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Exchange-rate-based inflation stabilization: The initial real effects of credible plans

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Abstract

This paper studies the initial effects of exchange-rate-based stabilization programs within a dynamic general equilibrium model of a small open economy in which inflation acts as a tax on intermediate transactions and capital accumulation is subject to convex adjustment costs and gestation lags. The model replicates the typical pattern of slow inflation convergence, sustained real exchange rate appreciation, trade balance deterioration, and expansion in domestic spending followed by a deflationary slowdown, without resorting to sticky prices, imperfect credibility, or adaptive expectations. Calibrated versions of the model are compared with the initial effects of the Argentine Convertibility Plan of April 1991.

Keywords: Inflation stabilization; Fixed exchange rates
JEL classification: F41

1. Introduction

In the past two decades, a large number of chronic-inflation countries has used the nominal exchange rate as an anchor to control high inflation. The main

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component of exchange-rate-based stabilization programs is the announcement of a reduction in the rate of devaluation aimed at curbing inflationary expectations. The stabilization attempts in Argentina (1979–1981, 1985–1986, 1991–), Brazil (1985–1986, 1994–), Chile (1978–1982), Israel (1982–1983 and 1985–), Mexico (1987–1994), and Uruguay (1978–1982) are well documented. These episodes were characterized by similar initial effects: The inflation rate converged slowly to the devaluation rate; the real exchange rate, defined as the price of tradables in terms of nontradables, declined gradually; the trade balance deteriorated; and domestic spending boomed.[1]

Much attention has been devoted to constructing models capable of explaining the initial effects of this type of stabilization plan. The theoretical explanations offered in the late 1970s and early 1980s were greatly influenced by the work of Rodríguez (1982) and Dornbusch (1982). In their models, adaptive expectations and sluggish adjustment of prices in the market for nontradable goods are key in explaining the initial effects: A permanent reduction in the devaluation rate induces a decline in the real interest rate because interest rate parity forces the nominal interest rate to fall instantaneously and inflationary expectations adjust slowly. The decline in the real interest rate induces a boom in aggregate domestic absorption and inflationary pressures in the market for nontradable goods. Persistent inflation, combined with the currency peg, produces real appreciation.

Many of the stabilization attempts mentioned above failed primarily because of fiscal inconsistencies. These failures motivated another branch of the literature known as the temporariness or imperfect credibility hypothesis, in which it is assumed that from the moment the stabilization program is announced the public believes that the program will be abandoned at some point in the future.[2] Pioneered by the work of Calvo (1986) and further developed by Calvo and Végh (1993) and Reinhart and Végh (1993a, b), among others, the temporariness hypothesis is formalized using models in which inflation acts as a tax on consumption – typically via cash-in-advance constraints. A temporary reduction in the inflation rate induces agents to substitute current for future consumption and thus generates an increase in aggregate demand, a deficit in the current account, and an appreciation of the real exchange rate.[3]

This paper presents a theoretical explanation that departs from the Rodríguez–Dornbusch model by assuming flexible prices and rational expectations and that departs from the temporariness hypothesis by requiring that the model replicate the observed empirical regularities even when the program is assumed to be

[1] See Kiguel and Liviatan (1992) and Végh (1992).

[2] This line of research has its roots in the literature on balance-of-payment crisis (Salant and Henderson, 1978; Krugman, 1979; Obstfeld, 1984; Calvo, 1987).

[3] Several authors have explored the alternative of assuming that at the moment the plan is announced the public expects a future fiscal reform rather than the abandonment of the currency peg (Drazen and Helpman, 1987, 1988; Helpman and Razin, 1987; Rebelo, 1994).

fully credible, that is, even when the public is assumed to understand that the announced path for the nominal exchange rate is sustainable over time. Departing from the assumption of temporariness is of particular empirical interest because the initial real effects described above were observed not only in stabilization episodes that lacked the necessary fiscal reforms to be sustainable over time (e.g., the Argentine and Uruguayan 'tablitas' of the late 1970s) but also in stabilization episodes that were accompanied from the outset by important fiscal reforms (e.g., Israel in 1985, Mexico in 1987, and Argentina in 1991).

In the model presented here, inflation acts as a tax on domestic market transactions and generates a wedge between the rate of return on domestic capital and the rate of return on foreign assets. This wedge causes the domestic capital stock to be a decreasing function of the rate of inflation. At the same time, inflation generates negative wealth effects as firms and consumers spend real resources in managing their holdings of domestic currency – the so-called shoe-leather cost. Thus, expectations of lower domestic inflation due to a reduction in the expected devaluation rate generate an expansion in domestic investment and consumption. As the domestic supplies of tradables and nontradables are less than perfectly elastic in the short run, the initial boom in aggregate domestic spending causes a deterioration in the trade balance and an increase in the relative price of nontradables in terms of tradables (i.e., a real appreciation of the domestic currency).

The model captures the stylized facts associated with the initial phase of exchange-rate-based stabilization plans. Among these stylized facts, the slow convergence of the inflation rate of nontradables to the inflation rate of tradables has been given particular attention. In the absence of sticky prices, both the Rodríguez–Dornbusch model and the temporariness hypothesis predict instantaneous inflation convergence. By contrast, the model developed in this paper produces slow convergence even with fully flexible prices. In obtaining this result, convex adjustment costs coupled with gestation lags in the accumulation of physical capital are emphasized and play an important role.

To assess the model's quantitative performance, it is calibrated to the Argentine economy and the simulated response to a permanent reduction in the devaluation rate is compared with the initial effects of the Argentine Convertibility Plan of April 1991. The model explains a sizable fraction of the initial real effects of the Convertibility Plan. The use of information on the size of intermediate transactions to calibrate the inflation distortion and the shoe-leather cost is key in obtaining real effects comparable in magnitude to those observed in the data and represents a departure from the traditional approach of assuming that money is used only for final transactions.

Other authors have constructed models that capture some of the stylized facts of exchange-rate-based stabilization plans under full credibility. Obstfeld (1985) and Roldós (1993) use standard continuous-time monetary models to show that stabilization plans that gradually reduce the devaluation rate may display transitional dynamics in which consumption and the trade deficit increase over time and the real exchange rate appreciates gradually. This approach, however, has two important shortcomings. First, the results crucially depend on the assumption of a gradual reduction in the devaluation rate. As a consequence, this approach cannot explain the initial dynamics of programs based on a once-and-for-all reduction in the devaluation rate (like the Argentine Convertibility Plan). Second, the Obstfeld-Roldós gradual disinflation model predicts a contraction in aggregate demand and a real exchange rate depreciation at the beginning of the stabilization program, neither of which is observed in the data.

Rebelo (1993) presents a model with a production structure similar to that of the monetary model developed here (except that it does not incorporate gestation lags) to explain the recent Portuguese experience under a fixed exchange rate regime. In his nonmonetary model, the initial expansion in aggregate demand is brought about by assuming that the prestabilization stock of capital is below steady state. In this paper, I explicitly model the effect of inflation on capital accumulation. Therefore, the prestabilization stock of capital is endogenously determined by the prestabilization inflation rate. Furthermore, the presence of shoe-leather costs introduces additional wealth effects not considered in Rebelo (1993).

