumed to expect that the reduction in the devaluation rate is temporary. Driven by this perception, households take advantage of the temporarily lower effective cost of goods by substituting present for future consumption. In Calvo's original model, which assumes time separable preferences, consumption and the relative price of nontradables jump up at the moment the program is announced, and then remain constant until the date in which the program is expected to be abandoned, when both variables fall to their respective long-run levels. Under habit formation, consumption and the real exchange rate first increase gradually, reach a peak at some point before the expected date of abandonment, and then begin to decline. The fact that the contraction in aggregate spending sets in before (and not at) the date of abandonment of the plan, is of particular interest because it is consistent with the observed timing of boom-recession cycles in failed ERB programs (Kiguel and Liviatan, 1992; Végh, 1992). Habit-forming agents choose to cut consumption before the anticipated collapse of the program in an attempt to arrive at the date of collapse with a lower stock of habit thereby ameliorating the pain of adjustment.

Another aspect of the price-consumption problem concerns the comovement between nontraded output and the real exchange rate. Specifically, standard models counterfactually predict that after the period of announcement of the program, a gradual appreciation of the real exchange rate must necessarily be accompanied by a declining trajectory in nontraded output. I demonstrate the ability of habit formation to resolve this problem by studying the dynamics of permanent and temporary ERB programs in an extension of the endowment economy model in which both traded and nontraded goods are produced with labor, which in turn is assumed to be perfectly mobile across sectors and fixed in aggregate supply.

In the model economies described above, without capital and with fixed aggregate labor supply, the real exchange rate is demand determined. In particular, those models predict that the contractionary phase of temporary ERB programs is necessarily accompanied by a depreciation of the real exchange rate. This prediction is unrealistic, for typically the real exchange rate continues to appreciate after the recession sets in. To address this issue, I develop a model with endogenous labor supply and capital accumulation. In this model, the contractionary phase of a temporary ERB program is accompanied by a contraction in the supply of nontradables that is strong enough to prevent the real exchange rate from depreciating before the abandonment of the program. Finally, I address the issue of how the quantitative predictions of the model differ under time-separable and habit-forming preferences. To this end, I calibrate the model and simulate the response of a number of key endogenous variables to permanent and temporary ERB stabilization programs.

The remainder of the paper is organized as follows: section 2 derives the price-consumption problem. Section 3 develops the basic theoretical framework. Sections 4 and 5 analyze, respectively, the dynamics of temporary and permanent ERB inflation stabilization programs. Section 6 extends the model to allow for endogenous product supplies. Section 7 analyzes the dynamics of a calibrated model with capital and endogenous labor supply. Section 8 concludes.

2 The price-consumption problem

Exchange-rate-based stabilization programs are characterized by an initial expansionary phase that lasts around twelve quarters. During this phase, private consumption continuously increases and the real exchange rate gradually appreciates. Formally, this price-consumption regularity can be stated as follows. Let t denote time measured in quarters, c_t denote private consumption in period t, and p_t denote the real exchange rate in period t defined as the relative price of nontradables in terms of tradables. Let $t = 0$ be the period in which the ERB program is announced and t' the period marking the end of the initial phase of the program. Then the price-quantity regularity says that for $0 \leq t \leq t'$, $c_t > c_{t-1}$ and $p_t > p_{t-1}$.

To see why standard optimizing models fail to replicate this stylized fact, consider an economy populated a large number of identical households with preferences described by the following intertemporal utility function:

$$\sum_{t=0}^{\infty} \beta^t U(c_t) \tag{1}$$

where $U(\cdot)$ is a strictly increasing, strictly concave period utility function. Assume that c_t is a composite of tradables, c_t^T, and non-tradables, c_t^N,

$$c_t = A(c_t^T, c_t^N), \tag{2}$$

where $A(\cdot,\cdot)$ is a homogeneous-of-degree-one aggregator function, strictly increasing in both arguments, and concave. This preference specification is quite general. It includes, for example, the class of CRRA period utility functions and CES aggregator functions. Given these preferences, optimizing models of ERB stabilization, include the following two equations as part of the representative household's first-order conditions:

$$p_t = \frac{A_2(c_t^T/c_t^N, 1)}{A_1(c_t^T/c_t^N, 1)} \tag{3}$$

$$U'(c_t)A_1(c_t^T, c_t^N) = \lambda_t h(i_t) \tag{4}$$

The first equation is a familiar condition stating that households will always choose to allocate their consumption expenditures in such a way that the marginal rate of substitution between nontradables and tradables equals the relative price of the two goods. The second equation states that the marginal utility of consumption of tradables must be equal to the product of the marginal utility of wealth, λ_t, and a monetary distortion $h(i_t)$. The monetary distortion is a non-decreasing function of the nominal interest rate, i_t, reflecting the role of money in reducing frictions in the process of exchange.[2]

Consider first equation (3). The fact that the aggregator function is concave and homogeneous of degree one implies that the right hand side of (3) is strictly increasing in c_t^T/c_t^N. Thus,

$$p_t \text{ is increasing in } c_t^T/c_t^N \text{ for } t \geq 0. \tag{5}$$

Intuitively, equation (3) states that as nontradables become more expensive relative to tradables, households will consume relatively more tradables and less nontradables.

Next turn to equation (4). Under perfect foresight and assuming that agents have access to an internationally traded bond that pays a constant interest rate, r, in terms of tradables, the marginal utility of wealth satisfies the familiar Euler equation $\lambda_t = \beta(1+r)\lambda_{t+1}$. Under the usual simplifying assumption that $\beta(1+r) = 1$, the Euler equation implies that λ_t is constant from the period of announcement of the ERB program on.[3] Further, the fact that during a currency peg the rate of devaluation of the domestic currency is constant implies, by the interest rate parity

[2] In models without money (Rebelo, 1993, 1994), $h(\cdot)$ is identically equal to one. In continuous-time, cash-in-advance models (Calvo, 1986; Calvo and Végh, 1993; Lahiri, 1995; Roldós, 1995), $h(i_t)$ takes the form $1 + \alpha i_t$, where $\alpha > 0$ is the fraction of consumption subject to a cash-in-advance constraint. In models where money reduces transaction costs (Rebelo and Végh, 1995; Reinhart and Végh, 1995; Mendoza and Uribe, 1996), $h(i_t)$ is of the form $1 + s(\nu(i_t)) + \nu(i_t)s'(\nu(i_t))$, where $s(\cdot)$ and $v(\cdot)$ are positive, increasing functions denoting transaction costs per unit of consumption and money velocity, respectively. In the next section, I derive the transaction cost model in detail.

[3] Assuming that the international real interest rate is exogenous but stochastic or that the rate of time preference differs from the international interest rate would introduce cyclical or trend components in consumption, but would clearly not alter the conclusions derived shortly regarding the ability of the class of models under analysis to explain the price-consumption regularity.

condition, that the domestic nominal interest rate must be constant as well. Therefore, as long as the currency peg is in effect, the right hand side of (4) is constant. Recalling that $U'' < 0$ and $A_{11} < 0$, it then follows from (4) that during a currency peg

$$c_t \text{ is decreasing in } c_t^T/c_t^N \text{ for } t > 0. \tag{6}$$

Finally, combining statements (5) and (6) implies that during a currency peg,

$$c_t \text{ is decreasing in } p_t \text{ for } t > 0 \tag{7}$$

which means that the family of models under consideration fails to replicate the price-consumption regularity.

Moreover, these models also fail to capture the increasing path in consumption of nontradables—such as services and housing—observed during the initial phase of ERB programs. To see this, note that the fact that the aggregator function is linearly homogeneous implies that equation (2) can be written as $c_t = c_t^N A(c_t^T/c_t^N, 1)$. This expression together with statements (5) and (7) implies that

$$c_t^N \text{ is decreasing in } p_t \text{ for } t > 0. \tag{8}$$

This completes the description of the price-consumption problem. It is important to note that the price-consumption problem concerns the joint behavior of the real exchange rate and consumption *after* and not *at* the moment of announcement of the program. To the extent that $\lambda_0\, h(i_0) < \lambda_{-1}\, h(i_{-1})$, the right hand side of (4) will decrease at $t = 0$, allowing both c_0 and p_0 to rise above their pre-stabilization levels. In fact, most existing models of ERB stabilization induce such an initial effect through substitution effects (e.g., the temporariness hypothesis) or wealth effects (e.g., the supply-side hypothesis). The price-consumption problem refers to the inability of the existing models to induce dynamics in which c_t and p_t continue to increase beyond period zero.

Before presenting the solution to the price-consumption problem proposed in this paper, I will discuss the role played by each of the assumptions used in deriving it. Consider first the assumption of lack of uncertainty. Clearly, the presence of exogenous stochastic shocks such as shocks to the international interest rate, the terms of trade, tastes, or technology, will not alter the nature of the problem, insofar as the stabilization policy is unrelated to the state of the underlying shocks. In the case in which such a relationship exists, the extent to which the equilibrium dynamics will be consistent with the price-consumption regularity will depend on the nature and stochastic structure of the shocks involved as well as on the form adopted by the relationship itself. A more direct link between uncertainty and the dynamics of ERB programs arises when specific elements of the program are assumed to be exogenous random variables. For example, using the analytical framework proposed by Drazen and Helpman (1988) and Calvo and Drazen (1993), Mendoza and Uribe (1996) study the dynamics of currency pegs of uncertain duration. Under this type of policy, both the marginal utility of wealth and the nominal interest rate become random variables with time-dependent distributions, so that the right hand side of (4) is no longer constant. Under certain assumptions about the form of the hazard function describing the probability of abandonment of the stabilization program at any given point in time, the model analyzed by Mendoza and Uribe is capable of generating dynamics that are consistent with the price-consumption regularity.

The assumption that agents have frictionless access to international financial markets allows the representative agent to choose a constant path for the marginal utility of wealth. By contrast, when agents are subject to credit constraints, the marginal utility of wealth becomes time dependent and therefore so does the right hand side of (4). However, the mere time dependence of the marginal utility of wealth is not sufficient to induce dynamics that are consistent with the price-consumption regularity. It is clear from equations (3) and (4) that in order for both p_t and c_t to increase during the initial phase of the program, λ_t must display a declining trajectory. In general, this will not be a necessary consequence of the presence of credit constraints.

