C.E.M.A.
Av. Córdoba 637 - Piso 1°
1054 Capital Federal

Tel.: 314-2269
Fax: 314-1654

CURRENCY SUBSTITUTION, CAPITAL FLIGHT AND REAL EXCHANGE RATES

Jorge Streb
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Currency substitution, capital flight and real exchange rates[1]

1. Introduction

A recurrent feature of economies that alternate between periods of high and low inflation is that they also alternate between periods of high and low real exchange rates, as the experience of Argentina shows.[2]

Figure 1. Real exchange rate and inflation, Argentina 1965-1994

Taking the 1975 episode as a starting point, Calvo and Rodríguez (1977) explain the cycles of real exchange rate depreciation and appreciation that accompany inflationary cycles as a monetary phenomenon. What is at work is currency substitution. Higher inflation induces a shift in asset portfolios from domestic currency to foreign currency. Under flexible exchange rates the supplies of currency are fixed in the short run, so the outward shift in the demand for foreign currency leads the real exchange rate to rise. On the other hand, lower inflation shifts the demand for foreign currency inward,

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[2]Inflation is the log difference of the CPI, taking December of successive years. The real exchange rate, as a measure of the relative price of tradables to nontradables, is proxied by the import component of the WPI, divided by the CPI.

leading the real exchange rate to fall. In either case, the supply of foreign currency adjusts over time, so real exchange rates gradually return to their long run equilibrium level.

The only problem with this explanation is that inflationary cycles in developing countries are typically linked to a regime switch. While central banks abandon exchange rate pegs when they run out of reserves, amid the balance of payments crises described by Krugman (1979), they typically return to fixed exchange rates, or to crawling pegs as the "tablita", when stabilization plans are launched. All major stabilization plans in the last 30 years in Argentina were exchange rate-based stabilizations.

Figure 2. Rate of devaluation and stabilization plans, Argentina 1965-1994

When the Calvo-Rodríguez model is considered under fixed exchange rates, currency substitution no longer leads to transitory changes in the real exchange rate. As long as the monetary authority is willing to supply domestic currency when inflation goes down, the transition period can be avoided and the economy can immediately jump to the new equilibrium.

How can we explain the fact that real exchange rates nevertheless appreciate with exchange rate-based stabilization plans? Among monetary explanations of this stylized fact, Rodríguez (1982) allows for inflationary inertia, that leads to a fall in real interest rates and a demand boom, while Calvo (1986) introduces credibility problems in a setting of rational expectations, where a temporary reduction of inflation leads to a demand boom through the substitution of current consumption for future consumption.

In this paper, I show how the introduction of inside money suffices to explain real exchange rate appreciation and current account deficits under fixed exchange rates, despite full price flexibility, perfect foresight and no credibility problems.

I formalize an insight in Rodríguez (1993) on the negative liquidity effect of capital flight, linking this effect to the process of currency substitution. When the exchange rate is stabilized, currency substitution leads to capital inflows. Capital inflows increase the amount of financial assets, through the money multiplier process of the domestic financial system that creates inside money. If higher liquidity causes an excess supply in asset markets, a demand boom ensues, leading to a current account deficit and to real exchange rate appreciation.

Under floating rates, the Calvo-Rodríguez model pointed to an inverse relationship between monetization and the real exchange rate. Under predetermined exchange rates, the liquidity effects of capital flight also lead to an inverse relationship between monetization and the real exchange rate. Indeed, an indication of this relationship is the strong negative correlation between the real exchange rate e and deviations of $M3^*/P$ from trend, which falls from -.58 to -.62 when e is lagged one quarter.[3]

Figure 3. Real exchange rate and deviations of monetization from trend, Argentina 1.65-4.93

Empirically, capital flows are a significant determinant of real exchange rates. Edwards (1989), who extends the Calvo-Rodríguez framework to incorporate real factors that affect the long run equilibrium level of real exchange rates, in addition to the monetary disturbances that cause transitory deviations, interprets capital flows as a real factor that proxies capital controls. However, according to the mechanism at work in the present paper, capital flows can partly be catalogued as monetary factors that result precisely from the process of currency substitution.

Section Two introduces inside money in the original Calvo-Rodríguez model. Section Three presents these same arguments in the Calvo (1985) model which adopts an explicit utility maximization framework. Section Four concludes.

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[3] I take quarterly data from the 1.65-4.93 period. P is the CPI. $M3^*$ is the sum of M3 (pesos in circulation, plus peso-denominated deposits in checking, savings and time accounts) and dollar-denominated deposits. The deviations x_t of $M3^*/P$ from trend are normalized using a nine quarter moving average, $x_t=9(M3_t^*/P_t)/\Sigma_{i=t-4}^{t+4}(M3_i^*/P_i)-1$. I use a measure of deviations of liquidity from trend, since quarterly nominal GDP figures are not available to compute quarterly monetization coefficients.

The real exchange rate e=import component WPI/CPI. When other measures of e are used, the correlations are lower in absolute value: with e=WPI/CPI, the (contemporaneous and lagged) correlations are -.21 and -.25, while with e=parallel exchange rate*US CPI/Argentine CPI, the correlations are -.39 and -.55.

2. The Calvo-Rodríguez model with inside money

The Calvo-Rodríguez model shows how monetary disturbances cause real exchange rates to diverge from the long run equilibrium level given by purchasing power parity. This model of currency substitution has been widely used in the literature (cf. Edwards, 1989, chapter 3, and the references quoted there). Under flexible exchange rates, the model captures exchange rate overshooting associated to inflationary outbursts, without need of price stickiness as in Dornbusch (1976).[4]

I formally link currency substitution to the phenomenon of capital flight. The stock of domestic money is held in the domestic financial sector, which creates inside money through the multiplier process of fractional reserves. The stock of foreign money is held outside the domestic financial sector, so these holdings do not lead to the creation of secondary money. In this formalization, the stock of assets is interpreted as total liquidity, instead of net financial wealth as in Calvo and Rodríguez (1977).