The paper is organized as follows. Section 2 presents a model of inflation as a tax on transactions and shows the derivation of the two forces driving the initial effects of disinflation: an inflation distortion in the domestic capital market and shoe-leather costs. These two sources of real effects are then embedded in a dynamic general equilibrium model of a small open economy whose formal structure is presented in Appendix A. Section 3 presents the qualitative response of the model to a permanent exchange-rate-based stabilization program and explains in some detail the role of adjustment costs and gestation lags in accounting for slow inflation convergence. Section 4 provides a brief description of the Argentine Convertibility Plan and compares its initial real effects with those predicted by calibrated versions of the model (the calibration of the model is described in Appendix B). Section 5 presents conclusions.

2. Inflation as a tax on intermediate transactions

In this section, I develop a simple Baumolian theory of money demand in which inflation acts as a tax on intermediate and final transactions. This theory has two desirable features: First, it provides expressions for the distortions and the shoe-leather cost of inflation which can be readily calibrated using information about the size of intermediate transactions relative to value added. Second, it can be easily embedded in a standard dynamic general equilibrium model of a small open economy. In the reduced form of such a general equilibrium model, inflation directly affects the demands for capital and labor and the economy-wide resource constraint. It is useful to begin by describing these three components of the reduced form of the model before deriving in detail the Baumolian demand for money.

Let k_t^{T} and H_t^{T} denote capital and labor services used in period t to produce tradable goods, y_t^{T}, and k_t^{N} and H_t^{N} denote capital and labor services used to produce nontradable goods, y_t^{N}. Let w_t denote the real wage, r_t^{T} and r_t^{N} the real rental rates of capital in the tradable and nontradable sectors, respectively, and p_t the price of nontradables, all expressed in terms of tradables. The real exchange rate is defined as the relative price of tradables in terms of nontradables (i.e., p_t^{-1}). Capital is assumed to be sector-specific, and labor is assumed to be homogeneous and perfectly mobile across sectors. Let $0 < d_t < 1$ be a decreasing function of the inflation rate denoting the (reduced form of) the distortion introduced by inflation in factor markets. The firm's objective function is to choose input quantities to maximize profits; that is,

$$\begin{aligned} &\max_{k_t^{\mathrm{T}},H_t^{\mathrm{T}},k_t^{\mathrm{N}},H_t^{\mathrm{N}}} \{d_t(y_t^{\mathrm{T}} + p_t y_t^{\mathrm{N}}) - r_t^{\mathrm{T}}k_t^{\mathrm{T}} - r_t^{\mathrm{N}}k_t^{\mathrm{N}} - w_t(H_t^{\mathrm{T}} + H_t^{\mathrm{N}})\} \\ &\text{s.t.} \quad y_t^{\mathrm{T}} = (k_t^{\mathrm{T}})^{\alpha_{\mathrm{T}}}(H_t^{\mathrm{T}})^{1-\alpha_{\mathrm{T}}}, \\ &\qquad\; y_t^{\mathrm{N}} = (k_t^{\mathrm{N}})^{\alpha_{\mathrm{N}}}(H_t^{\mathrm{N}})^{1-\alpha_{\mathrm{N}}}. \end{aligned} \tag{1}$$

From the familiar first-order conditions associated with this problem, it follows that inflation introduces a wedge between marginal products and factor prices. Let a_t^{T} denote aggregate domestic spending in tradables, b_t net domestic holdings of an internationally traded bond that pays the constant real interest rate r in terms of tradables, and SLC_t the shoe-leather cost of inflation. The reduced form of the intertemporal resource constraint of the economy is then given by

$$b_{t+1} = (1+r)b_t + y_t^{\mathrm{T}} - a_t^{\mathrm{T}} - SLC_t, \tag{2}$$

$$\lim_{j\to\infty} \frac{b_{t+j}}{(1+r)^j} = 0.$$

A decline in expected inflation reduces SLC_t and therefore is equivalent to an increase in the endowment of tradable goods. In what follows, I derive expressions for d_t and SLC_t. For the moment, I will drop time subscripts and the superscripts T and N. Suppose that in each sector, tradable and nontradable, there are n subsectors. In each subsector, value added is produced with capital and labor via a Cobb–Douglas technology which is common across subsectors. In subsector i, $i=2,\dots n$, gross output is produced with a Leontief technology whose arguments are value added and intermediate goods produced in subsector $i-1$. No intermediate inputs are used in the first subsector, that is, in subsector 1 gross output equals value added. Formally, let y_i, k_i, H_i, and m_i denote, respectively, gross output, capital, labor, and intermediate inputs in subsector i; the production structure is then given by

$$y_1 = k_1^{\alpha} H_1^{1-\alpha},$$

$$y_i = \min\{k_i^{\alpha} H_i^{1-\alpha}, m_i\} \quad i = 2, \ldots, n.$$

Let p_i, $i = 1, \ldots, n$, denote the relative price of goods produced in subsector i in terms of final goods (so $p_n = 1$). Assume that due to the inflation tax firms in subsector i pay the effective price $d^s p_{i-1} > p_{i-1}$ per unit of intermediate inputs purchased from firms in subsector $i-1$ and receive the effective price $d^f p_i < p_i$ per unit of goods sold to firms in subsector $i+1$ or to final buyers if $i = n$. The problem of a firm in subsector $i = 1, \ldots, n$ is to choose k_i and H_i so as to maximize profits; that is,

$$\max_{k_i, H_i} (p_i d^f - p_{i-1} d^s) k_i^{\alpha} H_i^{1-\alpha} - r k_i - w H_i, \tag{3}$$

where $p_0 \equiv 0$. It follows from the first-order conditions associated with (3) that, because all subsectors face the same technology and the same factor prices, the capital–labor ratio is the same across subsectors. Moreover, because in equilibrium we have that $y_i = m_i = y_{i-1}$, $i = 2, \ldots, n$, the demand for capital and labor is the same across subsectors. Comparing the first order conditions of (3) with those of (1), it follows that d is given by

$$d = d^f - p_{n-1} d^s.$$

Combining the first-order conditions of (3) for subsectors i and $i+1$ yields the following difference equation determining the relative prices $\{p_i\}_{i=1}^{n}$,

$$d^f p_{i+1} - (d^f + d^s) p_i + d^s p_{i-1} = 0; \quad p_0 = 0; \quad p_n = 1.$$

Next, I derive expressions for d^s and d^f. As is standard in the small open economy literature, I will assume that the foreign-currency price of tradable goods is equal to one and that the law of one price holds. Thus, the home-currency price of tradables is just equal to the nominal exchange rate, defined as the price of the foreign currency in terms of the domestic currency. Let ε denote the devaluation rate, that is, the growth rate of the nominal exchange rate. I will refer to the domestic currency as pesos and to the foreign currency as dollars. The time unit is 1 month.

