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A DYNAMIC SIMULATION ANALYSIS OF CURRENCY SUBSTITUTION IN AN OPTIMIZING FRAMEWORK WITH TRANSACTIONS COSTS*

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Abstract:

This paper investigates the dynamic paths of inflation and real balances in a general equilibrium intertemporal optimization model, with transactions costs and currency substitution, when budget deficits are financed by money creation.

The results show that inflationary paths show more "jumps" or explosions under the assumptions of lower transactions costs or an increasing degree of currency substitution. Even small changes in the degrees of currency substitution with positive transactions costs sharply change the paths of inflation and real balances. Similarly, small changes in transactions costs for foreign currency, even without prior currency substitution, have marked effects on the paths of inflation and real balances.

The results obtained from the simulated data are consistent with inflation processes in recent Latin American experience, where currency substitution may have taken place. Estimates of the simulated data for even a small degree of currency substitution generate generalized autoregressive conditionally heteroskedastic (GARCH) estimates of the inflation process, which are consistent with estimates for Argentina, Bolivia, México, and Perú. In these countries currency substitution may have gone hand-in-hand with inflationary instability through money-financed fiscal deficits.

Our results suggest that fiscal deficits financed by monetary expansion should be avoided under conditions of increasing financial openness, which provide greater opportunities for financial adaptation through currency substitution or lower transactions costs on foreign currency accumulation.

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I. Introduction

This paper investigates the dynamic behavior of inflation and domestic real balances in an intertemporal optimizing framework with transactions costs and varying degrees of currency substitution, when budget deficits are financed by monetary expansion. The goal is to determine the sensitivity of the dynamic equilibrium paths to changes in currency substitution and transactions-cost parameters, two forms of financial adaptation which are likely to take place in inflation-prone economies. In particular, we wish to examine whether decreasing transactions costs and increasing currency substitution make the inflation path of the economy increasingly unstable, and demonetization more rapid, when domestic deficits are persistent and financed by monetary expansion.

Both money-financed deficits and currency substitution have been prevalent in Latin America during the past decade. The inflationary adjustment of Latin America in the 1980's could well be the experience of Eastern Europe and the members of the Commonwealth of Independent States in the 1990's. As Sturzenegger (1991) points out, these countries have had a long experience of money-financed deficits with effective price controls. Decontrol of prices and financial adaptation through currency substitution increase the chances of hyperinflation.

Money-financed budget deficits in Latin America reflect the lack of development of both an income tax base and domestic capital markets for selling government debt. The lack of a tax base is due to the peculiar political coalitions in each country, which have delayed implementing tax structures with efficient administration. The slow development of financial markets is due in part to the years of financial repression, when there was widespread credit rationing, foreign exchange controls, and restrictions on convertibility of currency. In addition, the burden of large external debts put further strains on the fiscal accounts, in many countries during a difficult process of transition to democratic governments. Fiscal expansion, often done to finance popular social spending, was financed through new money.

What is striking about the Latin American experiences of the 1980's is that the inflationary explosions were not preceded by large proportionate jumps in the fiscal deficits. Fiscal correction simply failed to take place. In Argentina, for example, the deficits during most of the 1980's were between six and ten percent of GDP, below the extremely high values of the early 1980's. As Dornbusch, Sturzenegger, and Wolf (1990) and Heyman (1991) point out, in the late 1980's the deficits simply reemerged after a series of failed stabilization attempts, and were financed by new money, that nobody wanted to hold.

Currency substitution is one form of financial adaptation to an inflation-prone environment; the other is indexed demand deposits. Sturzenegger (1991) has pointed out two major effects of both forms of adaptation: first, they reduce the base over which the inflation tax is levied, and thus increase the rate of inflation and its distortions, such as the transfer of large resources from the productive sector to the financial sector; and secondly, they have regressive income distribution effects, since they benefit those individuals with higher income, and thus greater access to indexed deposits or foreign currency, while forcing those classes without access to bear the full burden of the inflation tax.