The interpretation of assets as total liquidity does not affect the model under flexible exchange rates: if domestic reserve requirements are lowered, real quantities are not affected and prices increase in the same proportion as domestic

[4]An increase in the rate of monetary expansion μ leads to a higher steady state inflation, leading to an immediate depreciation of the real exchange rate to assure portfolio balance. Over time, current account surpluses lead the stock of foreign assets F to increase, and the initial real exchange rate is restored. Conversely, this model predicts exchange rate appreciation when μ falls.

money. The introduction of a banking sector, *however, changes the* results under fixed exchange rates, as I now show.

The model describes a small open economy that produces and consumes traded and non-traded goods, and has domestic and foreign assets. With *predetermined exchange rates*, the monetary base is endogenous.

$$e=\frac{EP_t^*}{P_n}=\frac{E}{P_n}, \quad \textit{assuming } P_t^*=1 \tag{1}$$

$$l=\frac{M+EF}{P_n}=m+eF, \quad \text{where } m=\frac{M}{P_n} \tag{2}$$

$$y=q_n+eq_t \tag{3}$$

$$q_t=Q_t(e), \qquad Q_t'(e)>0 \tag{4}$$

$$q_n=Q_n(e), \qquad Q_n'(e)<0 \tag{5}$$

$$c_t=C_t(e,l), \qquad \partial C_t/\partial e<0,\ \partial C_t/\partial l>0 \tag{6}$$

$$c_n=C_n(e,l), \qquad \partial C_n/\partial e>0,\ \partial C_n/\partial l>0 \tag{7}$$

$$\frac{m}{eF}=L\left(\frac{\dot{E}}{E}\right), \qquad \textit{where } L\left(\frac{\dot{E}}{E}\right)>0,\ L'(\dot{E}/E)<0 \tag{8}$$

$$\frac{\dot{E}}{E}=\rho \tag{9}$$

$$M=\frac{B}{r}, \quad \textit{where } 0<r<1, \quad \textit{while } r^*=1 \tag{10}$$

$$CA \equiv (q_t - c_t) \tag{11}$$

$$y - (c_n + ec_t) + s - e\dot{F} + \frac{\dot{E}}{P_n} \tag{12}$$

The real exchange rate is defined in (1) as the ratio of the price of tradables to nontradables. Real liquidity in terms of nontradables is defined in (2), where M stands for domestic money and F for foreign money.

The economy produces traded and non-traded goods, q_t and q_n, which make up per capita income y in (3). Production depends only on the real exchange rate, according to (4) and (5). Consumption of traded and nontraded goods, c_t and c_n, depends on the real exchange rate and on liquidity, as assumed in (6) and (7).

As to asset portfolios, the currency substitution hypothesis is stated in (8), where the expected rate of depreciation is equal to the actual change under perfect foresight. With predetermined exchange rates, devaluation equals the exogenous rate of crawl ρ in (9). The creation of inside money by the domestic financial system is described in (10), where domestic deposits are a multiple of high powered money. Since currency substitution is linked to capital flight from the domestic financial system, the feature that foreign money holdings do not create secondary money is represented by the higher implicit reserve requirements, $r^*=1$.

The current account surplus, (11), is by definition the difference between production and consumption of tradables. By (12), private savings plus government subsidies s can be used to either increase the stock of foreign money or of domestic money in hands of the private sector.[5]

To solve the model, full price flexibility assures that the market for nontradables always clears. Equating (5) and (7), there is a negative relationship between the level of liquidity and the real exchange rate.

$$Q_n(e)=C_n(e,l) \quad \Rightarrow \quad l=v(e),\ v'(e)<0 \tag{13}$$

Tradables need not clear, affecting the stock of foreign money. Substituting (4) and (6) into (11), the behavior of the current account, for private sector transactions, is derived.

$$CA\equiv f(e)=Q_t(e)-C_t(e,v(e)), \qquad f'(e)=Q_t'(e)-\frac{\partial C_t}{\partial e}+\frac{\partial C_t}{\partial l}v'(e)>0 \tag{14}$$

To represent a purely monetary experiment, seigniorage is assumed to go as subsidies s to the private sector, an assumption implicit in the original model.

$$s=\frac{\dot{B}}{P_n} \tag{15}$$

Plugging (15) into (12), and using (13) and (14), the change in private foreign assets is determined by the current account.

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[5]The monetary base can increase by the purchase of reserves R or the extension of domestic credit C.

$$\dot{B}=E\dot{R}+\dot{C}$$

To avoid inconsistencies between exchange rate policy and monetary policy, a problem emphasized by Edwards (1989), domestic credit expansion cannot exceed seigniorage on a permanent basis. Otherwise, the central bank would eventually run out of reserves.

$$\dot{F}=f(e) \tag{16}$$

The steady state value of the real exchange rate e_∞ that solves $f(e_\infty)=0$ does not depend on the rate of crawl. The monetary experiments thus only lead to transitory effects on the real exchange rate.[6]

Total liquidity is invariant across steady states, by (13) and (16). However, its composition depends on the rate of inflation. Since the stock of foreign currency is directly related to the rate of inflation at the steady state, F is reduced if the economy is stabilized. Since ρ goes down in an exchange rate-based stabilization, the stock of reserves jumps discontinuously as capital inflows of foreign currency F are exchanged for high powered money B.

$$\frac{dF}{d\rho}\Big|_{e=e_\infty} = -\frac{v(e_\infty)\ L'(\rho)}{e_\infty(1+L(\rho))^2}>0 \tag{17}$$

Though a switch from foreign to domestic assets does not change net financial assets $a/e=F+rm/e$ on impact, which are given

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[6]This is not true in general. The relation between private foreign assets and the current account, for a given rate of crawl ρ, can be found differentiating (8) and (10), and plugging these, together with (13) and (14), into (12).

$$f(e)=\dot{F}+\frac{rL(\rho)\,(\dot{E}F+E\dot{F})}{E}-\frac{s}{e}$$

When s=0 and seigniorage is used to accumulate reserves or to finance external payments by the government, the steady state real exchange rate depends on the inflation rate:

$$\dot{F}=\frac{f(e)-rL(\rho)\rho F}{1+rL(\rho)}$$

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at a point in time under fixed exchange rates, it affects liquidity. When $r<r^*$, capital inflows increase total liquidity, as Rodríguez (1993) points out.

$$d(1/e)|_{dB=-EdF} = -\frac{1-r}{r}dF \tag{18}$$

Though liquidity is constant across steady states, inside money is initially created by the financial system due to the capital inflows. This leads desired net assets to fall. This liquidity effect fits in nicely with the discussion in Calvo (1985) on stabilizations with predetermined exchange rates, according to which an appreciation occurs if desired steady state net assets are lower than the existing level of net assets.