A third assumption implicit in the derivation of the price-consumption problem is that agents do not value leisure. It is straightforward to see that the problem remains when the period utility function depends on leisure but in a separable way. In the more general case in which the period utility function is not separable in leisure and consumption, equation (3) is unaffected, but equation (4) takes the form

$$U_c(c_t, h_t)A_1(c_t^T/c_t^N, 1) = \lambda_t h(i_t) \tag{9}$$

where h_t stands for hours worked, and $U(\cdot,\cdot)$ is strictly increasing in its first argument, strictly decreasing in its second argument, and strictly concave. Equations (3) and (9) imply that, as in the case in which leisure is not valued, an equilibrium in which the real exchange rate is gradually appreciating requires the marginal utility of consumption, $U_c(c_t, h_t)$, to increase over time. If in addition hours are to increase during the initial phase of the program—arguably the case of greatest empirical interest—then it follows that if U_{ch} is negative, c_t must necessarily decline over time. Thus, $U_{ch} > 0$ is a necessary condition for leisure to be able to resolve the price-consumption problem. I explore this avenue in greater detail in section 7, and argue that leisure alone is unlikely to provide a satisfactory answer to the price-consumption problem.

In deriving the price-consumption problem, the devaluation rate was assumed to be constant. Obstfeld (1985) and Roldós (1993) have noted, using standard optimizing models, that ERB programs consisting in the pre-announcement of a declining path for the devaluation rate—like *tablita* programs of the late 1970s in the southern cone of Latin America—induce dynamics that are consistent with the price-consumption regularity. To see why, note that in this case, by the uncovered interest parity condition, the nominal interest rate follows a declining path. Consequently the right hand side of (4) will also decrease over time, allowing both c_t and the ratio c_t^T/c_t^N to increase during the initial phase of the program.[4] As an explanation of the price-consumption problem, however, this avenue is limited. A large number of ERB programs including, for example, the heterodox programs of the mid 1980s in Argentina, Brazil, Mexico, and Israel, and more notably the orthodox Argentine Convertibility Plan of 1991, did not establish a declining path for the devaluation rate

[4] I am grateful to Charlie Végh for pointing this case out to me.

and nevertheless displayed dynamics consistent with the price-consumption regularity.

Implicit in the derivation of the price-consumption problem is the assumption that preferences are time separable. The solution to the price-consumption problem proposed in this paper consists in relaxing this assumption by allowing for habit formation. Under habit formation, equation (3) is unchanged, as is the right hand side of (4), but the marginal utility of consumption on the left hand side of (4) becomes an increasing function of both past consumption and future consumption. As shown later, this allows both the equilibrium marginal utility of consumption and consumption itself to increase during the initial phase of the program.

Finally, it is worth noting that because the derivation of equations (3) and (4) does not involve assumptions about technology, the degree of nominal rigidity, or the duration of the currency peg, such assumptions will not provide a remedy to the problem, as long as the five assumptions discussed in the previous paragraphs are in place.

3 The model

Households

Consider a perfect-foresight, small open, endowment economy populated by a large number of identical, infinitely lived consumers with preferences described by the utility function

$$\sum_{t=0}^{\infty} \beta^t U(c_t - \alpha c_{t-1}) \tag{10}$$

This utility function encompasses the cases of time separable preferences analyzed in the previous section ($\alpha = 0$), habit formation ($\alpha > 0$), and durability ($\alpha < 0$).[5]

The consumption good, c_t, is assumed to be a composite of tradables and non-tradables,

$$c_t = c_t^T f(c_t^N), \tag{11}$$

where $f(\cdot)$ satisfies $f' > 0$, $f'' < 0$, and $f(0) = 0$.[6]

Households are assumed to have access to two financial assets: money, M_t, and a foreign-currency-denominated bond, b_t, that pays the constant interest rate r in foreign currency. To avoid unessential long-run dynamics, r is assumed to satisfy $\beta(1 + r) = 1$. Following Kimbrough (1986), money is assumed to facilitate transactions. Specifically, purchases of goods are subject to transaction costs that are increasing in expenditure and decreasing in real balances.

Each period, the representative household is endowed with y^T units of tradables and y^N units of nontradables, and receives from the government a lump-sum transfer τ_t measured in terms of

[5]The results of the paper are qualitatively similar in the more general case in which the argument of the period utility function takes the form $c_t - \alpha S_t$, with $S_t = (1 - \delta)S_{t-1} + \delta c_{t-1}$ and $\delta \in (0, 1]$. The case analyzed throughout the paper, $\delta = 1$, was chosen for analytical convenience.

[6]This functional form delivers simple equilibrium dynamics without driving the main results of the paper in any important way. In sections 6 and 7, I analyze the more familiar case in which the aggregator function is homogeneous of degree one in c^T and c^N.

tradables. As a simple way to introduce wealth effects stemming from inflation, I assume that each period part of the transaction costs is wasted, and the rest is rebated to the public in the form of a lump-sum transfer η_t expressed in terms of tradables, which can be interpreted as profits received from financial institutions.[7]

Let P_t denote the domestic-currency price of nontradables, and E_t denote the nominal exchange rate defined as the domestic-currency price of foreign currency. I assume that the foreign-currency price of tradables is constant and normalized to one, and that the law of one price holds for tradables. Then the domestic-currency price of tradables is simply given by E_t. Letting $m_t \equiv M_t/E_t$ denote real balances measured in terms of tradables, $p_t \equiv P_t/E_t$ denote the real exchange rate defined as the price of nontradables in terms of tradables, and $\epsilon_t \equiv E_t/E_{t-1} - 1$ denote the devaluation rate, the period-by-period budget constraint of the household is given by

$$b_t + m_t + (c_t^T + p_t c_t^N)(1 + s(v_t)) = (1 + r)b_{t-1} + \frac{m_{t-1}}{1 + \epsilon_t} + y^T + p_t y^N + \tau_t + \eta_t, \qquad (12)$$

where

$$v_t \equiv \frac{c_t^T + p_t c_t^N}{m_t}. \qquad (13)$$

The function $s(\cdot)$ denotes transaction costs per unit of expenditure, and is assumed to be strictly increasing and to satisfy the condition $2s'(v) + vs''(v) > 0 \ \forall v > 0$, which guarantees that total transaction costs are a convex function of expenditure and real balances (i.e., that $c\, s(c/m)$ is convex in c and m).

In addition, households are assumed to be subject to the following borrowing constraint that prevents them from engaging in Ponzi games:

$$\lim_{t\to\infty} \frac{b_t + m_t}{(1 + r)^t} \geq 0 \qquad (14)$$

The assumptions of perfect foresight and perfect international capital mobility imply that the domestic nominal interest rate, denoted by i_t, must satisfy the uncovered interest parity condition; that is,

$$1 + i_t = (1 + r)(1 + \epsilon_{t+1}). \qquad (15)$$

Constraints (12) and (14) are equivalent to the following intertemporal budget constraint:

$$(1 + r)b_{-1} + \frac{m_{-1}}{1 + \epsilon_0} \geq \sum_{t=0}^{\infty} \left(\frac{1}{1 + r}\right)^t \left[(c_t^T + p_t c_t^N)(1 + s(v_t)) + \frac{i_t m_t}{1 + i_t} - y^T - p_t y^N - \tau_t - \eta_t\right]. \quad (16)$$

The household's problem consists in choosing a set of sequences $\{c_t, c_t^T, c_t^N, m_t, v_t\}_{t=0}^{\infty}$, so as to maximize (10) subject to (11), (13), and (16), taking as given b_{-1}, m_{-1}, ϵ_0, and the sequences $\{p_t, i_t, \tau_t, \eta_t\}_{t=0}^{\infty}$. In an interior optimum, the chosen sequences must satisfy (11), (13), (16) holding

[7] In section 7, I analyze a production economy in which inflation generates additional wealth effects through the labor and capital markets.

with equality, and

$$[U'(c_t-\alpha c_{t-1})-\alpha\beta U'(c_{t+1}-\alpha c_t)]f(c_t^N)=\lambda[1+s(v_t)+v_t s'(v_t)] \tag{17}$$

$$p_t=\frac{c_t^T f'(c_t^N)}{f(c_t^N)} \tag{18}$$

$$v_t^2 s'(v_t)=\frac{i_t}{1+i_t} \tag{19}$$

where λ is the Lagrange multiplier associated with the present-value budget constraint (16). The assumptions imposed on $s(\cdot)$ imply that both the right hand side of (17) and the left hand side of (19) are positive and increasing functions of v_t. Equation (19) implies that money velocity is an increasing function of the nominal interest rate that can be written as

$$v_t=\nu(i_t);\quad \nu'>0. \tag{20}$$

The government

The government holds international bonds, f_t, makes lump-sum transfers, and supplies money. Its period-by-period budget constraint is

$$f_t=(1+r)f_{t-1}+m_t-\frac{m_{t-1}}{1+\epsilon_t}-\tau_t$$

The government is also subject to a no-Ponzi-game borrowing constraint of the form

$$\lim_{t\to\infty}\frac{f_t-m_t}{(1+r)^t}\geq 0.$$

The above two constraints are equivalent to the following present-value budget constraint

$$(1+r)f_{-1}-\frac{m_{-1}}{1+\epsilon_0}\geq\sum_{t=0}^{\infty}\left(\frac{1}{1+r}\right)^t\left[\tau_t-m_t\frac{i_t}{1+i_t}\right] \tag{21}$$

which states that the present discounted value of primary deficits net of seignorage revenue must not exceed the value of initial net asset holdings. The government is assumed to satisfy this budget constraint with strict equality.

In period zero, the monetary authority announces the entire time path of the devaluation rate, $\{\epsilon_t\}_{t=0}^{\infty}$, and guarantees free convertibility of the domestic currency at the corresponding exchange rate, $E_t=E_{-1}\prod_{j=0}^{t}(1+\epsilon_j)$. Note that the specified exchange rate policy along with the interest parity condition (15) uniquely determines the time path of the nominal interest rate.

Equilibrium

In equilibrium, the nontraded goods market clears,

$$c_t^N = y^N, \tag{22}$$

and η_t satisfies

$$\eta_t = \phi\, s(v_t)(c_t^T + p_t c_t^N). \tag{23}$$

where $\phi \in [0,1]$ denotes the fraction of transaction costs rebated to the public. Assume, without loss of generality, that $f(y^N) = 1$, and let $w_t \equiv b_t + f_t$ denote the economy's net asset holdings in period t. Then combining the budget constraints (16) and (21) holding with equality, and the equilibrium conditions (22) and (23) yields the country's intertemporal resource constraint:

$$(1+r)(w_{-1} + y^T/r) = \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t [1 + (1-\phi)g(i_t)]\, c_t, \tag{24}$$

where $g(i) \equiv (1 + f'(y^N))s(\nu(i_t))$ is positive and increasing in i_t. Combining (17) and (22) yields

$$U'(x_t) - \alpha\beta U'(x_{t+1}) = \lambda h(i_t), \tag{25}$$

where

$$x_t \equiv c_t - \alpha c_{t-1}, \tag{26}$$

and $h(i) \equiv 1 + s(\nu(i_t)) + \nu(i_t)s'(\nu(i_t))$ is positive and increasing in i_t.