Each month, firms buy intermediate inputs and sell output in a continuous fashion subject to domestic-cash-in-advance constraints. Firms cannot use the proceeds from the sale of goods to pay for intermediate inputs in the same period. To reduce their exposure to domestic inflation, firms may hold dollars and exchange them for pesos at any point during the month at the proportional transactions cost of q dollars per dollar of monthly transactions. I will refer to this transactions cost as the cost of one trip to the bank. The dollar value of each withdrawal of pesos by a firm that purchases a constant stream of m units of intermediate inputs at the price of p dollars per unit and makes N evenly spaced trips to the bank per month is $p \cdot m \cdot \int_0^{1/(N+1)} e^{j\varepsilon}\, dj$, and the dollar cost of each trip to the bank is $q \cdot p \cdot m$. The total cost of intermediate inputs is then given by[4]

$$\left[Nq + (N+1) \int_0^{1/(N+1)} e^{j\varepsilon}\, dj \right] p \cdot m.$$

Let N^s denote the optimal number of trips to the bank; that is, the natural number that minimizes the above expression with respect to N. It can be shown that N^s exists and is unique. The effective cost of intermediate goods, $d^s \equiv d^s(\varepsilon, q)$, is then given by the expression within brackets in the above equation evaluated at N^s. The function $d^s(\varepsilon, q)$ is greater than or equal to one and increasing in ε and q.

Similarly, the revenue measured in end-of-month dollars obtained by a firm that sells for pesos a constant stream of y units of output at the price of p dollars per unit and makes N evenly spaced trips to the bank to exchange pesos for dollars is given by[5]

$$\left[(N+1) \int_0^{1/(N+1)} e^{[j-1/(N+1)]\varepsilon}\, dj - Nq \right] p \cdot y.$$

Let N^f denote the optimal number of trips to the bank; that is, the natural number that maximizes this expression with respect to N. Then $d^f \equiv d^f(\varepsilon, q)$ is given by the expression within brackets in the above equation evaluated at N^f. The function $d^f(\varepsilon, q)$ is less than or equal to one and decreasing in ε and q. This completes the derivation of the inflation distortion $d_t = d(\varepsilon_t, q, n)$ that appears in Eq. (1).

Next, I derive an expression for the shoe-leather cost of inflation. The shoe-leather cost paid by firms is given by the sum of the cost of all trips to the bank

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[4] I am assuming that at the beginning of each month firms hold the desired amounts of pesos and dollars and therefore do not need to make a trip to the bank at that point. This is why the length of the interval between two consecutive trips to the bank is $1/(1+N)$ rather than $1/N$. This assumption guarantees that when the devaluation rate is zero firms choose to make no trips to the bank. Throughout the derivation of d^s and d^f, I will apply simple sums to compute the value of dollar amounts dated at different points within a certain month. In the numerical examples considered below, the difference between ε and r is so large that the results obtained using simple sums are not significantly different from those obtained following the correct procedure of using r to compute discounted values.

[5] I am assuming that at the end of the month the firm does not make a trip to the bank to exchange its peso holdings for dollars. This is why the length of the interval between two consecutive trips is $1/(1+N)$ rather than just, $1/N$.

during the month; that is,

$$q(y^{\mathrm{T}}+py^{\mathrm{N}})\left[N^{\mathrm{s}}\sum_{i=2}^{n}p_{i-1}+N^{\mathrm{f}}\sum_{i=1}^{n}p_{i}\right].$$

The total shoe-leather cost, SLC, is the sum of the above expression and the shoe-leather cost paid by buyers of final consumption and investment goods. Using an argument similar to the one applied to analyze the cash management problem of the firm, it is straightforward to show that buyers of consumption and investment goods will make N^{s} trips to the bank per month. In equilibrium, aggregate domestic spending in consumption and investment goods, measured in terms of tradables, is given by $a^{\mathrm{T}}+py^{\mathrm{N}}=y^{\mathrm{T}}+py^{\mathrm{N}}-TB-SLC$, where $TB\equiv y^{\mathrm{T}}-a^{\mathrm{T}}-SLC$ denotes the trade balance. Let $tb\equiv TB/(y^{\mathrm{T}}+py^{\mathrm{N}})$ denote the trade balance to output ratio. Then the shoe-leather cost originated in purchases of final consumption and investment goods is given by

$$qN^{\mathrm{s}}[(y^{\mathrm{T}}+py^{\mathrm{N}})(1-tb)-SLC].$$

The total shoe-leather cost of inflation is given by the sum of the above two expressions,

$$\begin{aligned}SLC &= q\cdot\left[N^{\mathrm{s}}\sum_{i=2}^{n}p_{i-1}+N^{\mathrm{f}}\sum_{i=1}^{n}p_{i}+N^{\mathrm{s}}(1-tb)\right]\\ &\quad\cdot(1+qN^{\mathrm{s}})^{-1}(y^{\mathrm{T}}+py^{\mathrm{N}})\\ &\equiv slc(\varepsilon,q,n,tb)(y^{\mathrm{T}}+py^{\mathrm{N}}).\end{aligned}\tag{4}$$

Given values for ε, q, n, and tb, one can obtain numerical values for the distortion $d=d(\varepsilon,q,n)$ and the ratio of the shoe-leather cost to output $slc(\varepsilon,q,n,tb)$. However, of the four parameters needed to compute d and slc, only the devaluation rate ε and the trade balance to output ratio tb are directly observed. In Appendix B, I show how the deep structural parameters q and n can be identified using long-run values for ε, tb, money velocity, and the ratio of total transactions to value added. The estimates obtained using data from Argentina are $q=0.26$ percent of monthly GDP, and $n=6$.

Table 1 shows the distortion introduced by inflation and the shoe-leather cost for different values of the devaluation rate when q and n are set at their calibrated values.[6] The average monthly inflation rate in Argentina in the four years prior to the implementation of the Convertibility Plan was 25%. The table shows that for this inflation rate the predicted inflation tax is about 19% of GDP and the predicted shoe-leather cost is about 10% of GDP. In the simulations performed below, these two numbers determine the magnitude of the initial impulse associated with a permanent reduction in the devaluation rate.

[6] In computing Table 1, q and n are fixed, but tb is endogenously determined by the steady state of the model (see Appendix A).

Table 1
Inflation tax and shoe-leather costs

Devaluation rate (percent per month)	Inflation tax (percent of GDP)	Shoe-leather cost (percent of GDP)
ε	$[d(0,q,n)/d(\varepsilon,q,n) - 1] \times 100$	slc
1	3.0	0
5	7.9	3.5
10	11.7	5.2
15	14.5	6.9
20	16.8	8.6
25	18.7	10.2
30	20.6	11.9
35	22.1	11.8
40	23.6	13.4
45	25.0	13.4
50	26.3	15.0

$q = 0.26\%$ of monthly transactions is the cost of one trip to the bank.
$n = 6$ is the number of subsectors producing intermediate inputs.

To characterize the propagation of this initial impulse, I embed d and SLC into a standard, two-sector, dynamic general equilibrium model of a small open economy. The production side of the model and the economy-wide resource constraint were described above (problem (1) and Equation (2)). In addition, I assume that consumption and investment goods are a composite of tradable and nontradable goods, and that the accumulation of physical capital is subject to convex adjustment costs as well as gestation lags. Appendix A contains the formal description of the model.

3. Credible stabilization plans

In this section, I simulate the response of the model to a credible stabilization plan that permanently reduces the devaluation rate. The simulation is carried out in the following way. First, I compute the steady state corresponding to the (high) prestabilization devaluation rate. This steady state provides a set of initial conditions for the capital stocks k^{T} and k^{N} and for the stock of foreign assets b. I then set the devaluation rate at its (low) poststabilization level and compute the dynamics of the model as it converges from the prestabilization steady state to the poststabilization steady state. Because closed-form solutions to the model are not available, I follow King et al. (1988) and restrict the analysis to a log-linearized version of the equilibrium conditions around the poststabilization steady state. The model is calibrated to the Argentine economy. The details of the calibration are gathered in Appendix B and summarized in Table 4.