For a given rate of devaluation, both components of liquidity are held in constant proportions, and along the adjustment path net assets a/e follow the evolution of F. Hence, net assets decrease if and only if e is below the steady state value, implying that the exchange rate must appreciate on impact.

$$\frac{d(a/e)}{dt} = \dot{F} + r\frac{d(m/e)}{dt} = (1+rL(\rho))\dot{F} = (1+rL(\rho))f(e) \tag{19}$$

The model can be represented in (a/e,e) space, to show the adjustment when the rate of devaluation is lowered.

Figure 4. Adjustment to stabilization under predetermined exchange rates.

The saddle path, along which asset markets clear, is derived from (8), (13), and the definition of net assets.

$$\frac{a}{e}=(1+r\frac{m}{eF})F=\frac{1+rL(\rho)}{1+L(\rho)}\frac{v(e)}{e}, \quad \frac{d(a/e)}{de}<0 \tag{20}$$

In summary, an exchange rate-based stabilization initially leads to a real exchange appreciation because of the positive liquidity effect, and a trade deficit is generated.

3. The utility maximization approach to currency substitution

The Calvo-Rodríguez model has a crucial assumption, that steady state liquidity is not affected by monetary experiments. Liviatan (1981), however, points out that steady state liquidity depends on the rate of inflation, and that a reduction in inflation may increase the demand for liquidity. We analyze this issue in the framework of the Calvo (1985) currency substitution model, that adapts the Calvo-Rodríguez model to an explicitly optimizing framework.

Except for the fractional reserve requirements on domestic money, the following setup is identical to Calvo, so I refer to the results in his paper. As to the relations with the model in Section 2, equations (1) through (5) remain unchanged. The consumption and portfolio decisions are derived from the solution of a utility maximization problem, so equations (6) through (8) are dropped. They are replaced by the representative individual's utility function in (21), where the functions V, u, and l are assumed to be concave, with positive first order derivatives; u represents consumption services and l represents liquidity services. The assumptions about differential reserve requirements on domestic and foreign money, equation (10), is incorporated in wealth restriction (22). Equation (12) is replaced by flow budget constraint (23), which is equivalent.

$$\int_0^\infty e^{-\delta t}\, V(u(c_n, c_t), l(m, eF))\, dt, \quad \delta>0 \tag{21}$$

$$a=rm+r^{*}eF, \quad \text{where } 0<r<1\ ,\ r^{*}=1 \tag{22}$$

$$\dot{a}=y+s-\frac{\dot{P}_n}{P_n}rm+\left(\frac{\dot{E}}{E}-\frac{\dot{P}_n}{P_n}\right)eF-(c_n+ec_t) \tag{23}$$

The optimization problem faced by the representative individual is that of maximizing (21) by choosing the paths of c_n, c_t, m, and F subject to the initial value of a, and the future expected paths of inflation (measured in terms of nontradables), devaluation, and subsidies s; the expected values equal actual values because of the assumption of perfect foresight. Plugging (22) and (23) into (21) to eliminate c_n and m, this problem can be solved with respect to c_t, F and a. Only the time derivative of a appears in the objective function, so the Euler conditions are

$$\frac{u_t}{u_n}=e \tag{24}$$

$$V_l\left(\frac{l_m}{r}-l_{eF}\right)=V_u u_n \frac{\dot{E}}{E} \tag{25}$$

$$\frac{1}{V_u u_n}\frac{d(V_u u_n)}{dt} = \frac{1}{r}\frac{V_l l_m}{V_u u_n} - (\delta + \frac{\dot{P}_n}{P_n}) \tag{26}$$

As to the interpretation of the first order conditions, they are discussed in Liviatan (1981): by (24), the marginal rate of substitution in consumption is equalized to the market price e; by (25), the required liquidity premium on m is increasing in the difference between the real rates of return of both assets; (26) is an usual condition in optimal growth models that relates the change over time in consumption to the return on assets.

Market equilibrium for nontradable goods requires, as in (13), that

$$q_n^* = c_n^* \tag{27}$$

Equations (24) and (27) imply there is an inverse functional relationship between c_t and e, if both goods are assumed to be Edgeworth-complementary in utility (cf. Appendix).

$$\frac{u_t(Q_n(e), c_t)}{u_n(Q_n(e), c_t)} = e \quad \Rightarrow \quad c_t = C_t(e), \; C_t'(e) < 0 \tag{28}$$

An equation for the current account similar to (14) holds for this model, using the previous result.

$$CA = f(e) = Q_t(e) - C_t(e), \quad f'(e) = Q_t'(e) - C_t'(e) > 0 \tag{29}$$

As in Section 2, a constant rate of devaluation in analyzed in a regime of predetermined exchange rates. To abstract from the distributive effects of inflation, Calvo assumes that subsidies equal the inflation tax. I assume instead, in line with the procedure in Section 2, that subsidies equal seigniorage, equation (15).[7]

Differentiating (22), equating it to (23), and plugging in (15), (27) and (29), the evolution of foreign money follows the same process as equation (16).

$$\dot{F}=f(e) \tag{30}$$

At the steady state F is constant, so (30) implies that consumption and production of tradable goods are equal. The set of steady state real exchange rates is thus invariant to changes in monetary variables, as in the previous model.[8]

$$\frac{u_t(Q_n(e),Q_t(e))}{u_n(Q_n(e),Q_t(e))}=e \tag{31}$$

Calvo (1985) analyzes in detail the particular case of linear homogeneous utility functions. The only predetermined variable in the system is assets in term of foreign exchange, $a/e=F+rm/e$, since the central bank stands ready to exchange domestic and foreign money at the going nominal exchange rate. Calvo demonstrates that exchange rates will appreciate on impact with a stabilization plan if the new steady state net assets

[7]Though both assumptions are equivalent at the steady state, in the transition period the former hypothesis leads either to a budget deficit or to a surplus: real money balances change during the transition phase. At the steady state, on the other hand, real money balances are constant, so the rates of inflation and monetary expansion equal each other, and the rate of devaluation ρ.