A perfect-foresight equilibrium is defined as a pair of sequences $\{c_t, x_t\}_{t=0}^{\infty}$ and a scalar $\lambda > 0$ satisfying (24), (25), and (26), given the initial conditions c_{-1} and w_{-1} and the forcing sequence $\{i_t\}_{t=0}^{\infty}$. Among the remaining endogenous variables of the model, the real exchange rate is of particular interest. Combining (11), (18), and (22), and recalling that $f(y^N) = 1$, it follows that in equilibrium the real exchange rate is proportional to consumption. Formally,

$$p_t = c_t f'(y^N) \tag{27}$$

4 Permanent ERB programs

Assume that up to period -1 the economy is in a steady state in which the devaluation rate, the nominal interest rate, and all real variables are constant. Let $\epsilon^H > 0$ be the value taken by the devaluation rate. Then by equation (15), the nominal interest rate is given by $i^H \equiv (1+r)(1+\epsilon^H)-1$, and by equation (24), c_{-1} is given by

$$c_{-1} = \frac{rw_{-1} + y^T}{1 + (1-\phi)g(i^H)} \tag{28}$$

Suppose that at $t = 0$ the monetary authority unexpectedly announces an ERB stabilization plan consisting in a permanent reduction in the devaluation rate from ϵ^H to $\epsilon^L < \epsilon^H$. Assume further that the program is sustainable over time and perfectly credible, so that by the uncovered interest parity condition the path of the nominal interest rate is given by $i_t = i^L < i^H \ \forall t \geq 0$, where i^L satisfies $1 + i^L = (1 + r)(1 + \epsilon^L)$.

Given the path of the nominal interest rate, equation (25) is a first-order linear difference equation in $U'(x_t)$ with a constant forcing term given by $\lambda h(i^L)$. Furthermore, because $|\alpha\beta| < 1$, it follows that equation (25) is globally unstable in $U'(x_t)$. Therefore, the only non-explosive solution is one in which $U'(x_t)$ reaches its new steady state, $\lambda h(i^L)/(1 - \alpha\beta)$, instantaneously. Since $U'(\cdot)$ is a monotone function, x_t must also attain its new steady-state level at $t = 0$. Equation (26) then implies that consumption evolves according to the following first-order linear difference equation:

$$c_t = \alpha c_{t-1} + (1 - \alpha)c^*, \tag{29}$$

where $c^* \equiv x^*/(1 - \alpha)$ denotes the steady-state value of c_t. Using (28) and (29) to eliminate w_{-1} and $\{c_t\}_{t=0}^{\infty}$ from (24), c^* can be written as

$$\frac{c^* - c_{-1}}{c_{-1}} = \left(\frac{1 - \alpha\beta}{1 - \alpha}\right) \left[\frac{(1 - \phi)(g(i^H) - g(i^L))}{1 + (1 - \phi)g(i^L)}\right]. \tag{30}$$

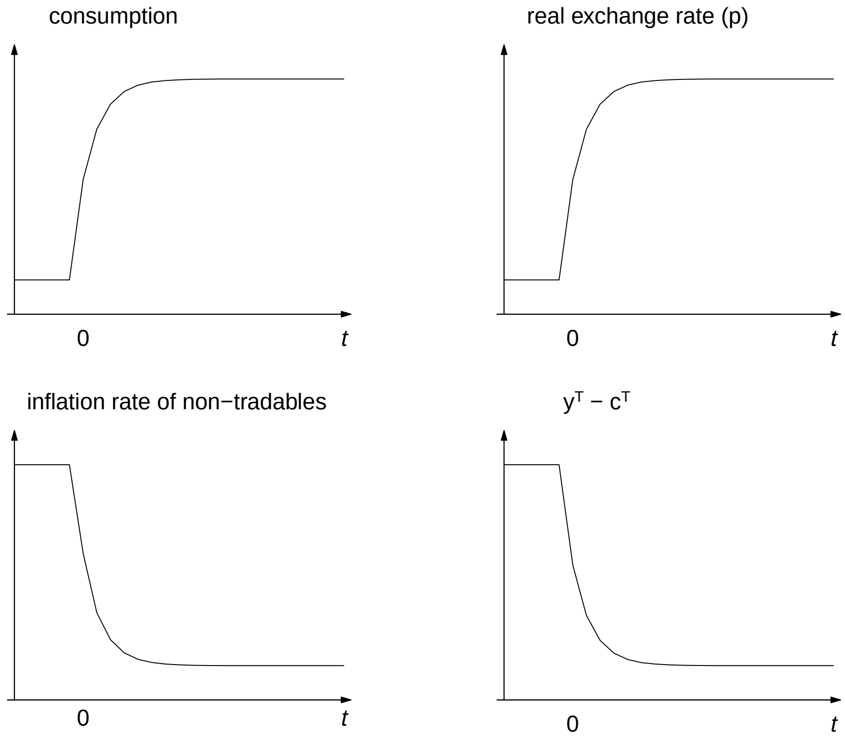
According to this expression, if transaction costs are not fully rebated, an assumption that I will maintain for the remainder of this section, then $c^* > c_{-1}$, that is, a permanent ERB stabilization program generates a long-run increase in consumption.

Under time separable preferences ($\alpha = 0$), equation (29) implies that $c_t = c^* \ \forall t \geq 0$; that is, consumption jumps up when the program is announced and remains constant thereafter. Since in equilibrium the real exchange rate is proportional to consumption (see equation (27)), the real exchange rate experiences a once-and-for-all appreciation in the period the program is announced. Therefore, when preferences are time separable, the model fails to replicate the observed price-consumption regularity.

Consider now the case of habit formation ($0 < \alpha < 1$). Since $c_{-1} < c^*$, equation (29) implies that when the program is announced consumption jumps up to a level between c_{-1} and c^* and then continues to increase monotonically until it reaches its steady-state level c^*. Being proportional to consumption, the real exchange rate appreciates on impact and then continues to do so gradually along the entire transition (figure 1). The joint behavior of consumption and the real exchange rate is therefore consistent with the price-consumption regularity.

The intuition behind the above results is as follows. The permanent reduction in the nominal interest rate induces a permanent decline in money velocity, which in turn generates a positive wealth effect by reducing transaction costs. In response to this wealth effect, agents rationally choose to adjust consumption gradually and build up their stock of assets so as to be able to maintain a higher level of habit in the future. Given the supply of nontradables, the gradual expansion in aggregate expenditure must occur entirely through tradables. The gradual appreciation of the real

Figure 1: Permanent ERB program under habit persistence

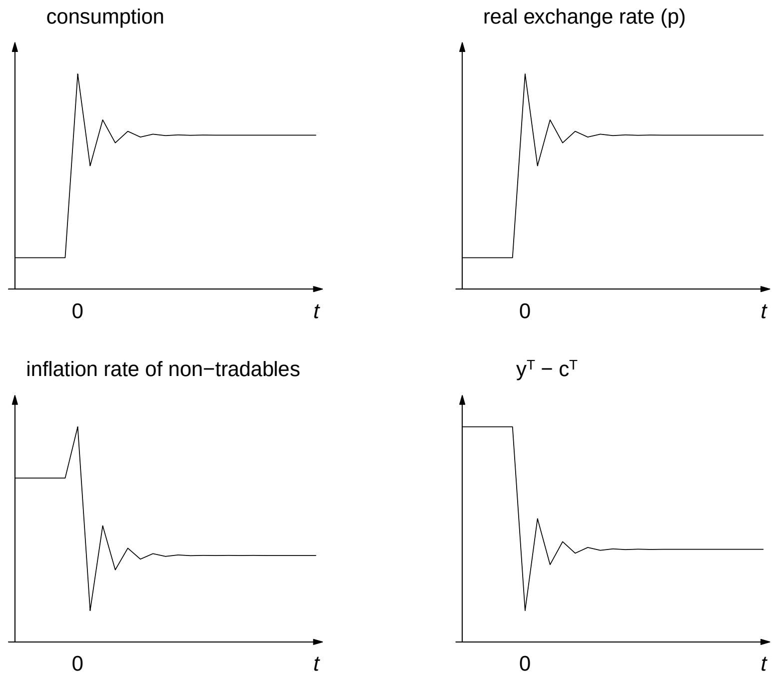


exchange rate induces agents to make the necessary expenditure switch away from nontradables and toward tradables.

The gradual appreciation of the real exchange rate implies that the model also captures the slow convergence of the inflation rate of nontradables to the devaluation rate typical of ERB programs.[8] However, the habit persistence model has two counterfactual implications: First, the current account, given by $rw_{t-1} + y^T - [1 + (1 - \phi)g(i^L)]\, c_t$, is positive along the entire transition. This effect follows directly from the fact that consumption converges monotonically from below to its higher steady state. The second counterfactual implication is the absence of a contraction in aggregate demand following the initial expansionary phase of the stabilization program. The first counterfactual implication can be overcome in a more general model with endogenous labor supply and capital accumulation like the one presented in section 7. In such a model, a permanent ERB program generates an investment boom that contributes a deterioration of the trade balance. In addition, in the more general model the announcement of a permanent ERB program is characterized by a reallocation of labor away from the traded sector and toward the nontraded sector that causes an initial contraction in the supply of tradables, thus also contributing to a deterioration of the current account. An alternative way to capture the initial deterioration in the current account is to allow for policy temporariness *à la* Calvo (1986). In this case, the initial boom in consumption

[8]Formally, let $\pi_t \equiv P_t/P_{t-1} - 1$ denote the rate of inflation of nontradables. Then recalling that the real exchange rate is defined as $p_t = P_t/E_t$ and that the devaluation rate is given by $\epsilon_t = E_t/E_{t-1} - 1$, it follows that $\pi_t - \epsilon_t = (1 + \epsilon_t)(p_t/p_{t-1} - 1)$.

Figure 2: Permanent ERB program under durability



is driven not by a wealth effect as in the case analyzed in this section, but by an intertemporal substitution effect caused by expectations of higher future inflation. The assumption of temporariness can also help resolve the second difficulty of the simple model analyzed in this section. I explore this temporariness hypothesis detail in sections 5 and 7.

Finally, under consumption durability ($-1 < \alpha < 0$), equation (29) and the fact that $c_{-1} < c^*$ imply that when the program is announced consumption jumps above its steady-state level and then converges to it in an oscillating fashion. The real exchange rate and inflation follow a similar pattern (figure 2).[9] In isolation, the assumption of durability does not provide a satisfactory explanation of the initial effects of ERB programs, as it fails to capture the gradual appreciation of the real exchange rate as well as the protracted expansion in aggregate consumption. However, I will argue later that in combination with the assumption of habit formation, durability enriches the predictions of the model.