Measurement of the degree of currency substitution is difficult, since a significant percentage of foreign currency holdings may not be reported. In some countries, such as Bolivia and Perú, dollar deposits became legal, once authorities recognized the widespread holding of foreign money. One can thus take the ratio of dollar deposits to

total deposits as an indicator of currency substitution. In Perú, the ratio of these dollar deposits grew to over 50 percent of total deposits within a few years after legalization in 1977. In Bolivia, this percentage has remained well over 70 percent since stabilization in August 1985.

Another method for assessing the degree of currency substitution is to measure the percentage of dollar quotations for key prices. In Argentina, for example, Sturzenegger pointed out that from March 1989 to October 1990, a period of two extreme inflations, the percentage of dollar quotations for cars grew from 5 percent to 100 percent; for rents from 77 percent to 86 percent.

Given that currency substitution is likely in an inflationary setting, and Latin American budget deficits are usually financed by money creation, our analysis concentrates on the macroeconomic adjustment process of this phenomenon. We do not consider its income-distribution consequences.

The model is a dynamic monetary open-economy extension of the Hansen-Sargent (1991) framework, but builds on recent analysis of transactions costs by Niehans (1991). The model is simple but is intended to capture some stylized facts of several Latin American economies. We have specified the model with an initial set of parameter values for simulation experiments. The simulations were repeated with stochastic adjustment, under different initial conditions. While we offer no empirical justification for the initial parameter values, we believe that the results based on estimation of the generated data are sufficiently close to estimates of actual data, so that the policy implications have an empirical warrant.

In earlier work, McNelis and Nickelsburg (1988, 1989) analyzed the experience of currency substitution and dollarization in Argentina, Chile, Ecuador and Perú. Their analysis shows that as dollar deposits became more widespread in Argentina, Ecuador and Perú, during the late 70's and early 80's, the money supply process became progressively less statistically antecedent to the inflation process, in terms of Granger and Sims causality, cross-spectral tests, and cointegration/error-correction analysis. This phenomenon did not take place in Chile, since the degree of currency substitution was much less than in the other three countries. More recently, Asilis, Honohan and McNelis (1992) analyzed the Bolivian experience of inflation and the demand for money. Their results show that the speed of adjustment of real balances varied quite a bit as the inflation process increased, and that inflation variance as well as expected inflation were significant determinants of money demand in the short run and in the long run. This paper argues that the increasing inflationary volatility, and accelerating demonetization are consistent with increasing currency substitution and lower transactions costs.

The bottom line of this investigation is that the combination of low transactions costs on foreign currency accumulation and currency substitution does make the inflation process more unstable, by increasing its overall volatility. The spikes or sudden explosions in inflation, observed in Argentina, Bolivia, and Perú, are consistent with a dynamic equilibrium path in an optimizing framework. While an inflation path may be relatively stable under one set of transactions-costs and currency-substitution parameters, only a small change in either can make the inflation path highly volatile. Thus, reliance on seigniorage becomes a precarious policy instrument for dealing with persistent fiscal deficits, even deficits which are not "large" or growing, since it may lead to increasing inflationary instability, rapid demonetization (of the domestic currency), and a shrinking base for seigniorage.

Previous work by Kareken and Wallace (1981), not directed at specific problems of inflationary instability, showed how currency substitution could make the exchange rate indeterminate. Calvo (1985) showed that the full effect of money depends not only on the degree of currency substitution but also on the degree of consumption and liquidity services. More recently, Bufman and Leiderman (1991) used an optimizing framework for obtaining restrictions on the behavior of consumption and liquid assets. They found that relatively small changes in the use of dollars would have marked effects on government seigniorage.

Our work includes both transactions costs on foreign currency accumulation as well as currency substitution, defined as a cash-in-advance restriction in which both domestic and foreign money can finance domestic consumption expenditures. The paths of inflation and real balances are extremely sensitive to changes in either parameter.

The next section is a description of the model, as well as a specification of the initial parameter values.

Section III is an analysis of the dynamic simulations under the initial and alternative parameter settings, which illustrate increasing degrees of currency substitution.