[8]The key is assumption (15). If seigniorage is disposed of otherwise, steady state real exchange rates depend on monetary variables, as footnote 5 shows.

fall. The discussion here follows his steps, with slight differences because of the change in the assumption on the disposal of seigniorage.

Linear homogeneity implies that both monies are Edgeworth complementary in utility, as in Liviatan (1981), and that both goods are Edgeworth-complementary in utility, as in the consumption of tradables above.[9] The results can be characterized through the elasticities of substitution between consumption and liquidity services, domestic and foreign money, and tradables and non-tradables.

$$\begin{aligned} d\log(u/l)/d\log(V_l/V_u) &= \sigma_{ul} \\ d\log(eF/m)/d\log(l_m/l_{eF}) &= \sigma_{eFm} \\ d\log(c_n/c_t)/d\log(u_t/u_n) &= \sigma_{nt} \end{aligned} \tag{32}$$

There are two steps in our argument, as in Section 2. The first is to show the conditions under which net assets fall in a stabilization. The second is to link the fall in net assets to an appreciation, on impact, of the exchange rate.

The condition for net assets to fall in the steady state is a slight generalization of Lemma 2 in Calvo (1985). Under fractional reserve requirements on domestic money, net steady

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[9]Edgeworth-complementarity can be derived as a consequence of linear homogeneity. If u is linear homogeneous, its partial derivatives are homogeneous of degree zero, so the concavity of u implies that the cross partial derivatives are positive.

$$u_n(\lambda c_n, \lambda c_t) = u_n(c_n, c_t) \quad \Rightarrow \quad \text{for } \lambda = 1,\ u_{nn}c_n + u_{nt}c_t = 0$$

$$\therefore \quad u_{nn} < 0 \quad \Rightarrow \quad u_{nt} > 0$$

state assets fall if and only if the following condition holds (cf. proof in Appendix):

Lemma 1: In the linear homogeneous case,

$$\frac{da_\infty}{d\rho}>0 \quad \Leftrightarrow \quad \sigma_{ul}<\sigma_{eFm}\frac{\rho_0}{\rho_0+\delta}\,\frac{e_0F_0}{rm_0+e_0F_0}$$

The elasticity of substitution between consumption and liquidity services can in principle be expected to be smaller than the elasticity of substitution between assets, because goods do not provide liquidity and liquidity does not allow to consume, so it is not easy to substitute liquidity with consumption. This is an empirical issue, on which Bufman and Leiderman (1992), for instance, report that this is the case for Israel. This is not enough, however, because the initial rate of inflation and the stock of assets outside the domestic financial system must be large enough to assure that net assets will fall with a stabilization.

A sufficient condition to assure that exchange rate appreciation is equivalent to a fall in steady state net assets is given by (cf. proof in Appendix):

Lemma 2: In the linear homogeneous case,

$$if\ \left(1+\frac{c_n}{ec_t}\right)\left(1-\frac{e(dQ_n(e)/de)}{Q_n(e)}\right)+\sigma_{nt}>\sigma_{ul}, \quad then \quad \frac{de_0}{d\rho}>0 \Leftrightarrow \frac{da_\infty}{d\rho}>0$$

It suffices for σ_{ul} to be smaller than 1, a condition that is consistent with the estimates in Bufman and Leiderman (1992).[10]

In view of the previous discussion, the following Proposition holds (which corresponds to Proposition 2 in Calvo):
Proposition 1: in the linear homogeneous case, starting from a steady state equilibrium that is disturbed by the announcement of a once and for all decrease in the rate of devaluation ρ, an appreciation of the short run real exchange rate will occur if

$$(1+\frac{c_n}{ec_t})(1-\eta_n)+\sigma_{nt}>\sigma_{ul} \quad \wedge \quad \frac{\rho_0}{\rho_0+\delta}\frac{e_0F_0}{rm_0+e_0F_0}\sigma_{eFm}>\sigma_{ul}$$

The results in Section Two about the appreciation of exchange rates with exchange rate-based stabilizations can carry over to this model, if both conditions are met.[11]

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[10]The elasticity of supply of nontradables with respect to the real exchange rate is negative, and $1+c_n/(ec_t)$ is larger than one, so the first term is larger than 1. Additionally, $\sigma_{nt}>\sigma_{ul}$ seems natural, though this is an empirical issue analogous to $\sigma_{eFm}>\sigma_{ul}$ discussed before.
Lemma 2 can be related to Sjaastad and Manzur (1996), who verify that capital inflows create more real exchange rate appreciation in countries that are relatively closed to international trade due to higher levels of protection. Their argument is that restrictive trade policies reduce the scope for substitution, in both demand and production, between traded and nontraded goods, which would reduce the (absolute) value of σ_{nt} and of the elasticity of supply of nontradables.

[11]The liquidity effect does not affect Proposition 1 in Calvo (1985) that refers to the case of flexible exchange rates. However, if reserve requirements on deposits are reduced because the domestic financial system becomes more efficient, and the Central Bank can reduce the stock of foreign reserves it has on hand and distribute the proceeds to the private sector, a demand boom would also ensue under floating rates.

Engel (1989) points out that the transitional dynamics in this model are due to the fact that the holdings of foreign exchange can only be changed through current account imbalances. In contrast, the introduction of a pure foreign bond and perfect capital mobility would imply that in response to a stabilization the economy would immediately jump to the new steady state, with a permanent real exchange appreciation due to the positive wealth effect. However, Calvo and Végh (1996) stress that as long as the entire stock of net foreign assets provides liquidity services, the original results on the trasitional dynamics go through.

The main message of this Section is that it implies a change in the interpretation of the Calvo (1985) model. Even if stabilizations lead to an increase in total liquidity demand, as Liviatan asserts, the creation of inside money by the banking system can make the stock of net assets fall, leading the real exchange rate to appreciate.

4. Conclusions

This paper formally links currency substitution to the phenomenon of capital flight. Currency substitution is linked to what can be named the "Rodríguez liquidity effect", so the decision to leave assets in pesos implies a decision to leave the domestic financial system, which leads to the destruction of inside money. The influence of inside money on exchange rate appreciation is analyzed both in the Calvo-Rodríguez model and within an optimizing framework by Calvo. Under fixed exchange rates, capital inflows have positive liquidity effects due to the fractional reserve requirements of the domestic financial system. This can lead to a demand boom that causes a current account deficit and a real exchange rate appreciation.