5 Temporary ERB programs

Consider a stabilization program whereby the monetary authority reduces the devaluation rate for only a finite period of time. Specifically, assume that the monetary authority sets ϵ_t to ϵ^L for $0 \leq t < T$ and to $\epsilon^H > \epsilon^L$ for $t \geq T$.[10] The uncovered interest parity condition then implies that

[9] De Gregorio et al. (1996) find a similar adjustment pattern in an (s,S) model of consumption durability. See also Calvo (1988) and Drazen (1990).

[10] The dynamics of the model are identical in the case in which the program is permanent but the public expects it to be abandoned in period T.

the time path of the nominal interest rate is given by

$$i_t = \begin{cases} i^L \equiv (1+r)(1+\epsilon^L) & 0 \leq t < T-1 \\ i^H \equiv (1+r)(1+\epsilon^H) > i^L & t \geq T-1. \end{cases} \tag{31}$$

To isolate the intertemporal effects arising from the assumption of temporariness, I will eliminate the wealth effect associated with changes in inflation by assuming that transaction costs are fully rebated ($\phi = 1$). The competitive equilibrium is thus given by a pair of sequences $\{c_t, x_t\}_{t=0}^{\infty}$ and a scalar $\lambda > 0$ satisfying the following equilibrium conditions:

$$U'(x_t) - \alpha\beta U'(x_{t+1}) = \lambda h(i_t) \tag{25}$$

$$c_t = \alpha c_{t-1} + x_t \tag{26}$$

$$(1+r)(w_{-1} + y^T/r) = \sum_{t=0}^{\infty}(1+r)^{-t}c_t \tag{32}$$

given the initial conditions c_{-1} and w_{-1} and the sequence of nominal interest rates described by (31). As in the previous section, I will assume that prior to the announcement of the program, the economy is in a steady state in which all real variables are constant, so that c_{-1} is given by

$$c_{-1} = rw_{-1} + y^T. \tag{33}$$

Combining (32) and (33) yields,

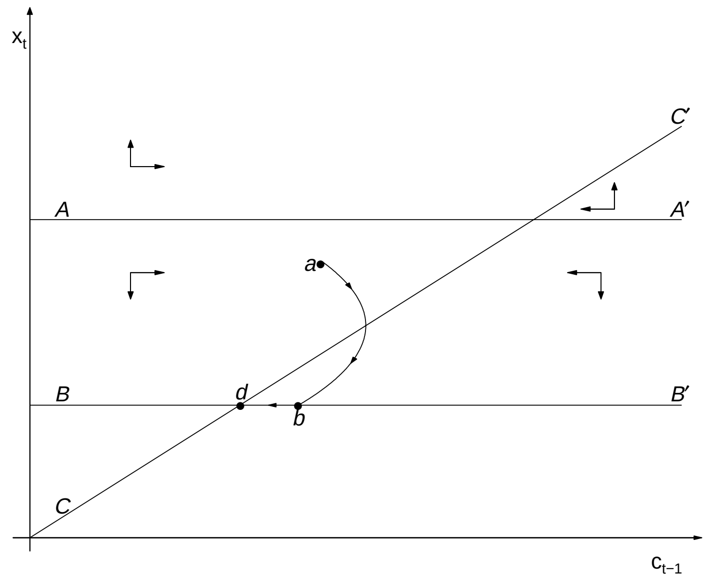
$$\frac{1+r}{r}c_{-1} = \sum_{t=0}^{\infty}(1+r)^{-t}c_t \tag{34}$$

which states that the pre- and post-stabilization streams of consumption must be equivalent in present-discounted-value terms. A competitive equilibrium can then be re-stated as a scalar λ and sequences $\{c_t, x_t\}_{t=0}^{\infty}$ satisfying (25), (26), and (34), given c_{-1} and the sequence of nominal interest rates described by (31).

Consider first the case of time-separable preferences (Calvo, 1986). Equation (26) implies that x_t equals c_t for all $t \geq 0$. Thus, equation (25) implies that consumption satisfies $U'(c_t) = \lambda h(i^L)$ for $0 \leq t < T-1$ and $U'(c_t) = \lambda h(i^H)$ for $t \geq T-1$. That is, consumption is constant until period $T-2$ and falls to its long-run level in period $T-1$. Therefore the model with time-separable preferences fails to capture the price-consumption regularity under temporary as well as permanent stabilization programs.

Consider now the case of habit formation. Figure 3 displays the phase diagram corresponding to equations (25) and (26) given λ. The horizontal line AA' marks the value of x_t that solves equation (25) for $x_t = x_{t+1}$ and $i_t = i^L$. Similarly, the horizontal line BB' marks the value of x_t that solves (25) for $x_t = x_{t+1}$ and $i_t = i^H$. Because $i^H > i^L$, AA' lies above BB'. It is clear from equation (25) that if in any period $t < T-1$ the system is above (below) AA', then x_{t+1} is greater (less)

Figure 3: Temporary ERB program under habit persistence: phase diagram



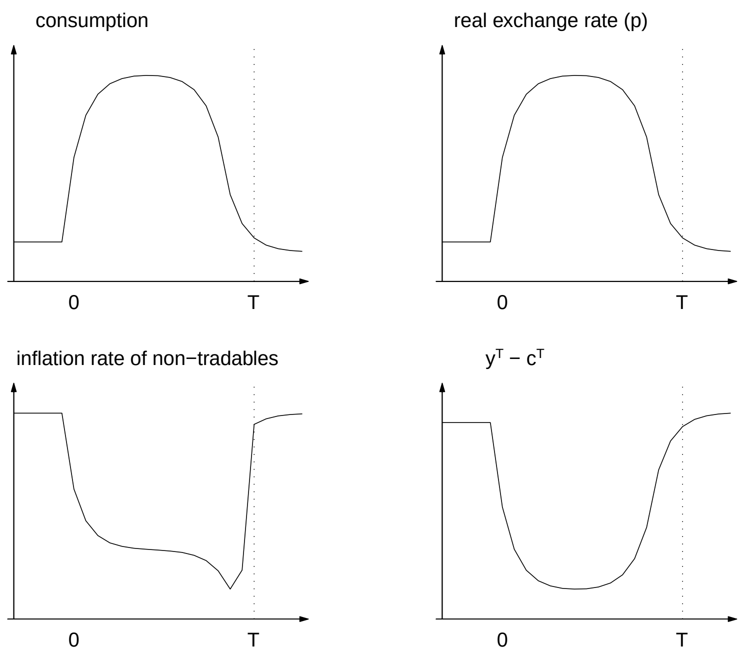
than x_t. Similarly, if in any period $t \geq T-1$ the system is above (below) BB', then x_{t+1} is greater (less) than x_t. This implies that x_t must hit the locus BB' at $t = T-1$ and stay on it thereafter. In other words, BB' is the saddle path of the system for $t \geq T-1$. The ray CC' displays the pairs (c_{t-1}, x_t) satisfying (26) for $c_t = c_{t-1}$. Because $\alpha \in (0,1)$, it follows that whenever the system is located to the left (right) of CC', c_t is greater (less) that c_{t-1}. The arrows display the direction of motion for $t < T-1$. The long-run steady state is given by the intersection of BB' and CC' (point d).

Consider the question of finding an initial condition c_{-1} and sequences $\{c_t, x_t\}_{t=0}^{\infty}$ consistent with the equilibrium conditions (25), (26), and (34) given λ.[11] Clearly, the pair (c_{-1}, x_0) must lie between AA' and BB', otherwise the system would move away from BB' and would therefore not reach the saddle path in period $T-1$. Also, the point (x_0, c_{-1}) cannot lie to the right of the locus CC' because in that case c_t would be less than c_{-1} for all t, which violates the resource constraint (34). Similarly, (c_{-1}, x_0) cannot lie to the left of the steady state d, because in that case c_t would be greater than c_{-1} for all t, which again violates the resource constraint (34). Consequently, the pair (c_{-1}, x_0) must lie between AA' and BB', above and to the left of CC', and to the right of the steady state d. In figure 3, (c_{-1}, x_0) is represented by point a.

The fact that point a lies above CC' implies that when the plan is announced, consumption jumps up (i.e., $c_0 > c_{-1}$). Then c_t continues to increase until the system reaches the locus CC'. At that point, consumption begins to decline. Note that since at this point the system has not yet reached the locus BB', the decline in consumption begins *before* the abandonment of the program (in fact, before period $T-1$). In period $T-1$, the system reaches the saddle path BB' (point b)

[11] Of course, c_{-1} is a pre-determined condition. However, for expositional convenience, I choose to characterize the pairs $(c_{-1}, \{c_t, x_t\}_{t=0}^{\infty})$ that support a given value of λ as an equilibrium outcome. The exercise is justified by the fact that the results are independent of the particular value of λ considered.

Figure 4: Temporary ERB program under habit persistence

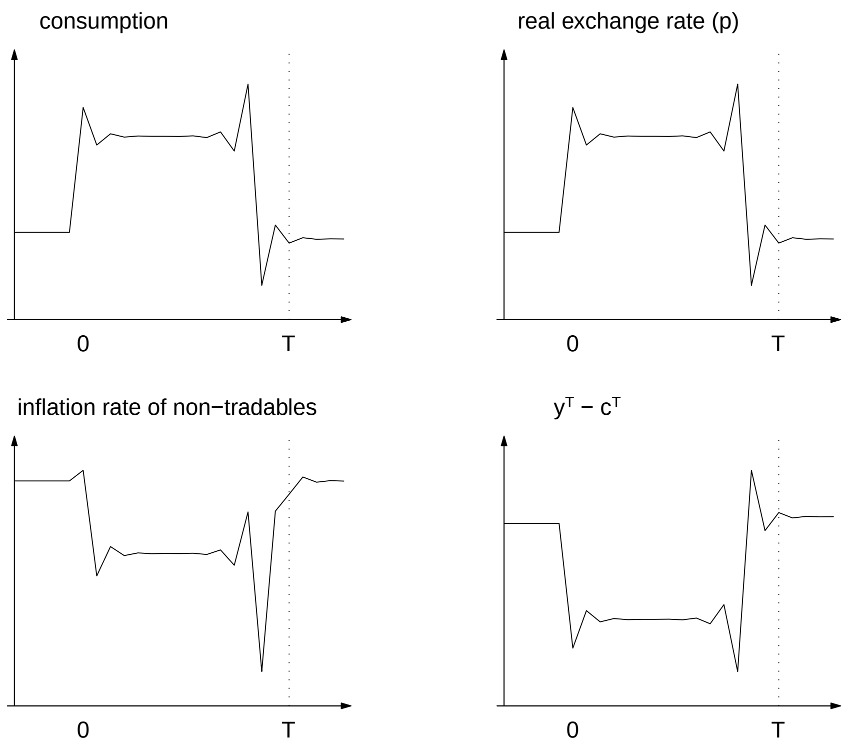


and travels along that locus toward the steady state (point d). Thus, from period $T-1$ on, x_t is constant and consumption decreases monotonically.