Section IV is an empirical analysis of the simulated inflation paths, and compares the time-series GARCH (generalized autoregressive heteroskedastic) statistics of the simulated inflationary process with similar statistics on inflation in Argentina, Bolivia, México, and Perú.

GARCH modelling allows the inflation variance to change through time. This approach is useful for analyzing the inflation-prone countries of Latin America, since this model can account for large explosions or swings in inflation without having to involve a regime change in the underlying moments of the distribution, since the distribution itself evolves through time. This type of model also allows a direct estimation of inflation uncertainty, proxied by the conditional variance of the GARCH model. Increasing currency substitution leads to the appearance of a significant GARCH estimate for inflation variance in the simulated data. Similar significant GARCH estimates characterize the inflation process for four Latin American countries.

The last section concludes.

II. The model

We consider a small open economy with one good, with a flexible shadow price for foreign currency. This price may either be a parallel market price or an official flexible exchange rate. Both traded and non-traded goods are produced by homogeneous productive capital.

There are three assets, productive capital, K, whose rate of return is r, domestic money M, whose (negative) rate of return is $-\pi$, expected inflation, and foreign money, M* held by domestic agents in the domestic economy, whose rate of return is simply domestic inflation, π. We assume for the sake of simplicity that foreign inflation is negligible. Thus, domestic inflation is simply the expected rate of appreciation of foreign money, M*.

The following budget constraint determines domestic private consumption expenditures, c_p, in terms of domestic currency:

$$c_p + \Delta M + \Delta M^* + \Delta K + g = (1 - \tau) r K_{t-1} - \pi M_{t-1} + \pi M_t^* + d \quad (1)$$

where Δ is the backward difference operator, with $\Delta M = M_t - M_{t-1}$, c_p represents private-sector consumption, d the dividend payments on non-traded goods, and g the transactions costs paid on domestic capital and foreign currency accumulation by residents. The rates of return, r, $-\pi$, and π represent the rates of return on the three assets. Domestic tax rates are τ and apply only to earnings from domestic capital. The dividends d, given exogeneously, are assumed to be after-tax dividends. Inflation π erodes the real value of domestic cash balances, and increases the value of foreign money, and is imputed in the total asset returns. However, we assume that returns due to inflation are not taxed.

The transactions costs are given by the following expression:

$$g = \tau_1 \Delta K + \theta_1 \Delta M^* \quad (2)$$

Following Niehans (1991), we assume that transactions costs on domestic money are insignificant. Since domestic money has a zero nominal rate of return, in the absence of inflation, *ceteris paribus*, the assumption of insignificant transactions costs gives domestic money a comparative advantage as a medium of exchange.

The goal of the social planning problem, discussed below, is to minimize the squared sum of these costs, as well as the squared sum of deviations of consumption from target levels of consumption.

Total liquidity services are produced with domestic and foreign money, through a Cobb-Douglas technology, with $0 < \rho < 1$:

$$L = A M^{\rho} (M^*)^{1-\rho} \quad (3a)$$

and the following cash-in-advance constraint applies:

$$c_p = L \quad (3b)$$

Since the optimization framework we employ requires linear constraints with linear quadratic objective functions, we linearize (3a) for the following cash-in-advance constraint:

$$c_p = L_M M + L_{M^*} M^* \quad (3c)$$

where L_M and L_{M^*} are the partial derivatives of total liquidity services (3a) with respect to M and M* at time t = 0. The payoffs from using this linearization are both ease of computation and restrictions on linear state-space and VAR representations from first-order conditions[1].

Initially, we assume that domestic money is mostly used for domestic consumption, with $\rho = .99$. With a progressively lower value of ρ, currency substitution increases.

A more elaborate model would set ρ as a negative function of current or past inflation, with $\rho = \rho(\pi)$, $\rho_\pi < 0$. While this approach would enrich the dynamics, it would also add to the complexity of the model. We would also have to replace the non-linear relation with another linear approximation. For this reason, we have chosen another approach: to simulate the model under alternative values of ρ, to illustrate the sensitivity of the dynamic adjustment paths to changes in the starting value of ρ. Our results, discussed below, do show that the adjustment is much more volatile for lower values of ρ. Since we can expect ρ to fall as inflation or expectations of continued inflation persist, we argue that the effect is to make future inflation increasingly unstable.