This paper treats currency substitution as the reason for capital flight, but the basic mechanism is more general and has to do with the effects of inflation on capital flight. As a matter of fact, in Argentina after 1991, or in Bolivia after 1985, the remonetization of the economy took in part the form of dollar deposits. However, as long as a high rates of inflation lead people to flee the domestic financial system, and a low rate of inflation lead people to return, the mechanisms of inside money creation described above will be operative. Indeed, Guidotti and Rodríguez (1992) point out that, under high inflation, many countries transform dollar deposits into pesos. Risks of this type can help explain why people flee from the domestic financial system when inflation rises.

The Rodríguez liquidity effect can complement non-monetary mechanisms that lead to exchange rate appreciation in credible stabilization plans, as Uribe-Echevarría (1993) or Roldós (1995), though the implications are different because of the transitory nature of the appreciation process described here. The stabilizations based on fixed exchange rates described in this paper imply that, after an initial boom, a process of deflation must follow to restore long-run equilibrium. If there is sluggish downward price adjustment, unlike this paper, a rise in unemployment can result, a feature displayed in Germany after the November 1923 stabilization and in Argentina after the March 1991 Convertibility plan. This relates to the discussion in Calvo and Végh (1994) on the problem of recession now versus recession later, when money-based stabilizations are contrasted to exchange rate-based stabilizations.

Appendix

- *Result (28) in Section Three (inverse relation between c_t and e).*

Totally differentiating (28), and solving for the implicit function $C_t(e)$, a sufficient condition to derive an inverse relationship is for the demand of both goods to be Edgeworth-complementary in utility (i.e., for the cross partial derivatives to be positive).

$$C_t'(e) = -\frac{u_n-(u_{nt}-eu_{nn})\,Q_n'(e)}{eu_{nt}-u_{tt}}<0 \tag{36}$$

In the linear homogeneous case, this expression can be simplified, using first order conditions and fact that consumption and production of nontradables are equal by market clearing.[12]

$$C_t'(e) = \left(-\sigma_{nt}+\frac{eQ_n'(e)}{Q_n(e)}\right)\frac{C_t(e)}{e}<0 \tag{37}$$

This expression equates, in absolute value, the elasticity of demand of tradables to the sum of the elasticity of substitution between tradables and nontradables and the elasticity of supply of nontradables.

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[12] In the linear homogeneous case, the elasticity of substitution between the consumption of tradables and nontradables is given by

$$\sigma_{nt}=\frac{u_n u_t}{u_{nt}\,(c_t u_t+c_n u_n)}$$

Note that $u=c_t u_t+c_n u_n$. By fact in footnote 9, the second order derivatives can be interchanged.

- *Lemma 1 in Section Three (necessary and sufficient conditions, in linear homogeneous case, for steady state assets to fall with a reduction in the rate of devaluation).*

At the steady state, from (25) and (26),

$$\begin{aligned} \frac{l_m(m, eF)}{r} &= \left(1+\frac{\rho_0}{\delta}\right) l_{eF}(m, eF) \\ \frac{V_l(u(c_n, c_t), l(m, eF))\, l_{eF}(m, eF)}{V_u(u(c_n, c_t), l(m, eF))} &= \delta u_n(c_n, c_t) \end{aligned} \tag{38}$$

Across steady states, e_∞ and the consumption of tradables and nontradables are invariant (see 31). The system can be totally differentiated with respect to steady state assets, which are the only variables that change with the steady state rate of devaluation.

$$\begin{aligned} &\left(l_{mm}-\left(1+\frac{\rho_0}{\delta}\right) r l_{eFm}\right)\frac{dm}{d\rho}+e\left(l_{meF}-\left(1+\frac{\rho_0}{\delta}\right) r l_{eFeF}\right)\frac{dF}{d\rho}=\frac{r}{\delta} l_{eF} \\ &\left((V_{ll} l_{eF}-\delta u_n V_{ul}) l_m+V_l l_{eFm}\right)\frac{dm}{d\rho}+e\left((V_{ll} l_{eF}-\delta u_n V_{ul}) l_{eF}+V_l l_{eFeF}\right)\frac{dF}{d\rho}=0 \end{aligned} \tag{39}$$

This system can be solved for the changes in domestic and foreign money. The change in total assets depends on numerator, Num, and denominator, Den.

$$\frac{da}{d\rho}=r\frac{dm}{d\rho}+e\frac{dF}{d\rho}=\frac{Num}{Den} \tag{40}$$

The numerator can be simplified using the properties of linear homogeneous functions and first order conditions in (38).[13]

$$Num = -((\delta u_h V_{ul} - V_{ll} l_{eF})(l_m - r l_{eF}) - V_l (l_{eFm} - r l_{eFeF}))\frac{r l_{eF}}{\delta}$$
$$= ((\frac{V_l}{V_u} + \frac{u}{l}) V_{ul} l_{eF} \frac{r\rho_0 l_{eF}}{\delta} - V_l l_{eFm}(1 + \frac{rm}{eF}))\frac{r l_{eF}}{\delta} \tag{41}$$
$$= (\frac{1}{\sigma_{ul}} - \frac{1}{\sigma_{eFm}} \frac{\delta l_m a}{r\rho_0 l_{eF} eF})\frac{r^2 l_{eF}^3 V_l \rho_0}{\delta^2 l}$$

Likewise, the denominator simplifies greatly,

$$Den = V_l (l_{eFeF} l_{mm} - l_{eFm}^2) + \frac{\delta u_h V_{ul} - V_{ll} l_{eF}}{l_{eF}}(2 l_{eFm} l_m l_{eF} - l_{eF}^2 l_{mm} - l_m^2 l_{eFeF})$$
$$= \frac{V_l l_{eF} l_m}{\sigma_{ul}\sigma_{meF} meF}, \tag{42}$$

due to the following facts:

$$l_{eFeF} l_{mm} - l_{eFm}^2 = \frac{(-m) l_{eFm}}{eF}\frac{(-eF) l_{eFm}}{m} - l_{eFm}^2 = 0;$$
$$\delta u_h V_{ul} - V_{ll} l_{eF} = \frac{V_l l_{eF}}{V_u} V_{ul} - V_{ll} l_{eF} = \frac{V_l l + V_u u}{V_u l} V_{ul} l_{eF} = \frac{V_l l_{eF}}{\sigma_{ul} l};$$
$$2 l_{eFm} l_m l_{eF} - l_{eF}^2 l_{mm} - l_m^2 l_{eFeF} = l_{eFm}(2 l_m l_{eF} + \frac{l_{eF}^2 eF}{m} + \frac{l_m^2 m}{eF}) \tag{43}$$
$$= l_{eFm}\frac{(l_{eF} eF + l_m m)^2}{meF} = \frac{l_m l_{eF}}{\sigma_{meF}}\frac{l_{eF} eF + l_m m}{meF}$$