Figure 4 displays the time paths of consumption, the real exchange rate, inflation of non-tradables, and the trade balance. The predicted dynamics are consistent with a number of facts associated with ERB stabilization programs. First, since in equilibrium the real exchange rate is an increasing function of consumption (see equation (18)), the initial expansionary phase of the program is accompanied by a gradual appreciation of the real exchange rate. Thus, the model is consistent with the price-consumption regularity. Second, the model captures the boom-recession pattern in consumption observed in the data. Moreover, unlike the model with time-separable preferences, the habit persistence model is consistent with the fact that in programs that failed, the contraction typically set in before the date of collapse. Third, because the initial consumption boom is entirely driven by intertemporal substitution effects, it translates one-by-one into current account deficits. This result is in contrast with the one obtained under permanent stabilization programs, which induce consumption booms driven solely by wealth effects, and are therefore initially characterized by current account surpluses.

The model's implication for the behavior of the real exchange rate is not entirely consistent with the stylized facts. Specifically, the model predicts a gradual real exchange depreciation during the contractionary phase of the program, which is not observed in the data. This counterfactual implication is a direct consequence of the fact that, because the supply of nontradables is fixed, the relative price of nontradables in terms of tradables is demand determined. In section 7, I study the dynamics of a model with endogenous labor supply and capital accumulation, and show that for

Figure 5: Temporary ERB program under consumption durability



plausible parameter specifications the real exchange rate appreciates along the entire transition.

Figure 5 presents the dynamics of the model under consumption durability.[12] As pointed out in the previous section, the oscillating nature of the equilibrium dynamics suggests that durability is not a good explanation for the price-consumption problem. On the other hand, durability introduces a realistic feature in the dynamics of temporary stabilization programs. Namely, as figure 5 shows, durability generates turbulence around the dates of announcement and collapse of the stabilization program, with a period of tranquility in between. This result suggests that durability and habit persistence are complementary rather than competitive explanations of the dynamics of ERB programs.

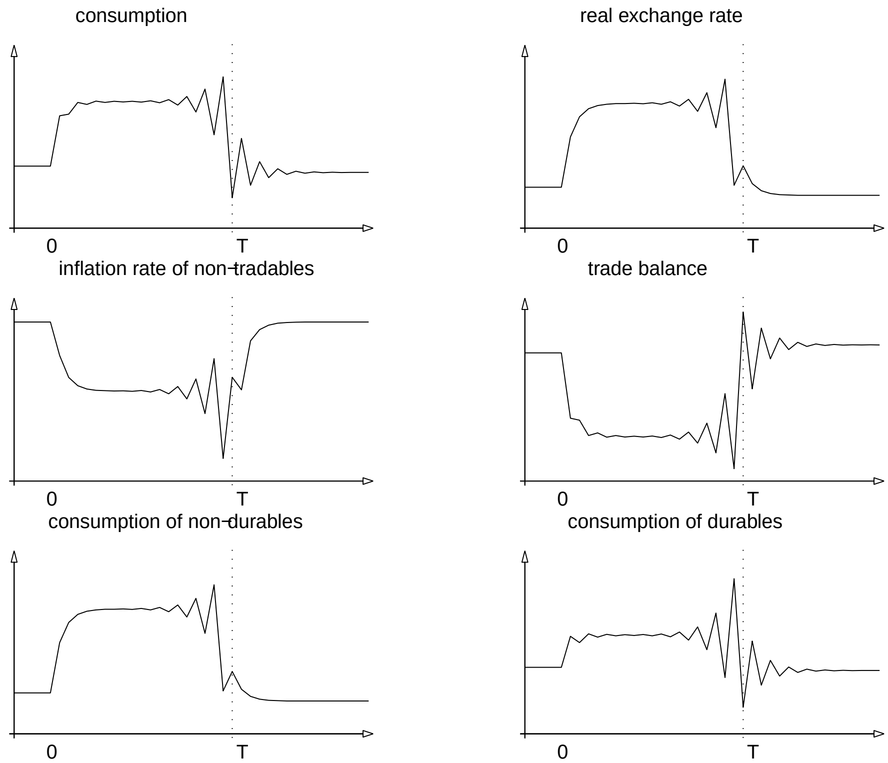
A digression: A model with habit formation and durable goods

To formalize this conjecture, consider an economy in which preferences are given by (10) and (11) and display habit formation, so that $\alpha > 0$. Assume also that the tradable consumption good, c_t^T, is a composite of a perishable traded good, z_t, and services from a durable traded good, s_t. Specifically, assume that c_t^T is given by

$$c_t^T = z_t^\theta s_t^{1-\theta}; \qquad \theta \in (0,1)$$

[12]This figure as well as figure 6 (discussed later), displays the exact equilibrium dynamics arising from an economy in which $U(\cdot)$ belongs to the family of CRRA functions. An analysis of quantitative issues is postponed until section 7.

Figure 6: Temporary ERB program under consumption durability and habit persistence



The evolution of the stock of durables is assumed to be given by

$$s_t = w_t + \omega w_{t-1}; \quad \omega > 0$$

where w_t denotes purchases of new durable goods. Figure 6 displays the equilibrium dynamics induced by a temporary ERB stabilization program.

The presence of durables makes the abandonment of the program look traumatic: the volatility of consumption, inflation and the trade balance increases as t approaches $T-1$. At the same time, the model inherits from the habit formation model an initial transition characterized by a gradual real exchange rate appreciation, a smooth consumption boom, and a slow convergence of the inflation rate to the devaluation rate. The combination of durability, habit persistence, and policy temporariness generates dynamics that look as if shortly before period $T-1$ the economy is hit by an adverse shock that leads to the eventual abandonment of the program.

6 Nontraded output dynamics

As pointed out in section 2, standard models of ERB stabilization have great difficulties explaining the observed comovement between nontraded output and the real exchange rate. In particular, they counterfactually predict that after the period of announcement of the program, those two variables move in opposite directions. In this section, I study an extension of the basic framework analyzed thus far, in which both tradables and nontradables are produced with labor, which is assumed to be perfectly mobile across sectors and fixed in aggregate supply. Formally,

$$y_t^N = F(h_t^N),$$

$$y_t^T = G(1 - h_t^N),$$

where h_t^N denotes labor services employed in the nontradable sector, $1 - h_t^N$ denotes labor services employed in the tradable sector, and $F(\cdot)$ and $G(\cdot)$ are production functions satisfying the Inada conditions. This extension introduces an additional marginal condition requiring that the value of the marginal product of labor be equalized across sectors,

$$p_t F'(h_t^N) = G'(1 - h_t^N).$$

According to this expression, p_t is a strictly increasing function of h_t^N. The market clearing condition $c_t^N = F(h_t^N)$ implies that in equilibrium c_t^N is also strictly increasing in h_t^N.

Another innovation introduced in this section is the departure from the convenient but rather unfamiliar assumptions regarding the form of the aggregator function. Specifically, the composite consumption good is now assumed to be produced via an increasing, homogeneous-of-degree-one, and concave aggregator function like the one described by (2), so that c_t can be written as $c_t = c_t^N A(c_t^T/c_t^N, 1)$, where $A(\cdot, 1)$ is an increasing and strictly concave function. Given this aggregator function, the real exchange rate is given by (3), which implies that p_t is a strictly increasing function of c_t^T/c_t^N. Thus, in equilibrium, p_t, c_t^N, c_t^T, h_t^N, y_t^N, c_t^T/c_t^N, and $-y_t^T$ are all strictly increasing functions of c_t. Letting $H(c_t) \equiv A_1(c_t^T/c_t^N, 1)$, $I(c_t) \equiv c_t^T - y_t^T$, and $L(c_t) \equiv c_t^T + p_t c_t^N$, a competitive equilibrium is given by a scalar λ and a pair of sequences $\{c_t, x_t\}_{t=0}^{\infty}$ satisfying,

$$[U'(x_t) - \alpha\beta U'(x_{t+1})]H(x_t + \alpha c_{t-1}) = \lambda h(i_t) \tag{35}$$

$$c_t = \alpha c_{t-1} + x_t \tag{26}$$

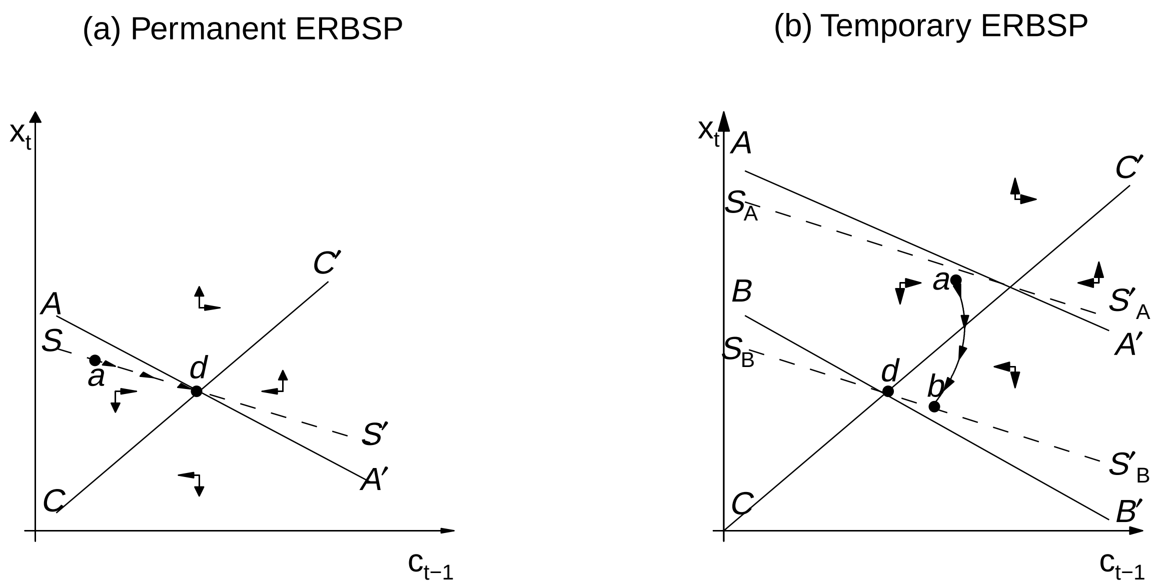
$$(1 + r)w_{-1} = \sum_{t=0}^{\infty}(1 + r)^{-j}[I(c_t) + (1 - \phi)s(\nu(i_t))L(c_t)] \tag{36}$$

given a sequence of nominal interest rates $\{i_t\}_{t=0}^{\infty}$. The first two equations originate in the household's first-order conditions, and the third one represents the economy's intertemporal resource constraint. Note that $H(\cdot) > 0$, $H'(\cdot) < 0$, $I'(\cdot) > 0$, $L(\cdot) > 0$, and $L'(\cdot) > 0$.[13]

I will limit the analysis to the case of habit formation. Consider first a permanent ERB stabilization program that reduces the nominal interest rate from i^H to i^L. Panel (a) of figure 7 displays the phase diagram corresponding to the difference equations (26) and (35). The locus AA' displays

[13] Note that these equilibrium conditions encompass those of an endowment economy. To see this, note that in that case c_t is given by $A(c_t^T, y^N)$, and therefore c_t^T is strictly increasing in c_t, $H(c_t) \equiv A_1(c_t^T, y^N)$ is positive and strictly decreasing, and $I(c_t) \equiv c_t^T - y^T$ is strictly increasing. Finally, evaluating (3) at $c_t^N = y^N$, it follows that in equilibrium p_t is strictly increasing in c_t, and therefore $L(c_t) = c_t^T + p_t y^N$ is positive and strictly increasing.