The budget constraint for government expenditures is:

$$c_g = T + \Delta M = \tau r (K_{t-1}) + \mu M \tag{4}$$

where μ is the rate of growth of the nominal money supply. We assume in this simple case that there is no government instrument other than money and that the government earns no revenue from foreign assets.

Following Hansen and Sargent (1991), we define the following objective function for the social planner

$$\text{Min} - .5 \, \Sigma \, \beta^t [(s_t - b_t)' (s_t - b_t) + g_t' g_t] \tag{5}$$

where s is the vector of consumption services of the representative household, including private consumption c_p and government consumption c_g, b are the targets or tastes for private and government consumption, and g'g is the squared sum of the transactions costs.

The objective function is minimized subject to the following constraints:

$$\Phi_c c_t + \Phi_g g_t + \Phi_i i_t = \Gamma k_t^* + d_t \tag{6}$$

$$k_t^* = \Delta_k k_{t-1}^* + \theta_k i_t \tag{7}$$

$$h_t = \Delta_h h_{t-1} + \theta_h c_t \tag{8}$$

$$s_t = \ell_s h_{t-1} + \Pi c_t \tag{9}$$

$$b_t = Ub \, z_t \tag{10}$$

$$d_t = Ud \, z_t \tag{11}$$

$$z_{t+1} = A_{11} z_t + C_2 w_{t+1} \tag{12}$$

In the Hansen-Sargent framework, the process $\{z_t\}$ is uncontrollable. The social planner is to choose stochastic processes $\{c_t, s_t, g_t, i_t, k_t^*, h_t\}$ that optimize the objective function, where the endogenous state vector $k_t^* = [K_t \, M_t \, M_t^*]'$, the stocks of domestic capital, domestic money, and foreign money held by domestic residents. The variable $i_t = \Delta k_t^*$. The state vector h_t in equation (8) represents household capital, and allows for an inertial effect or habit formation in consumption behavior.

In the Hansen-Sargent model, equation (6), the first constraint, encompasses the household expenditure constraint, equation (1), the transactions and cash-in-advance constraint, equations (2) and (3), and the government expenditure constraint (4). In terms of the first four equations, we define the following matrices and vectors, where a semi-colon signifies the end of a series of entries in one row:

$$\Phi_c = [1 \;\; 0; \; 0 \;\; 0; \; 1 \;\; 0; \; 0 \;\; 1], \quad c = [c_p \; c_p]'$$

$$\Phi_i = [1 \;\; 1 \;\; 1; \; 0 \;\; -\theta_1 \;\; -\tau_1; \; 0 \;\; 0 \;\; 0; \; 0 \;\; -1 \;\; 1]; \quad i = [\Delta K \; \Delta M \; \Delta M^*]'$$

$$\Phi_g = [1 \;\; 1 \;\; 0 \;\; 0]; \quad g = g$$

$$\Gamma = [(1-\tau)r \;\; -\pi \;\; \pi; \; 0 \;\; 0 \;\; 0; \; 0 \;\; \rho \;\; (1-\rho); \; \tau r \;\; 0 \;\; 0]; \quad k^* = [K \; M \; M^*]'$$

$$d = [d_1 \, d_2 \, d_3 \, d_4]'$$

$$b = [c_{p,t-1} + z_{p,t} \;\; c_{g,t-1} + z_{g,t}]'$$

We set the column vector d to be an exogenous factor affecting both domestic private consumption, transactions costs, the cash-in-advance constraint, and the government budget. In our simulations we concentrate on continuing deterministic shifts in the government budget, causing the rate of monetary growth to be 5 percent per period. We thus eliminate shocks to the other constraints. Hence $d = [d_1 \; 0 \; 0 \; d_4]'$, where d_1 and d_4 are constants. In our model, we set $h_t = 0$. There will thus be no habit-persistence in either private or government consumption behavior. Hence, $\Delta_h = \theta_h = \lambda = 0$. For the evolution of k, we set $\Delta_k = \theta_k = I(3)$, a 3-by-3 identity matrix.