Thus, the change in net assets is given by

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[13]In the linear homogeneous case, the relevant elasticities of substitution are given by

$$\sigma_{ul} = \frac{V_l V_u}{V_{ul}(l V_l + u V_u)}, \qquad \sigma_{eFm} = \frac{l_m l_{eF}}{l_{eFm}(m l_m + eF l_{eF})}$$

As in the previous footnote, the expressions can be further simplified.

$$\frac{da}{d\rho} = (\sigma_{meF}\frac{\rho_0}{\delta+\rho_0}\frac{eF}{a} - \sigma_{ul})\frac{a\,rm\,l_{eF}}{\delta l} \tag{44}$$

It is straightforward to verify that this result checks with the derivation in the Appendix of Calvo (1985), when r=1.

- *Lemma 2 in Section Three (sufficient condition, in linear homogeneous case, for exchange rate appreciation to be equivalent to a fall in steady state assets).*

Since exchange rates are predetermined and only the rate of crawl changes in the monetary experiments, net assets a/e are a predetermined variable that changes in a continuous fashion, without jumps. Therefore, if desired steady state assets fall below the initially given equilibrium level $(a/e)_0$ when there is a reduction in the rate of devaluation, d(a/e)/dt must be negative.

The evolution of total assets depends on the evolution of foreign and domestic assets, which differs from expression (26) in Calvo (1985) due to the different assumptions on subsidies s.

$$\frac{d(a/e)}{dt} = \dot{F} + r(\frac{\dot{m}}{e} - \frac{m}{e}\frac{\dot{e}}{e}) \tag{45}$$

The behavior of money balances in terms of the price of non-tradables can be found differentiating Euler condition (25). When the utility functions V, u and l are linear homogeneous, this yields[14]

[14]In the process of this derivation, the properties that $l(m,eF)=eF\ l(m/eF,1)$, $l_i(m,eF)=l_i(m/eF,1)$ and $l_{mi}(m,eF)=l_{mi}(m/eF,1)/eF$, for i=m,eF, are used.

$$\dot{m} = \frac{c_1}{c_0}\dot{e} + \frac{c_2}{c_0}(F\dot{e} + e\dot{F}) = \frac{c_1 + c_2 F}{c_0}\dot{e} + \frac{c_2 e}{c_0}\dot{F}, \quad where$$

$$c_0 \equiv (V_{11}(\frac{l_m}{r} - l_{eF}) - \rho u_n V_{ul})\, l_m + V_l(\frac{l_{mm}}{r} - l_{eFm}),$$

$$c_1 \equiv -(V_{lu}(\frac{l_m}{r} - l_{eF}) - \rho u_n V_{uu})\,(u_n Q_n'(e) + u_t C_t'(e)) + \rho V_u (u_{nn} Q_n'(e) + u_{nt} C_t'(e)),$$

$$c_2 \equiv (V_{11}(\frac{l_m}{r} - l_{eF}) - \rho u_n V_{ul})\,(\frac{m l_m}{eF} - \frac{l(m, eF)}{eF}) + \frac{m V_l}{eF}(\frac{l_{mm}}{r} - l_{eFm})$$

(46)

Plugging (46) into (45), and using result (30), the evolution of a/e turns out to depend on the real exchange rate e and its time derivative:

$$\frac{d(a/e)}{dt} = \frac{c_0 + r c_2}{c_0} f(e) + r\frac{c_1 + c_2 F - c_0(m/e)}{c_0}\,\frac{\dot{e}}{e} \tag{47}$$

I now establish a sufficient condition for a fall in steady state assets to be equivalent to an appreciation, on impact, of the real exchange rate. This proof involves two steps, showing first that the coefficient of f(e) is positive and then that the coefficient of $\dot{e}/e$ is negative in expression (47). This suffices, because Calvo (1985) argues that in this system all variables converge to their steady state values in a monotonic fashion, linking both arguments: if exchange rates initially appreciate below their steady state value, e will depreciate over time, making $\dot{e}$ positive.

The properties of linear homogeneity and Euler condition (25) imply that the denominator $c_0 < 0$.

$$c_0 = -\left(\frac{uV_u}{lV_l}+1\right)\rho u_n V_{ul} l_m - V_l l_{eFm}\left(\frac{eF}{rm}+1\right)$$
$$= -\left(\frac{V_u \rho u_n}{\sigma_{ul} V_l} + \frac{l_{eF} a}{\sigma_{meF} rm}\right)\frac{V_l l_m}{l} < 0 \tag{48}$$

Therefore, it remains to prove that the numerator of the coefficient of f(e) is negative and that the numerator of the coefficient of ė/e is positive.

The numerator of the coefficient of f(e), after algebraic manipulations using linear homogeneity and the Euler conditions, is clearly negative.

$$c_0 + rc_2 = \left(V_{ll}\left(\frac{l_m}{r} - l_{eF}\right) - \rho u_n V_{ul}\right)(l_m - r l_{eF}) + \frac{a}{eF} V_l\left(\frac{l_{mm}}{r} - l_{eFm}\right)$$
$$= -\frac{V_l}{leFm}\left(\frac{rmeF}{\sigma_{ul}}\left(\frac{l_m}{r} - l_{eF}\right)^2 + \left(\frac{a^2}{\sigma_{meF}}\left(\frac{l_m l_{eF}}{r}\right)\right)\right) < 0 \tag{49}$$

The numerator of the coefficient of ė/e can be transformed using procedures similar to the above, and replacing $C_t'(e)$ through (37). This finally leads to

$$c_1 + c_2 F - c_0 (m/e) = \frac{\rho V_u u_n}{e\sigma_{ul}}\left(1 - \frac{e(dQ_n(e)/de)}{Q_n(e)} + \frac{1}{1+\frac{c_n}{ec_t}}(\sigma_{nt} - \sigma_{ul})\right) \tag{50}$$

The numerator of the coefficient of ė/e is positive if the term in parenthesis is positive, and the Lemma is proved.