Fig. 1 displays the predicted dynamics of key macroeconomic variables in response to a permanent reduction in the devaluation rate from 25% per month to 0%. These pre- and post-stabilization values for the devaluation rate are consistent with the average devaluation rate prevailing in Argentina over the 4 years prior to the implementation of the Convertibility Plan and with the fact that the Plan fixed the exchange rate between the Argentine peso and the US dollar. The predicted response of the model is consistent with the empirical regularities of exchange-rate-based stabilization plans. In particular, the model predicts that in the early phase of the program the real exchange rate appreciates continuously, the trade balance deteriorates for several periods, and consumption, investment, and capital inflows expand.

The booms in consumption and investment are driven by two forces. First, the decline in the shoe-leather cost (SLC_t) induced by the permanent reduction of the devaluation rate generates an effect equivalent to a permanent increase in the endowment of tradables (see Eq. (2)). Second, as inflation expectations fall, the marginal product of capital net of inflation tax increases generating an expansion in the desired capital stock and a positive wealth effect.

3.1. Slow inflation convergence

The predicted gradual appreciation of the real exchange rate shown in Fig. 1 implies that the inflation rate of nontradables converges slowly to the inflation rate of tradables. Unlike the Dornbusch–Rodríguez model and the temporariness hypothesis in which slow inflation convergence is obtained by assuming price stickiness (Dornbusch, 1982; Rodríguez, 1982; Calvo and Végh, 1993), in the flexible-price model developed in this paper the seemingly sluggish adjustment of the domestic price level is driven by adjustment costs and gestation lags in the accumulation of physical capital.[7]

Fig. 2 shows the dynamics of the real exchange rate under 2 months and 24 months of gestation lags. When the number of gestation lags is 2, the real exchange rate jumps down on impact and then increases gradually towards its steady-state value. That is, the inflation rate in nontradables rises above the devaluation rate for only 2 periods, then falls below the devaluation rate and remains below it along the transition. This quick convergence of domestic inflation to the devaluation rate is clearly at odds with the empirical regularities associated with

[7] Adjustment costs have been extensively used in business cycle models of the small open economy to avoid excess investment volatility (Cardia, 1991; Mendoza, 1991; Schmitt-Grohé, 1995). Gestation lags have been emphasized in both closed economy RBC models (Kydland and Prescott, 1982) and open economy RBC models (Backus et al., 1992).

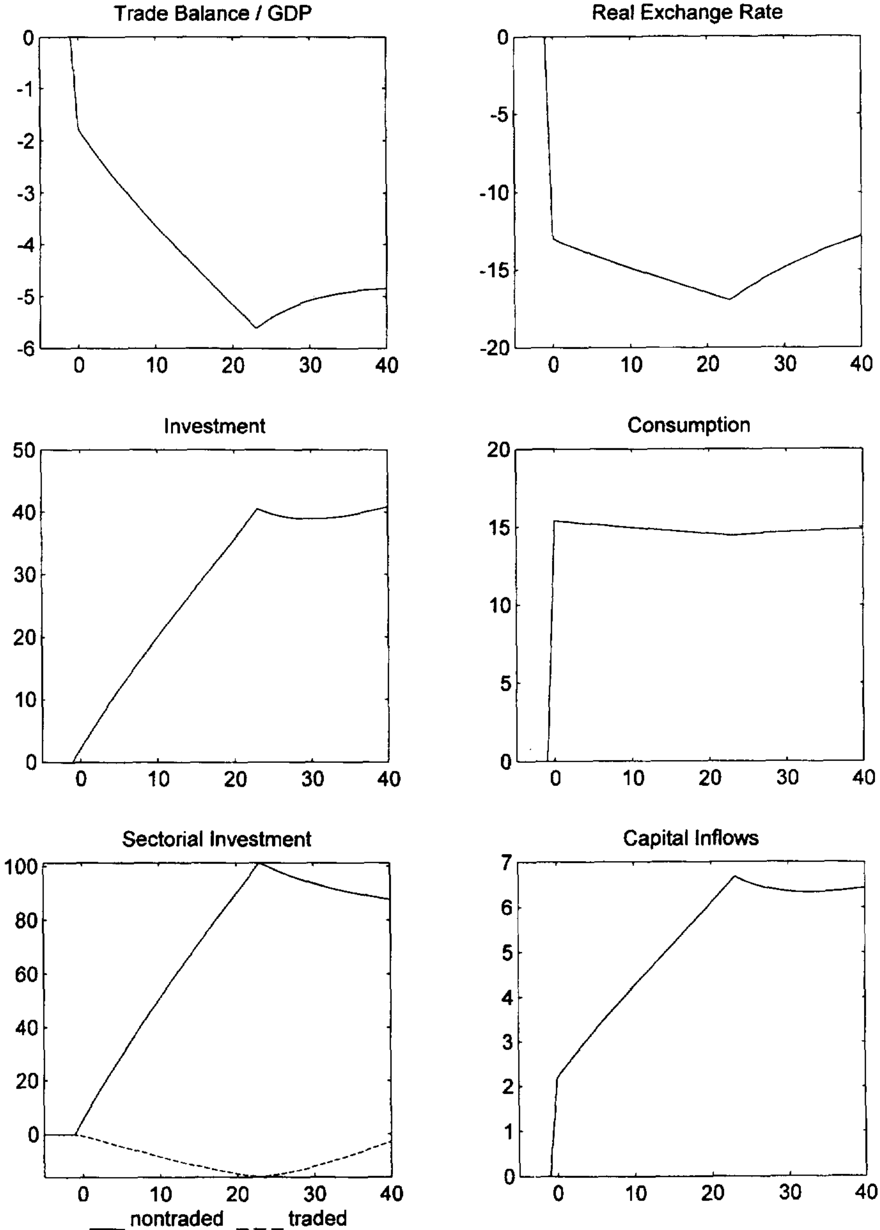

Fig. 1. The initial dynamics of credible plans (percent deviations from the high-inflation steady state).

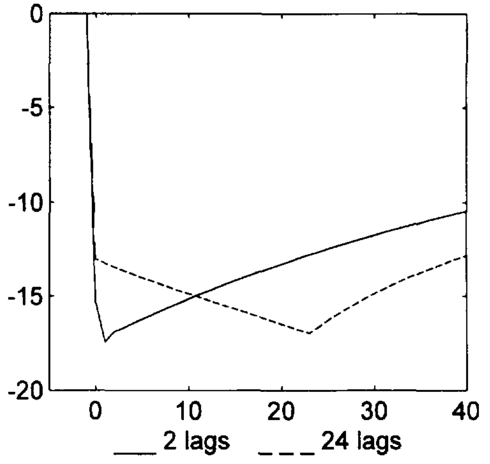

Fig. 2. The real exchange rate: 2 vs 24 periods of gestation lags (percent deviations from the high inflation steady state).

currency pegs. By contrast, in the economy with 24 gestation lags, the inflation rate takes 24 periods to converge to the devaluation rate.