Figure 7: ERB program in an economy with labor mobility and homogeneous-of-degree-one aggregator function: phase diagram



the pairs (c_{t-1}, x_t) satisfying equation (35) for $x_{t+1} = x_t$ and $i_t = i^L$. Because both $U'(\cdot)$ and $H(\cdot)$ are strictly decreasing, AA' is negatively sloped. Moreover, it follows from (35) that along AA', $\partial x_{t+1}/\partial x_t = [1 + (1 - \alpha\beta)U'H'/(U''H)]/(\alpha\beta) > 1$. So, if in any period $t \geq 0$ the system is above (below) AA', then $x_{t+1} > (<)\, x_t$. The ray CC' displays the pairs (c_{t-1}, x_t) satisfying (26) for $c_t = c_{t-1}$. Clearly, if the system is above (below) CC' then $c_t > (<)\, c_{t-1}$.

The system is saddle-path stable. The saddle path is given by the locus SS'. The post-stabilization steady state is given by point d at the intersection of AA' and CC'. The economy must be on the saddle path along the entire transition, otherwise it would not converge to the steady state. The initial position of the system (c_{-1}, x_0), must lie at a point such as a located on the saddle path and to the left of the steady state. To see this, assume that (c_{-1}, x_0) on SS' but to right of d. Since such a position is below CC', it follows that $c_0 < c_{-1}$, that is, consumption declines when the program is announced. Moreover, it is clear from the figure that c_t would continue to fall along the entire transition. Thus, $c_t < c_{-1}\ \forall t \geq 0$. But this clearly violates the resource constraint (36), because c_{-1} satisfies that constraint for $i_t = i^H > i^L$ (recall that $I', L', s'\nu' > 0$).

The fact that the initial position a is located above CC' implies that $c_0 > c_{-1}$, that is, consumption increases in the period in which the stabilization program is announced. After the announcement, the system travels smoothly from a to d along the saddle path, which implies that consumption increases monotonically toward its higher steady-state level. Since in equilibrium y_t^N and p_t are strictly increasing functions of c_t, it follows that the habit persistence model captures the observed pattern of gradual real exchange rate appreciation combined with a protracted expansion in both nontraded output and consumption.

Consider now a temporary stabilization program whereby the nominal interest rate follows a pattern like the one described by equation (31). As in section 5, I isolate the intertemporal substitution effects stemming from the temporary nature of the stabilization program by assuming that transaction costs are mere transfers among private agents ($\phi = 1$). The equilibrium conditions are then given by (26), (35), and

$$(1+r)w_{-1} = \sum_{t=0}^{\infty}(1+r)^{-j}I(c_t) \tag{37}$$

with the forcing term $\{i_t\}_{t=0}^{\infty}$ given by equation (31).

Panel (b) of figure 7 displays the phase diagram associated with equations (26) and (35) under habit persistence. The locus AA' shows the set of pairs (c_{t-1}, x_t) satisfying (35) for $x_{t+1} = x_t$ and $i_t = i^L$. Similarly, the locus BB' displays the pairs (c_{t-1}, x_t) satisfying (35) for $x_{t+1} = x_t$ and $i_t = i^H$. The loci $S_AS'_A$ and $S_BS'_B$ represent the saddle paths of the system for $t < T-1$ and $t \geq T-1$, respectively. The arrows display the direction of motion for $t < T-1$. The post-stabilization steady state is given by the intersection of BB' and CC' (point d). Because at $t = T-1$ the nominal interest rate jumps from i^L to its long-run level i^H, the system must reach the saddle path $S_BS'_B$ at exactly that date. This implies that at $t = 0$ the system must be somewhere between the loci $S_AS'_A$ and $S_BS'_B$. Also, the initial position of the system cannot be above CC' and to the left of d, for that would imply that $c_t > c_{-1}$ $\forall t$, which violates the resource constraint (37). Similarly, the system cannot be initially located below CC' and to the right of d, because in that case $c_t < c_{-1}$ $\forall t$, which also violates the resource constraint. Consequently, the initial position must be a point such as a located between $S_AS'_A$ and $S_BS'_B$, above CC', and to the right of the steady state d. The fact that point a lies above the locus CC' implies that $c_0 > c_{-1}$, that is, consumption jumps up when the program is announced. Along the transition, consumption initially grows until the system crosses the locus CC'. At that moment, consumption begins to fall. In period $T-1$, the system reaches point b on the saddle path $S_BS'_B$ and begins to travel along that path until it reaches the steady state d. Note that because the system crosses the locus CC' before period $T-1$, the contraction in consumption begins before the abandonment of the peg. Note also that because in period $T-1$ the system is to the right of its steady-state position, consumption continues to fall after the collapse of the program.

Since in equilibrium y_t^N is strictly increasing in c_t, a temporary stabilization program generates a smooth boom-recession cycle in nontraded output, with the recession beginning before the collapse of the program. Because p_t is also an increasing function of c_t, the model is consistent with the fact that during the expansionary phase of ERB programs the real exchange rate gradually appreciates. The fact that $-I(c_t) \equiv y_t^T - c_t^T$ is strictly decreasing in c_t, implies that the initial boom in consumption is accompanied by a progressive deterioration of the trade balance. However, the model inherits from the endowment economy the counterfactual implication that the contractionary phase of the program is accompanied by a depreciation of the real exchange rate. As it turns out, this difficulty is not present in economies with capital.

7 An economy with capital and endogenous labor supply

The endowment economy models analyzed thus far leave a number of important questions open: First, is the price-consumption problem present in model economies with more realistic technology and preference specifications? As noted in section 2, if the assumption that preferences are separable in leisure and consumption is relaxed—specifically, if the cross derivative of the period utility function with respect to consumption and leisure is assumed to be negative—it is no longer necessarily the case that consumption falls as the real exchange rate appreciates during the initial phase of ERB programs. Second, in a more realistic model economy with capital and endogenous labor supply, is habit formation still a useful way to fix the price-consumption problem? Third, can the interaction of habit formation, leisure, and capital accumulation help explain aspects of the observed adjustment process that the endowment economy is unable to capture? Of particular interest is the behavior of the real exchange rate during the contractionary phase of ERB programs. As shown earlier in the paper, the fact that in the endowment economy the real exchange rate is demand determined implies counterfactually that a contraction in aggregate demand is necessarily associated with a depreciation of the real exchange rate. Finally, how does habit persistence affect the quantitative predictions of standard models? A well-known quantitative difficulty of the model with time separable preferences is that it generates consumption booms and real exchange rate appreciations that are too small relative to those observed in the data (Rebelo and Végh, 1995). The fact that habit persistence introduces additional smoothness in the response of consumption to changes in expected inflation raises the question of whether habit formation makes the quantitative problems worse.

To address these questions, I extend the model presented in the previous section by including capital accumulation and endogenous labor supply. In the resulting model, a permanent reduction in expected inflation generates real effects stemming from three different sources: (1) purchases of investment goods are assumed to be subject to transaction costs, thus inflation creates a wedge between the rate of return on physical capital and the rate of return on foreign bonds; (2) because consumption is subject to transaction costs while leisure is not, expected inflation introduces a wedge between the wage rate and the marginal rate of substitution between consumption and leisure; and (3) changes in expected inflation create income effects by altering the amount of resources spent by households in reducing their exposure to the inflation tax (shoe-leather costs). The first two effects are usually referred to as supply-side effects (see Lahiri, 1995, Roldós, 1995, and Uribe, 1997a,b).

I will limit the presentation of the model to a description of the components that distinguish it from the endowment economy. Let $h_t \in [0,1]$ denote the fraction of time devoted to work by the representative household in period t. Then the household's utility function is given by

$$\sum_{t=0}^{\infty} \beta^t \frac{\left[(c_t - \alpha c_{t-1})(1-h_t)^{\psi}\right]^{1-\sigma} - 1}{1-\sigma},$$

where σ, $\psi > 0$ and $\sigma \neq 1$. Note that if $\sigma > 1$, then the cross derivative of the period utility function with respect to c_t and $1 - h_t$ is negative.

Consumption is a composite of traded and nontraded goods produced with a Cobb-Douglas aggregator function. Formally,

$$c_t = c_t^{T\gamma} c_t^{N1-\gamma}; \quad \gamma \in (0,1).$$

In addition to money and bonds, households can now invest in physical capital, k_t^T. Investment, i_t^T, is made of traded goods and is, like consumption, subject to transaction costs. The evolution of asset holdings is then given by

$$b_t + m_t + (c_t^T + p_t c_t^N + i_t^T)(1 + s(v_t)) \leq (1 + r_{t-1})b_{t-1} + \frac{m_{t-1}}{1+\epsilon_t} + y_t^T + p_t y_t^N + \tau_t$$

where money velocity is now defined as

$$v_t = \frac{c_t^T + p_t c_t^N + i_t^T}{m_t}.$$

The accumulation of physical capital is subject to adjustment costs. Specifically, the law of motion of k_t^T is given by

$$k_{t+1}^T = \phi(i_t^T / k_t^T) k_t^T + (1 - \delta) k_t^T,$$

where $\phi(\cdot)$ satisfies $\phi(\delta) = \delta$, $\phi'(\delta) = 1$, and $\phi''(\delta) < 0$.