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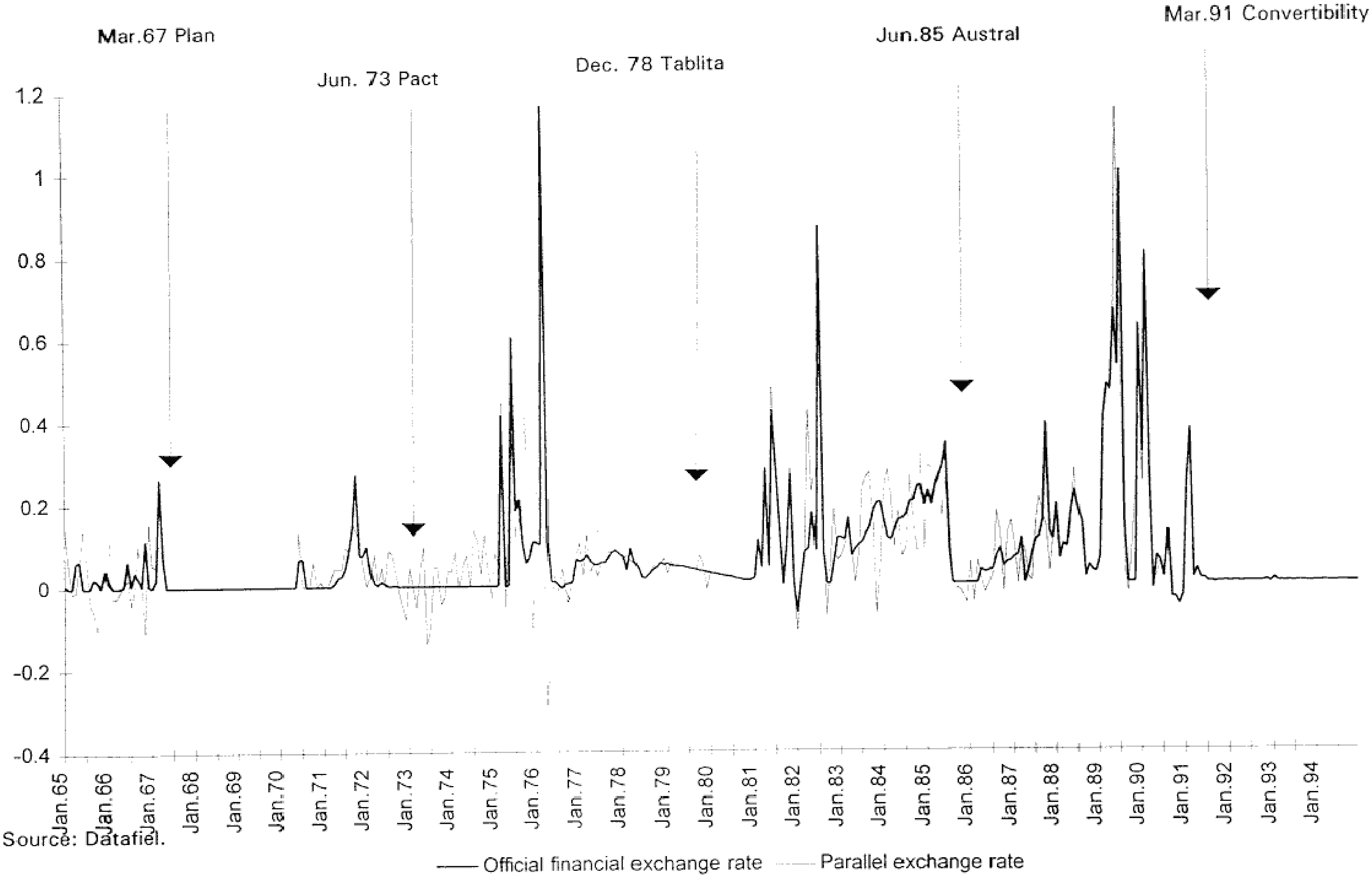
Real exchange rate and inflation, Argentina 1965-1994

Figure 1

Rate of devaluation and stabilization plans, Argentina 1965-1994



Source: Datafiel.

Figure 2

Real exchange rate and deviations of monetization from trend, Argentina 1.65-4.93