The presence of adjustment costs and gestation lags induces slow inflation convergence – or, equivalently, a progressive increase in the relative price of nontradables in terms of tradables – through two different channels: First, adjustment costs and gestation lags induce a sluggish response in the supply of nontradables, as they introduce frictions in the accumulation of physical capital. Second, adjustment costs and gestation lags cause the initial expansion in aggregate demand to be gradual. The following example illustrates this second channel. Suppose that in response to a permanent reduction in the devaluation rate in period one, firms decide to increase the capital stock by 10 units. Assume also that in order to build one unit of new capital firms must invest 0.2 units of goods for five consecutive periods. Assume also that changes in the stock of capital are subject to convex adjustment costs. The presence of convex adjustment costs induces firms to spread the installation of new units of capital over time. Suppose that the optimal plan consists of installing 4 units of capital in period six, 3 units in period seven, 2 units in period eight, and 1 unit in period nine.

Then firms must invest 0.8 units of goods in period one, 1.2 units in period two, 1.8 units in period three, 2 units in periods four and five, 1.2 units in period six, 0.6 units in period seven, and 0.2 units in period eight (Fig. 3). The time path of investment has an inverted-U shape with a peak in period five – the number of gestation lags. Since the path of consumption is relatively flat, aggregate domestic spending inherits the inverted-U shape from the behavior of investment.

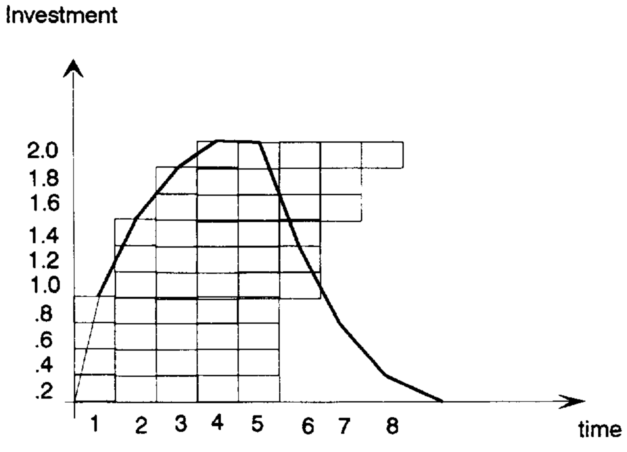

Fig. 3. Gestation lags, adjustment costs, and investment.

4. Quantitative analysis

In this section, I compare the initial effects of the Argentine Convertibility Plan with the quantitative predictions of the calibrated model.

4.1. The Argentine Convertibility Plan

In April 1991, the Argentine government ended a long period of high inflation by launching a stabilization plan that pegged the nominal exchange rate to the US dollar at a one-to-one parity, eliminated all exchange and capital controls, and required that most of the monetary base be backed by international reserves.[8] The currency peg succeeded in quickly reducing inflation. The CPI inflation rate fell from a monthly average of 12% in the year preceding the announcement of the program to 2.2% in the first year after the announcement, 1% in the second year, and 0.4% in the third year (Fig. 4).

What distinguishes the Convertibility Plan from past attempts at stopping inflation in Argentina is an important fiscal reform that accompanied the plan from the outset and included a tax reform, expenditure cuts, a vast privatization program, and reductions in the stock of domestic and foreign public debt. As a result, the fiscal deficit of the federal government, before income from privatizations, fell from an average of 8.4% of GDP in the period 1985–1990 to an average of 1.5% of GDP in the period 1991–1992 (Fig. 5).

[8]The charter of the central bank stipulates that the central bank cannot hold more than 20% of international reserves in Argentine government bonds.

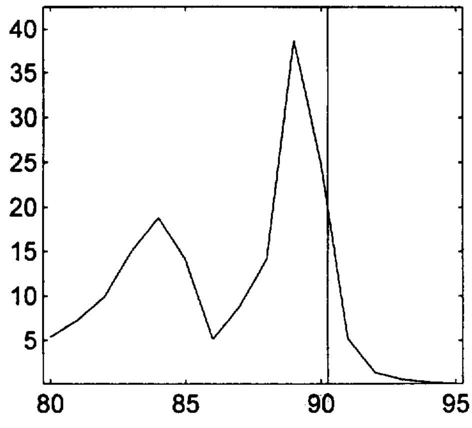

Fig. 4. Argentina: CPI inflation (percent per month).

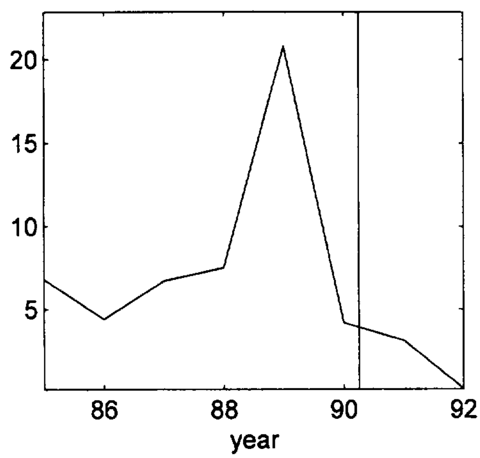

Fig. 5. Argentina: Fiscal deficit of the federal government (before income from privatizations, percent of GDP).

The initial real effects of the program were entirely consistent with the empirical regularities associated with currency pegs. Domestic inflation converged slowly to the US inflation. In 1993, 2 years after the currency peg was enacted, domestic CPI inflation was almost three times as high as US CPI inflation (Fig. 6). As a consequence, the real exchange rate appreciated progressively during the early phase of the program (the CPI-adjusted exchange rate between the Argentine peso and the US dollar appreciated by almost 25% in the first 2 years of the program). At the same time, domestic spending boomed and real activity

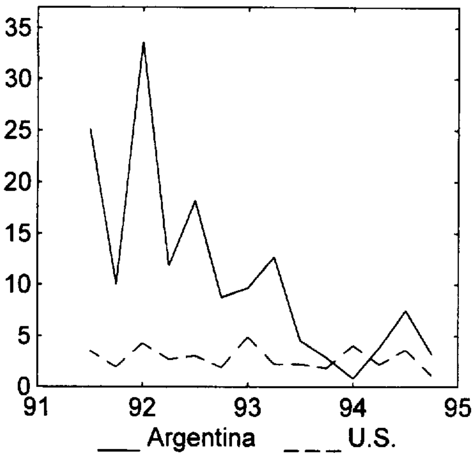

Fig. 6. CPI inflation in Argentina and the United States (percent per annum).

expanded. In the first 2 years of the plan, consumption grew at an annual rate of 11.7%, gross investment at 28.0%, and GDP at 8.7%.[9] The boom in domestic spending translated into large current account imbalances. In the first two years of the plan, imports grew at an annual rate of 31.1% while exports remained constant, resulting in a sharp deterioration of the trade balance from a surplus of 7% of GDP in 1990 to a deficit of 3% of GDP in 1992 (Fig. 7).