Following Mendoza and Uribe (1996), Rebelo and Végh (1995), Roldós (1995), and others, I assume that traded goods are produced with capital and labor via an homogeneous-of-degree-one technology, while nontraded goods are produced with labor only. Specifically,[14]

$$y_t^T = h_t^{T\alpha_T} k_t^{T1-\alpha_T}; \quad \alpha_T \in (0,1)$$

$$y_t^N = h_t^{N\alpha_N}; \quad \alpha_N \in (0,1)$$

where h_t^T and h_t^N denote the fraction of time devoted by the representative household to work in the traded and nontraded sectors, respectively, and satisfy

$$h_t = h_t^T + h_t^N$$

The market clearing conditions in the nontraded goods market is:

$$c_t^N = y_t^N.$$

Letting w_t denote the sum of private and public foreign assets, the equilibrium intertemporal

[14]Uribe (1997a) analyzes the dynamics of ERB programs in a model with capital in the nontraded sector.

resource constraint of the economy is given by

$$w_t = (1 + r_{t-1})w_{t-1} + TB_t,$$

$$TB_t = y_t^T - c_t^T - i_t^T - s(v_t)(c_t^T + p_t c_t^N + i_t^T),$$

where TB_t denotes the trade balance in period t. Note that transaction costs are not rebated.

I base the analysis on simulations of a log-linearized version of the equilibrium conditions. Under the assumption of a constant international interest rate maintained in the previous sections, the log-linearized model contains a unit root that invalidates the use of standard theoretical arguments linking its dynamic properties to those of the original, non-linear model. To circumvent this problem, I assume that in equilibrium the international real interest rate is decreasing in the country's net foreign asset position. That is,

$$r_t = r^* \mu(w_t - w^*);$$

where w^* is a constant, $1 + r^* = \beta^{-1}$, $\mu(0) = 1$, and $\mu'(0) < 0$.[15]

I calibrate the model using data from the Argentine economy during the period 1970-1990. I set the pre-stabilization devaluation rate at 35 percent, the average level prevailing over the calibration period (Uribe, 1997a). The steady-state international interest rate, r^*, takes a value of 1.62 percent per quarter, which corresponds to the average real rate of return on U.S. equity between 1948 and 1981 (King et al., 1988). The transaction cost is assumed to be of the form

$$s(v) = Av^{\xi}; \quad \xi > 0.$$

This specification implies a money demand elasticity with respect to $i/(1+i)$ equal to $1/(1+\xi)$. I set this elasticity at -0.4, a value consistent with the estimates for Argentina reported by Arrau et al. (1995). The scale parameter A takes a value consistent with a steady-state seignorage revenue of 7 percent of GDP (Rebelo and Végh, 1995). The sectorial labor shares α_T and α_N were set at .48 and .63, respectively, following Uribe (1997a). The depreciation rate was set at 2.5 percent per quarter. The elasticity $\phi''(\delta)\delta/\phi'(\delta)$ was set at -1/15 following Rebelo and Végh (1995). Based on the estimate of the intertemporal elasticity of substitution for Argentina obtained by Reinhart and Végh (1995), I set σ at 5. I choose a value for ψ such that households allocate on average 20 percent of their time to work. The share of traded goods in the aggregator function, γ, takes a value consistent with a share of traded output in GDP of 42 percent (Uribe, 1997a). The steady-state level of wealth, w^*, was set so as to be consistent with a long-run trade balance to GDP ratio of 2.67 percent reported by Uribe (1997a)—which implies that in the long run the country is a net debtor—and the steady-state wealth elasticity of the real interest rate, $\mu'(0)w^*$, was set at a low

[15] Two alternative ways to avoid the unit-root problem are to assume that the subjective discount factor is a decreasing function of a weighted average of current and past consumption (Obstfeld, 1981) and to introduce finite lives as in Blanchard's (1985) perpetual youth model.

value, 10^{-4}, so that in the short run the model behaves as if the interest rate was constant. Finally, due to scarce econometric evidence on the size of the habit persistence parameter α for developing countries, I simulate the model under two arbitrary values, 0 and .7.

Figure 8 displays the dynamics of the model in response to an unexpected, credible, and permanent ERB stabilization program that reduces the devaluation rate from 35 to zero percent per quarter. The figure shows with solid lines the case of habit persistence ($\alpha = .7$) and with dashed lines the case of time-separable preferences ($\alpha = 0$). Under both habit persistence and time-separable preferences, the model correctly predicts a gradual real exchange rate appreciation that begins immediately after the program is announced. However, under time-separable preferences, the model counterfactually predicts a flat path for total consumption and a decreasing path for consumption of nontradables. By contrast, under habit persistence both total consumption and consumption of nontradables expand gradually. From a quantitative standpoint, the increase in consumption and the appreciation of the real exchange rate cumulated over the first three years of the program are roughly of the same magnitude under each of the two preference specifications considered.

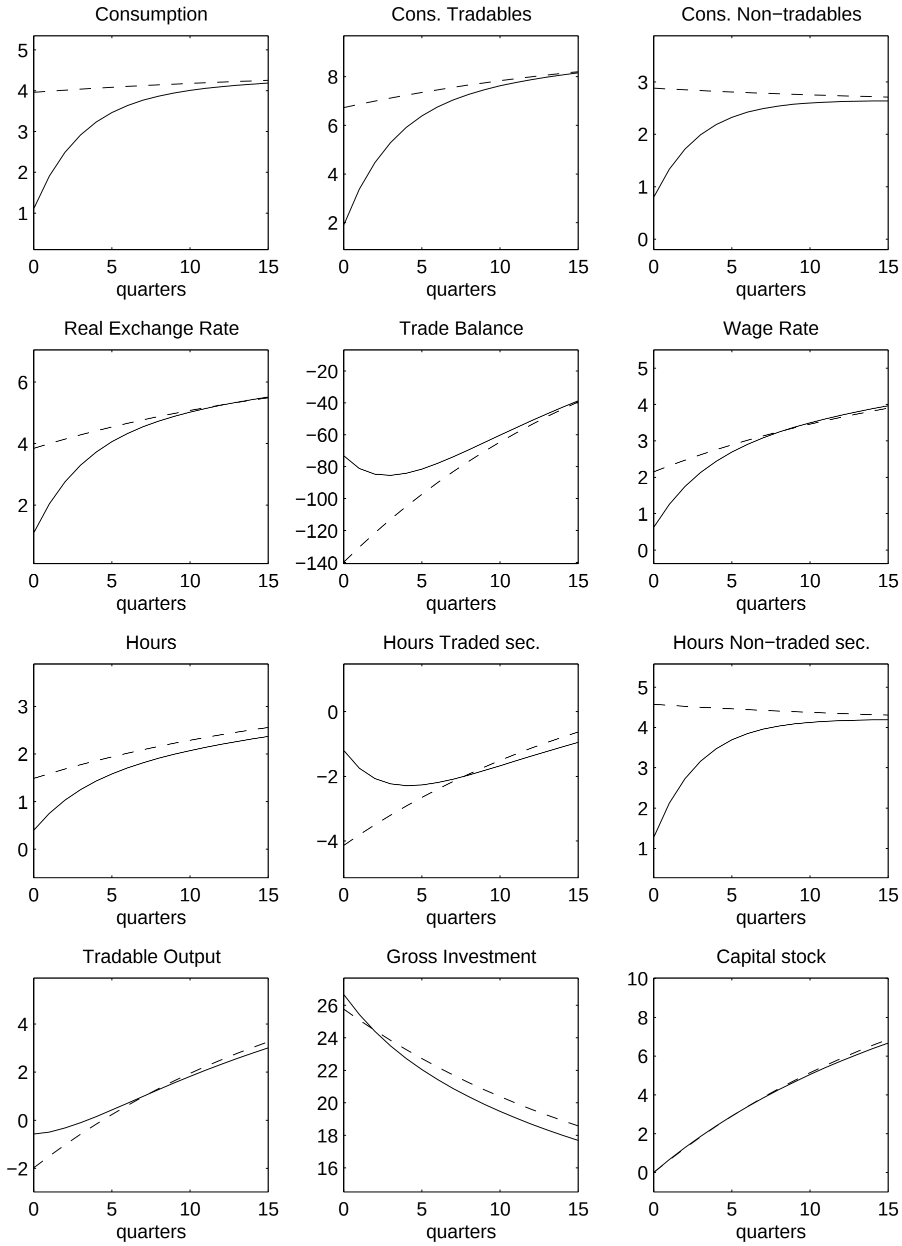
On the supply side, the main difference between habit forming and time separable preferences lies in the behavior of sectorial employment in the early phase of the program. Under time separable preferences, there is a more pronounced shift in employment away from the traded sector and toward the nontraded sector than under habit persistence. Gross investment displays a similar pattern under both types of preferences: It increases by over 25 percent on impact and then declines gradually along the transition.[16]

Figure 9 displays the dynamics of a temporary ERB stabilization program that reduces the devaluation rate from 35 to zero percent per quarter for three years, after which the devaluation rate increases (and is expected to increase) back to its pre-stabilization level of 35 percent. Like the endowment economy model, the model with capital and labor predicts that under habit persistence total consumption as well as consumption of nontradables display a smooth boom-recession cycle, with the recession beginning before the expected date of abandonment of the program. This pattern is absent in the economy with time-separable preferences.

The presence of supply-side effects induces a more realistic response of the real exchange rate than the endowment economy. As pointed out before, in the endowment economy a contraction in aggregate demand is necessarily associated with a depreciation of the real exchange rate. Under temporary programs, this property of the endowment economy model produces the counterfactual implication that the real exchange rate begins to depreciate several periods before the collapse of the program. By contrast, as shown in the left panel of the second row of figure 9, in the economy with capital and endogenous labor supply, the real exchange rate continues to appreciate after the contraction sets in. This is because the continuous increase in the capital stock that takes place in the traded sector raises the marginal product of labor in that sector, thereby inducing a re-allocation

[16]This pattern is not completely consistent with the observed investment booms, during which investment increases for several years before reaching its peak. Uribe (1997a) shows that this pattern can be accounted for by introducing gestation lags.