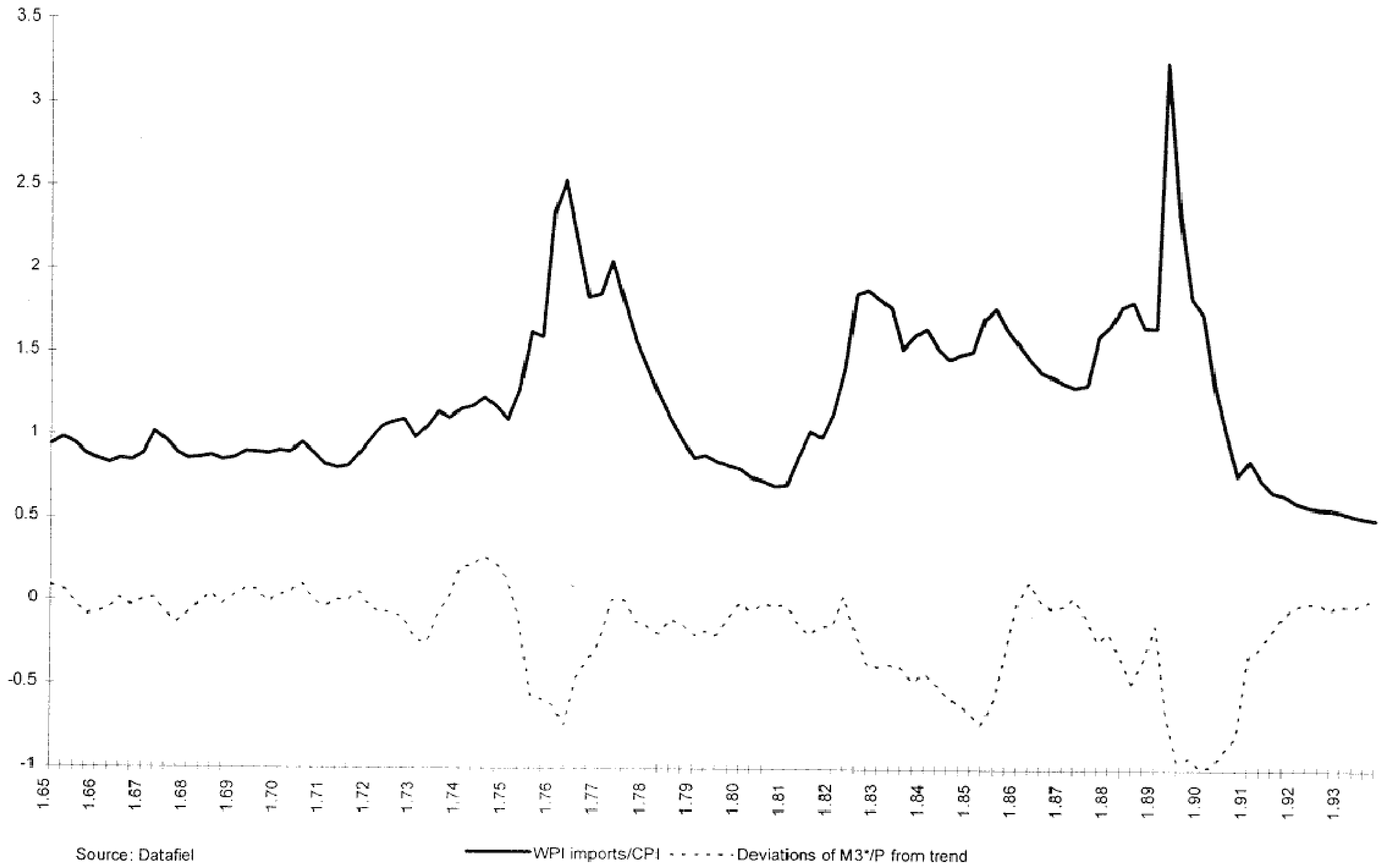


Figure 3

Adjustment to stabilization under predetermined exchange rates

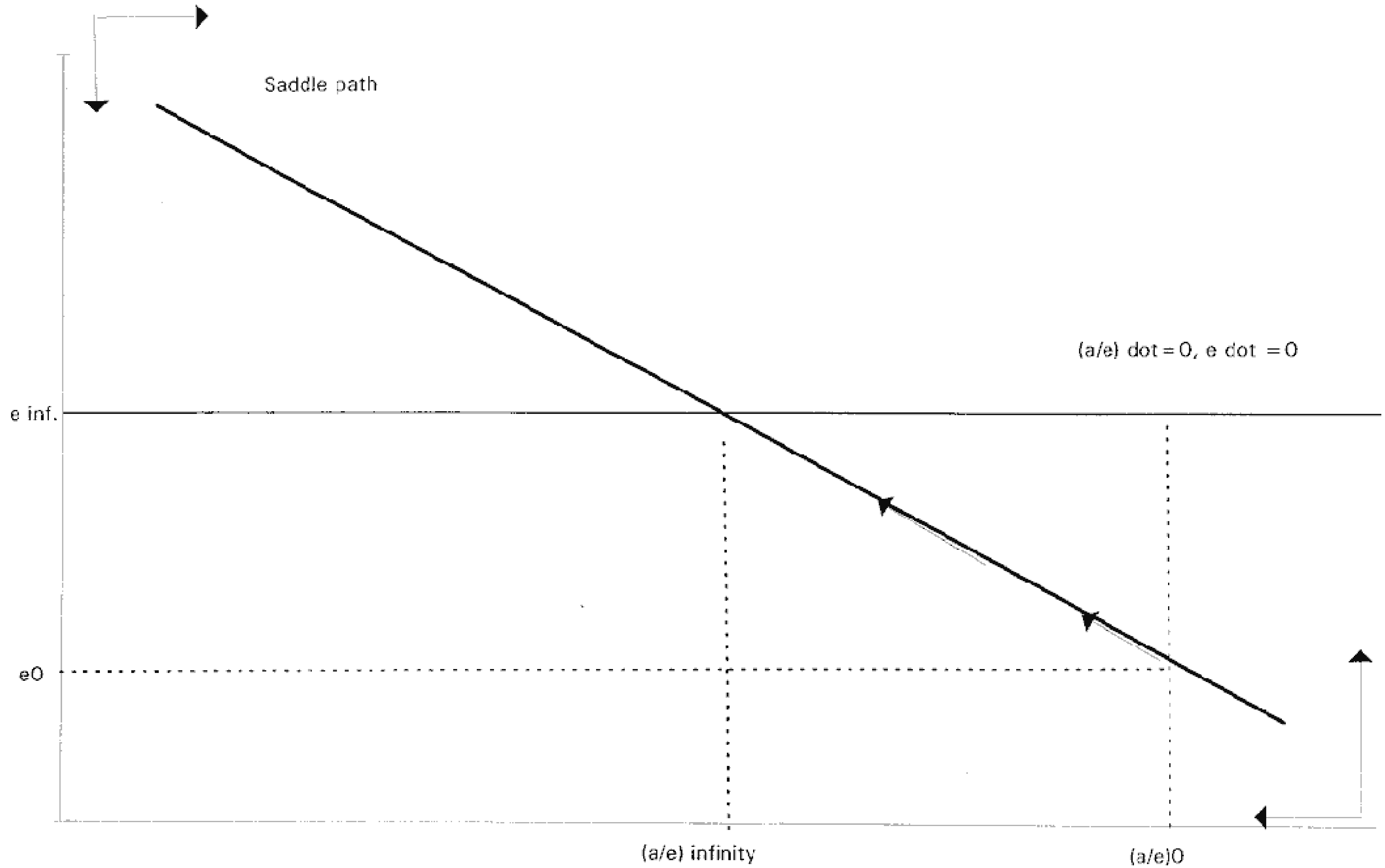


Figure 4