4.2. *The model's predictions*

Table 2 provides a quantitative comparison of the predictions of the baseline model with the effects of the Convertibility Plan during its first two years in existence. In computing the predicted initial effects, I set the prestabilization devaluation rate at 25% per month and the poststabilization devaluation rate at zero. As pointed out above, these values are consistent with the average monthly devaluation rate in the four years preceding the announcement of the Convertibility Plan and with the pegging of the Argentine peso to the US dollar in effect since April 1991. The model does relatively well at replicating the magnitude of the real exchange rate appreciation (17% predicted versus 23% actual), the trade balance deterioration (5.8% of GDP predicted versus 7.1% of GDP actual), the

[9]The expansion in GDP was not even across sectors: the agricultural and mining sectors, which generate mostly exportable goods, grew only 1.4% in 1991, while the sector composed by wholesale and retail trade, restaurants, hotels, transportation, communications, storage, financial institutions, insurance, and real estate, which produces mostly nontraded services, grew 10.4% in the same period.

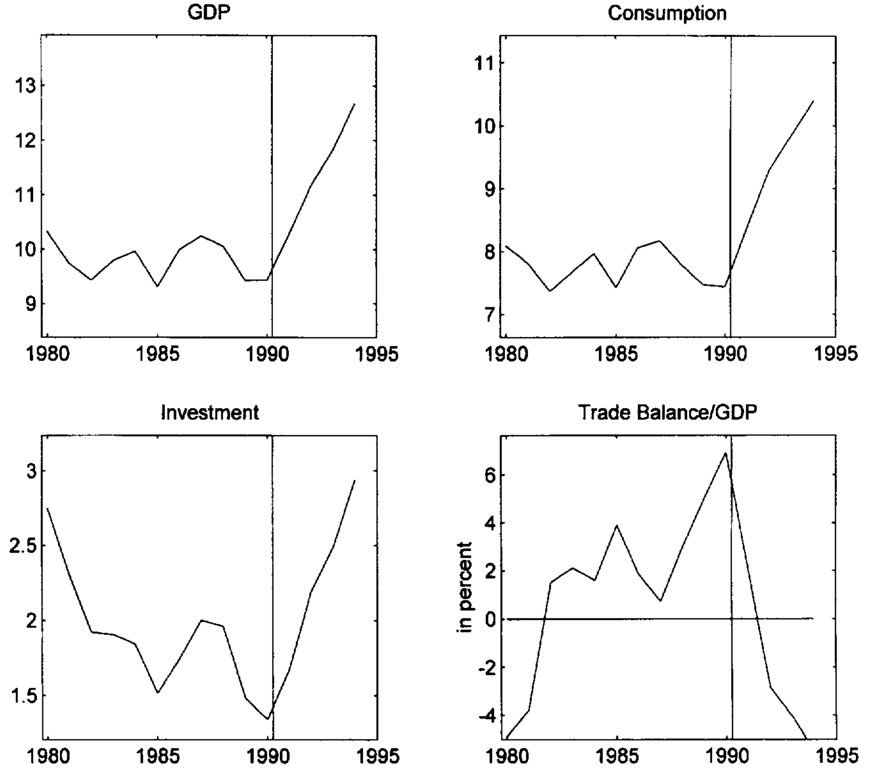

Fig. 7. Argentina: Output and aggregate spending (millions of 1986 pesos).

investment boom (32% predicted versus 29% actual), and the consumption boom (14.7% predicted versus 20.4% actual).[10]

Table 3 displays the sensitivity of the predicted response to changes in several parameters. The quantitative results are quite sensitive to the size of the reduction in the devaluation rate. In particular, the model predicts small real effects associated with the elimination of moderate levels of inflation. This result suggests that the important real effects observed in the aftermath of exchange-rate-based stabilization programs in low-inflation economies such as the recent episodes in Portugal, Italy, Spain, and France, may be hard to explain as resulting exclusively from the elimination of inflation distortions.

[10]If the shoe-leather cost of inflation is not taken into account in computing the trade balance, the predicted deterioration in the trade balance is twice as large as the one actually observed (Uribe, 1995, p. 29).

Table 2
Predicted and actual initial effects
Percent changes between prestabilization values and values 2 years into the currency peg

	Real exchange rate	Trade balance over GDP	Investment	Consumption
Data	−22.8	−7.1	29.1	20.4
Model	−16.0	−5.8	31.8	14.7

The actual prestabilization values of the trade balance, investment, and consumption are defined as the respective averages over the period 1987–1990. The initial value of the real exchange rate is defined as the one corresponding to March 1991, because the average 1987–1990 is dominated by the extreme values observed during the hyperinflations of June–July, and December 1989, and January–March 1990. The real exchange rate is the CPI-adjusted, trade-weighted exchange rate between the Argentine peso and a basket of currencies composed of the US dollar, the German mark, the Japanese yen, the British pound, the Italian lira, and the Brazilian real.

Increasing the cost of one trip to the bank, q, or the number of subsectors producing intermediate inputs, n, has the same effect as increasing the prestabilization devaluation rate. The reason is that given the devaluation rate the demand for domestic currency is increasing in q and n. Finally, varying the cost of adjusting the stock of capital, as measured by the parameter ϕ (see Appendix A), has little effect on the variables of interest. This is because an increase in adjustment costs dampens the initial expansion of investment in the nontraded sector and the initial contraction of investment in the traded sector with no significant net effect.

5. Summary and conclusion

This paper presents a model of a small open economy capable of explaining the stylized facts of exchange-rate-based stabilization programs without resorting to credibility problems, adaptive expectations, or sticky prices. Instead, the main ingredients of the model are an inflation distortion in the domestic capital market, shoe-leather costs, and adjustment costs combined with gestation lags in the accumulation of physical capital.

Inflation is modeled as a tax on intermediate and final transactions rather than as a tax on final transactions only as it is traditionally done. This modeling approach involves more parameters (that have to be identified using long-run data restrictions) than the traditional approach, but has the advantage that it generates significant shoe-leather costs and hence is capable of causing large initial effects in response to permanent reductions in inflation.

Table 3
Sensitivity analysis

The data

	Real Exchange Rate	Trade Balance over GDP	Investment	Consumption
Data	−22.8	−7.1	29.1	20.4

Varying the devaluation rate

ε	RER	TB/GDP	I	C
5	−6.9	−2.5	12.7	5.2
25	−17.0	−5.8	31.8	14.7
40	−21.4	−7.4	42.6	19.0

Varying the proportional transactions cost

q	RER	TB/GDP	I	C
0.13	−13.6	−4.4	24.5	10.9
0.26	−17.0	−5.8	31.8	14.7
0.52	−20.1	−7.5	40.3	19.5

Varying the number of subsectors producing intermediate inputs

n	RER	TB/GDP	I	C
1	−6.1	−1.9	11.6	3.9
6	−17.0	−5.8	31.8	14.7
10	−20.9	−7.6	37.2	23.1

Varying the adjustment cost parameter

ϕ	RER	TB/GDP	I	C
5	−16.7	−5.6	29.7	14.7
25	−17.0	−5.8	31.8	14.7
100	−15.3	−4.3	20.3	14.7

The devaluation rate ε is expressed in percent per month and q in percent of monthly transactions.