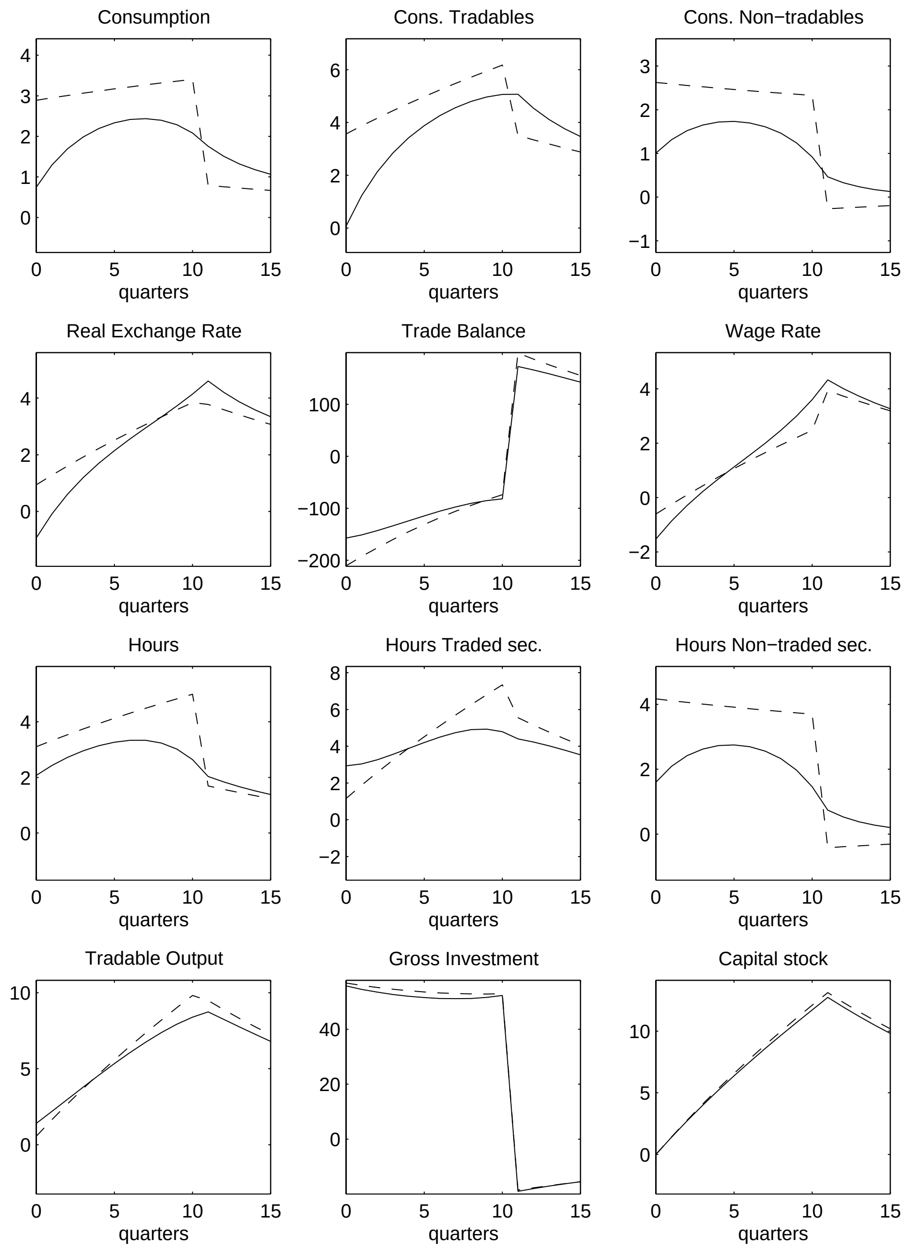
Figure 8: Permanent ERB stabilization under habit persistence in an economy with capital and endogenous labor supply.



——— habit forming preferences ($\alpha = .7$) - - - - time-separable preferences ($\alpha = 0$)

Note: The program consists in a credible, permanent reduction of the devaluation rate from 35 to 0 percent per quarter. All variables are expressed in percentage deviations from their pre-stabilization steady states.

Figure 9: Temporary ERB stabilization under habit persistence in an economy with capital and endogenous labor supply.



——— habit forming preferences ($\alpha = .7$) - - - - time-separable preferences ($\alpha = 0$)

Note: The program consists in a reduction of the devaluation rate from 35 to 0 percent per quarter for 12 quarters, after which the devaluation rate returns to its pre-stabilization level of 35 percent per quarter. All variables are expressed in percentage deviations from their pre-stabilization steady states.

of hours away from the nontraded sector that reduces the supply of nontradables. Finally, when ERB programs are expected to be temporary, the presence of habit persistence introduces not only qualitative but also quantitative differences in the initial dynamics. This is particularly the case for consumption and its components, whose cumulated growth rates during the expansionary phase of the program are much larger under time separable preferences than under habit formation (top row of figure 9).

8 Conclusion

In this paper, I argue that existing optimizing models are unable to capture a defining empirical regularity of exchange-rate-based stabilization programs, namely, that their initial phase is characterized by several years of gradual appreciation of the real exchange rate and a continuous expansion in private consumption. Specifically, existing models predict that after the date of announcement of an exchange-rate-based stabilization program, the real exchange rate and consumption must move in opposite directions.

This counterfactual implication is driven by assumptions related to the specification of preferences, the ability of domestic residents to borrow from international financial markets, and the law of motion of the rate of devaluation implied by the stabilization policy. In particular, the price-consumption problem is a necessary implication of small-open-economy models with time separable preferences, frictionless access to international capital markets, and perfect foresight about the path of the rate of devaluation. Accordingly, modifications of the standard framework such as allowing for preferences that are non-separable over time, borrowing constraints, or uncertainty are obvious candidates for solving the problem. This paper explores the first of these avenues and finds that under habit formation exchange-rate-based stabilization programs induce dynamics that are consistent with the price-consumption regularity.

Clearly, habit formation does not exclude other modifications of the standard framework—such as borrowing constraints or uncertainty —as potential explanations of the price consumption regularity. At a general level, this paper aims to draw attention to the need to incorporate at least a subset of such modifications into any theoretical account of the dynamic effects of exchange-rate-based stabilization programs and, perhaps more importantly, to provoke applied econometric work to assess their empirical relevance.

References

Arrau, P., J. De Gregorio, C. Reinhart, and P. Wickham, "The Demand of Money in Developing Countries: Assessing the Role of Financial Innovation," *Journal of Development Economics,* April 1995, 46(2) 317-40.

Blanchard, Olivier J., "Debt, Deficits, and Finite Horizons," *Journal of Political Economy,* April 1985, 93(2), 223-47.

Calvo, Guillermo A., "Temporary Stabilization: Predetermined Exchange Rates," *Journal of Political Economy,* 1986, 94, 1319-1329.

Calvo, Guillermo A., "Costly Trade Liberalizations: Durable Goods and Capital Mobility," *IMF Staff Papers,* 1988, 35, 461-473.

Calvo, G. A. and C. A. Végh, "Exchange Rate Based Stabilization Under Imperfect Credibility," in Helmut Frisch and Andreas Worgotter, eds., *Open Economy Macroeconomics,* MacMillan Press, London, 1993, 3-28.

Calvo, Guillermo A. and Allan Drazen, "Uncertain Duration of Reform: Dynamic Implications," Working Papers in International Economics No. 4, Center for International Economics, Department of Economics, University of Maryland at College Park, 1993.

De Gregorio, José, Pablo Guidotti, and Carlos Végh, "Stabilization and the Consumption of Durable Goods," mimeo, International Monetary Fund, 1994.

Drazen, Allan , "Can Exchange Rate Freezes Induce Business Cycles?," Unpublished manuscript, University of Maryland, 1990.

Drazen, A. and E. Helpman,, "Stabilization with Exchange Rate Management," *Quarterly Journal of Economics,* 1987, 102 835-855.

Drazen, A. and E. Helpman,, "Stabilization with Exchange Rate Management Under Uncertainty," in E. Helpman, A. Razin and E. Sadka, Eds., *Economic Effects of the Government Budget,* The MIT Press, Cambridge, MA, p. 310-327 1988.

Helpman, Elhanan, and Assaf Razin, "Exchange Rate Management: Intertemporal Tradeoffs 77," *American Economic Review,* 1987, 107-123.

Kiguel, Miguel A. and Nissan Liviatan, "The Business Cycle Associated with Exchange-Rate Based Stabilizations," *The World Bank Economic Review,* 1992, 6, pp. 279-305.

Kimbrough, Kent, "The Optimal Quantity of Money Rule in the Theory of Public Finance," *Journal of Monetary Economics,* 1986, 18, 277:284.

King, R.G., C.L. Plosser and S.T. Rebelo, "Production, Growth and Business Cycles I: The Basic Neoclassical Model," *Journal of Monetary Economics 21,* 1988, 191-232.

Lahiri, Amartya, "Exchange-Rate Based Stabilization Under Real Frictions: The Role of Endogenous Labor Supply," mimeo Department of Economics UCLA, 1995.

Mendoza, Enrique G. and Martín Uribe, "The Syndrome of Exchange-Rate Based Stabilizations and the Uncertain Duration of Currency Pegs," International Finance Discussion Paper # 548, Board of Governors of the Federal Reserve System, Washington DC, April 1996.

Obstfeld, Maurice, "The Capital Inflows Problem Revisited: A Stylized Model of Southern Cone Disinflation," *Review of Economic Studies 52,* 1985, 605-625.

Obstfeld, Maurice, "Macroeconomic Policy, Exchange Rate Dynamics, and Optimal Asset Accumulation," *Journal of Political Economy,* 1981, 89, 1142-1161.

Rebelo, Sergio T., "Inflation in Fixed Exchange Rate Regimes: The Recent Portuguese Experience," in Torres and Giavazzi (eds.), *Adjustment and Growth in the European Monetary Union,* Cambridge University Press, 1993.

Rebelo, Sergio T., "What Happens When Countries Peg Their Exchange Rates? (The Real Side of Monetary Reforms)," Mimeo. (University of Rochester, Rochester, NY), 1994.

Rebelo, Sergio T. and Carlos A. Végh, "Real Effects of Exchange Rate-Based Stabilization: An Analysis of Competing Theories," *NBER Macroeconomics Annual,* 1995, Vol. 10.

Reinhart, Carmen M., Vegh, Carlos A. , "Nominal Interest Rates, Consumption Booms, and Lack of Credibility: A Quantitative Examination ," *Journal of Development Economics,* April 1995, 46(2), 357-78.

Roldós, Jorge E., "On Credible Disinflation," Mimeo. (International Monetary Fund, Washington, DC), 1993.

Roldós, Jorge E., "Supply Side Effects of Disinflation Programs," *IMF Staff Papers,* March 1995, 42(1), 158-83.

Uribe, Martín, "Exchange-Rate-Based Inflation Stabilization: The Initial Real Effects of Credible Plans," *Journal of Monetary Economics,* June 1997a, 39(2), 197-221.

Uribe, Martín, "On the Analytics of Credible Exchange-Rate-Based Disinflation," mimeo, Board of Governors of the Federal Reserve System, Washington, DC., 1997b.

Végh, Carlos A., "Stopping High Inflation: An Analytical Overview," *IMF Staff Papers,* September 1992, 39(3), pp. 626-95.