The model predicts the typical boom–recession cycle associated with exchange-rate-based stabilization programs: the expansionary phase of the cycle is characterized by a boom in aggregate spending, persistent inflation, real exchange rate appreciation, trade balance deterioration, and capital inflows. In the contractionary phase, these effects are reversed: aggregate spending slows down, the inflation rate falls below the devaluation rate, the real exchange rate depreciates, the trade balance improves, and capital inflows decrease. In this latter phase, the depreciation of the real exchange rate occurs because after some periods of gestation the initial investment boom in the nontraded sector becomes productive and causes an expansion in the supply of nontradables putting downward pressure on the price of home goods. Similarly, the slowdown in capital inflows occurs because the return on domestic investment decreases with the expansion of the capital stock.

Calibrated versions of the model using data restrictions from Argentina predict a real exchange rate appreciation, a trade balance deterioration, and an expansion in consumption and investment of the same order of magnitude as observed after the implementation of the Argentine Convertibility Plan of April 1991.

A high prestabilization inflation rate, as the one observed in Argentina prior to the announcement of the Convertibility Plan, is crucial for the model to generate sizable real effects. In particular, the model may be unable to account for the large real effects observed in the aftermath of recent stabilization episodes in moderate-inflation economies like Spain, France, Italy, and Portugal. Understanding the forces driving the dynamics of these episodes is the task of future research.

Appendix A: Consumption and capital accumulation

Each month $t \geq 0$ households start with a stock of liquid wealth x_t measured in terms of tradables, with $n \cdot k_t^{\mathrm{T}}$ units of capital productive in the traded sector and with $n \cdot k_t^{\mathrm{N}}$ units of capital productive in the nontraded sector, and receive a lump-sum transfer of τ_t units of traded goods from the government. The parameter n, introduced in Section 2, denotes the number of subsectors of which the traded and nontraded sectors are composed. At this point, a financial market opens in which households invest part of their wealth at the constant interest rate r and allocate the rest to buying traded and nontraded goods a_t^{T} and a_t^{N}. Purchases of goods are made in a continuous fashion during the month and are subject to a domestic-cash-in-advance constraint. Each month, households supply inelastically H hours of labor and capital stocks productive in the traded and nontraded sectors. The wage rate is w_t and the rental prices of capital are r_t^{T} for capital productive in the traded sector and r_t^{N} for capital productive in the nontraded sector. The wage rate and rental prices are measured in terms of tradables and are paid at the end of each month. The household's budget constraint is then given by

$$\begin{aligned} x_{t+1} = {} & (1+r)[x_t + \tau_t - d^{\mathrm{s}}(\varepsilon_t, q)(a_t^{\mathrm{T}} + p_t a_t^{\mathrm{N}})] \\ & + w_t H + n(r_t^{\mathrm{T}} k_t^{\mathrm{T}} + r_t^{\mathrm{N}} k_t^{\mathrm{N}}), \end{aligned} \tag{A.1}$$

where $d^s(\varepsilon_t, q)$, derived in Section 2, denotes the price of tradable goods including the inflation tax. Households aggregate tradable and nontradable goods into composite goods which are used for direct consumption, c_t, and for investment, $n \cdot i_t^{\mathrm{T}}$ and $n \cdot i_t^{\mathrm{N}}$,

$$c_t + n(i_t^{\mathrm{T}} + i_t^{\mathrm{N}}) = (a_t^{\mathrm{T}})^{\theta}(a_t^{\mathrm{N}})^{1-\theta}, \tag{A.2}$$

where $0 < \theta < 1$.

Production of capital is subject to convex adjustment costs and gestation lags. Specifically, in order to build s units of capital available in period $t + J$ the household has to invest s/J units of composite goods for J consecutive periods starting in period t. The evolution of the capital stocks is then given by

$$k_{t+J}^{\mathrm{T}} = (1-\delta)k_{t+J-1}^{\mathrm{T}} + s_t^{\mathrm{T}} - \phi/2\frac{(k_{t+J}^{\mathrm{T}} - k_{t+J-1}^{\mathrm{T}})^2}{k_{t+J-1}^{\mathrm{T}}}, \tag{A.3}$$

$$k_{t+J}^{\mathrm{N}} = (1-\delta)k_{t+J-1}^{\mathrm{N}} + s_t^{\mathrm{N}} - \phi/2\frac{(k_{t+J}^{\mathrm{N}} - k_{t+J-1}^{\mathrm{N}})^2}{k_{t+J-1}^{\mathrm{N}}}, \tag{A.4}$$

$$i_t^{\mathrm{T}} = J^{-1}\sum_{i=0}^{J-1} s_{t-i}^{\mathrm{T}}, \tag{A.5}$$

$$i_t^{\mathrm{N}} = J^{-1}\sum_{i=0}^{J-1} s_{t-i}^{\mathrm{N}} \tag{A.6}$$

given

$$k_0^{\mathrm{T}},\ k_0^{\mathrm{N}},\ s_{-i}^{\mathrm{T}},\ s_{-i}^{\mathrm{N}}, \quad i = 0, 1, \ldots, J-1,$$

where ϕ is an adjustment cost parameter and s_{t-i}^{T} and s_{t-i}^{N} denote the number of investment projects initiated in period $t - i$ that will be productive in period $t - i + J$ in the traded and nontraded sectors, respectively.

The period utility function is defined over consumption of the composite good. To ensure the existence of a locally unique steady state, I assume that the subjective discount factor is decreasing in consumption. This assumption makes it possible to characterize the properties of the competitive equilibrium using standard numerical techniques (Mendoza, 1991). The lifetime utility function is given by

$$\sum_{t=0}^{\infty} \gamma_t \frac{c_t^{1-\sigma}}{1-\sigma}, \qquad \gamma_{t+1} = \gamma_t(1 + c_t)^{-\beta}, \tag{A.7}$$

where $\sigma > 1$, $\beta > 0$, and $\gamma_0 > 0$.

The household chooses sequences c_t, x_{t+1}, γ_{t+1}, a_t^{T}, a_t^{N}, i_t^{T}, i_t^{N}, k_{t+J}^{T}, k_{t+J}^{N}, s_t^{T}, s_t^{N}, $t \geq 0$ so as to maximize (A.7) subject to (A.1)–(A.6) and to a borrowing constraint that prevents the household from engaging in Ponzi games and taking as given the sequences p_t, w_t, r_t^{T}, r_t^{N}, τ_t, $t \geq 0$ and the initial conditions γ_0, k_0^{T}, k_0^{N}, s_{-i}^{T}, s_{-i}^{N}, $i = 0, 1, \ldots, J-1$.

A.1. Market-clearing conditions

In equilibrium, the labor market and the nontradable goods market must clear; that is,

$$n(H_t^{\mathrm{T}} + H_t^{\mathrm{N}}) = H,$$

$$a_t^{\mathrm{N}} = k_t^{\mathrm{N}\,\alpha_{\mathrm{N}}} H_t^{\mathrm{N}\,1-\alpha_{\mathrm{N}}}.$$

In addition, the evolution of lump-sum taxes and the devaluation rate must be such that the government does not engage in Ponzi-type schemes. The evolution of consolidated (private plus public) foreign asset holdings per capita, b_t, is given by Eq. (2).

Appendix B: Calibration

Following King et al. (1988), Kydland and Prescott (1982), and many other authors in the equilibrium business cycle literature, I use long-run empirical relations and steady-state model restrictions to identify the deep structural parameters of the model. Table 4 presents a summary of the results of this section.[11] The time unit is meant to be one month. I calibrate the model to the Argentine economy using data from 1970 to 1990. The average inflation rate over this period was 10.2% per month. The parameter θ of the aggregator function was set at 0.36, which is consistent with the observed average share of tradables in GDP of 42% and with the average trade balance to GDP ratio of 2%.[12] The parameters α_{T} and α_{N} denoting the partial capital elasticities of the production functions of tradables and nontradables were set to make the steady-state share of labor equal to the estimated values of 0.48 in the tradable sector and 0.63 in the nontradable

[11] See Uribe (1995) for a detailed derivation of the steady-state restrictions used to identify each parameter.

[12] The sectors considered traded were Agriculture, Manufacturing, and Mining. Data on sectorial output were obtained from 'Indicadores de Coyuntura', FIEL, Argentina, various issues.

Table 4
Calibration

Symbol	Description	Value
	Long-run data relations	
ε	Inflation rate (percent per month)	10.2
v	Annual Money velocity ($CPI \cdot GDP/M1$)	15.4
r	Real return of foreign assets (percent per annum)	6.5
tb	Trade balance over GDP ratio (percent)	2.6
s_i	Investment share in GDP (percent)	17.0
$\frac{y^{\mathrm{T}}}{y^{\mathrm{T}} + py^{\mathrm{N}}}$	Traded-good output share in GDP (percent)	41.8
$\frac{wH^{\mathrm{T}}}{y^{\mathrm{T}}}$	Labor share in the tradable goods sector (percent)	48.0
$\frac{wH^{\mathrm{N}}}{py^{\mathrm{N}}}$	Labor share in the home goods sector (percent)	63.0
GOR	Gross output over GDP ratio	3
	Deep structural parameters	
$-\beta$	Elasticity of the discount factor with respect to (1+c)	−0.012
$-\sigma$	Consumption elasticity of the period marginal utility	−5
θ	Traded-good elasticity of the aggregator function	0.36
α_{T}	Capital elasticity of traded output	0.45
α_{N}	Capital elasticity of nontraded output	0.28
δ	Depreciation rate (percent per year)	9.52
q	Cost of one trip to the bank (percent of monthly income)	0.26
n	Number of subsectors producing value added	6
J	Number of gestation lags (months)	24
ϕ	Adjustment cost parameter	25

sector.[13] The implied values are $\alpha_{\mathrm{T}} = 0.45$ and $\alpha_{\mathrm{N}} = 0.28$. The difference between the labor shares and the elasticities $1 - \alpha_{\mathrm{T}}$ and $1 - \alpha_{\mathrm{N}}$ is due to the wedge introduced by the inflation distortion $d(\varepsilon, q, n)$. The depreciation rate δ was set at 9.52% per annum to make the steady-state investment share in GDP consistent with the observed value of 17%. The adjustment cost parameter ϕ was set at 25 to ensure positive sectorial gross investment during the initial phase of the simulated stabilization experiments. The number of gestation lags J was arbitrarily set at 24 months. The parameter β that defines the endogenous discount factor was set at 0.012, which is consistent with a world real interest rate of 6.5% per year and with the observed ratio of the trade balance to GDP of 2.6%. The intertemporal

[13] Data on employment were obtained from 'Estadísticas de la Evolución Económica de Argentina: 1913–1984', Estudios, No. 39 (1986), Argentina and from 'La Cuestión Ocupacional Argentina: Una Evaluación de la Situación Actual y de Perspectivas Hacia Fines del Siglo XX' Instituto de Investigaciones Económicas de la C.G.E., Argentina, January 1989.

elasticity of substitution $1/\sigma$ was set at 0.2, which is the value estimated for Argentina by Reinhart and Végh (1993a, b).

B.1. Inflation distortions and shoe-leather costs

I now derive the restrictions used to identify the inflation distortions $d^s(\varepsilon, q)$, $d^f(\varepsilon, q)$, and $d(\varepsilon, q, n)$ and the ratio of the shoe-leather cost of inflation to GDP $slc(\varepsilon, q, n, tb)$. Because the functions d^s, d^f, d, and slc are known and the ratio of the trade balance to GDP, tb, and the devaluation rate ε are directly observable, it is only necessary to identify the proportional transactions cost q and the number of subsectors producing intermediate inputs n.

From the model developed in Section 2, it follows that the ratio of gross output to GDP, GOR, is given by

$$GOR = \sum_{i=1}^{n} p_i, \tag{B.1}$$

where p_i, the relative price of the intermediate input produced in subsector i in terms of the final good, is a known function of ε, q, and n. Because GOR can be directly observed, (B.1) represents one equation in the two unknowns q and n. I show below that the model provides a second steady-state restriction involving q, n and directly observable variables. This restriction is given by an expression for money velocity, v, of the form

$$v = v(\varepsilon, q, n, tb). \tag{B.2}$$

Thus, using observed values for ε, GOR, v, and tb, one can solve (B.1) and (B.2) for the structural parameters q and n.[14]

To obtain $v(\varepsilon, q, n, tb)$, first consider the real money balances held by an agent purchasing one dollar's worth of goods per month subject to a domestic-cash-in-advance constraint. Let $m^s(h, \varepsilon, q)$ denote the domestic money balances held by the agent at instant h between two consecutive trips to the bank measured in dollars; then

$$m^s(h, \varepsilon, q) = \int_h^{1/(1+N^s)} e^{\varepsilon(j-h)}\,dj = \frac{e^{\varepsilon(1/(1+N^s)-h)} - 1}{\varepsilon}.$$

[14]The average (M1) money velocity over the calibration period was 15.4 per annum. The number used for the ratio of gross output to value added is 2.96. Data on money, prices, and output were obtained from 'Indicadores de Coyuntura', FIEL, Argentina, various issues. The ratio of gross output to GDP was obtained from 'Input–Output Tables for Developing Countries, Volume II', Industrial Development Organization, United Nations, 1985, New York, NY.

The average money demand, $m^s(\varepsilon, q)$, results from taking the average of $m^s(h, \varepsilon, q)$ over $h \in [0, (1 + N^s)^{-1}]$,

$$m^s(\varepsilon, q) = (1 + N^s) \int_0^{1/(1+N^s)} m^s(h, \varepsilon, q)\, \mathrm{d}h = \frac{(1 + N^s)(\mathrm{e}^{\varepsilon/(1+N^s)} - 1) - \varepsilon}{\varepsilon^2}.$$

A similar argument can be used to obtain the average real balances held by an agent selling one dollar's worth of goods per month, $m^f(\varepsilon, q)$,

$$m^f(\varepsilon, q) = \frac{(1 + N^f)(\mathrm{e}^{-\varepsilon/(1+N^f)} - 1) + \varepsilon}{\varepsilon^2}.$$

The average money velocity in the model economy is then given by

$$v(\varepsilon, q, n, tb) = \left[m^s(\varepsilon, q)(1 - tb - slc(\varepsilon, q, n, tb)) + m^s(\varepsilon, q) \sum_{i=1}^{n-1} p_i + m^f(\varepsilon, q) \sum_{i=1}^{n} p_i) \right]^{-1}.$$

The first term inside the bracket represents the money demand of households to purchase final consumption and investment goods, the second term represents the money demand of firms to purchase intermediate inputs, and the third term represents the money demand of firms originated in sales of intermediate inputs and final goods.

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