The process for b_t is a random walk, so that there will be "taste shocks" facing the social planner for private and public consumption. In this way, we incorporate private and political uncertainty factors, which illustrate random changes in both private consumption spending and pressures on fiscal authorities for public consumption. With these elements, the simulations become stochastic. The variance of shocks $[z_p z_g]$ is proportional to the starting values of private and government consumption. Hence, $[\text{var}(z_p) \; \text{var}(z_g)]' = .1 \, [c_{p,0} c_{g,0}]'$.

Prices do not appear in the constraints. Hansen and Sargent (1991) show that dynamic Lagrangean multipliers coming from the optimal solution to this social planner's problem can be transformed to represent the prices of consumption goods and the assets in a decentralized economy. In our simulation analysis, we shall evaluate the dynamic paths of both quantities and prices for various shocks, transactions costs and cash-in-advance parameters.

The use of equation (5) and constraints (6) - (12) is simply a tractable and equivalent route for computing competitive equilibria, in which we would model household intertemporal maximization of utility subject to budget constraints, and firm maximization of discounted profits subject to cost constraints. Thus the social planner's problem is simply a device for ease of both modelling and computation, subject to the absence of externalities and other non-convexities. Equation (5) for the social planner corresponds to the preferences for householders for minimizing deviations from "bliss values" of private and government consumption. It captures the desirability of consumption smoothing.

For the base simulation, the following parameter values apply:

$$\beta = .9; \; \tau = .3; \; \tau_1 = 4.0; \; \theta_1 = .8; \; \rho = .99; \; A = 1.02$$

There is thus a social discount rate, a tax rate of 30 percent, and relatively higher transactions costs or adjustment costs for real capital than for foreign money.

The following initial conditions apply:

$$K = 10{,}000;\ M = 1000;\ M^* = 100;\ r = .03;\ \pi = .05;\ c_p = 1000;\ c_g = 100$$

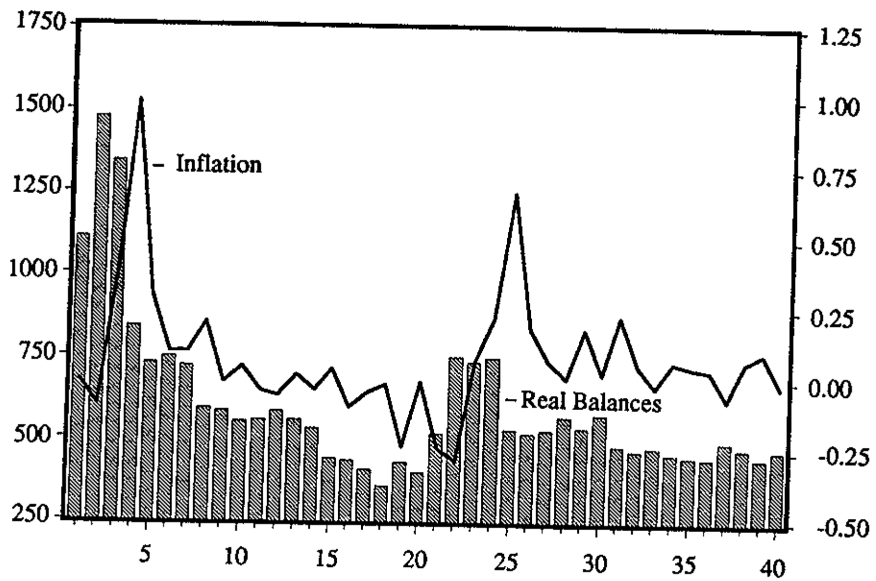
With an expected rate of inflation at five percent, the rate of monetary growth is also set at five percent. Given initial settings for the rate of return on capital and for the tax parameter, the exogenous components of the expenditure and government budget constraints are set at values which put the system in an initial equilibrium, so that government spending is equal to tax revenue, and consumption is equal to income. In our comparative dynamic analysis, we wish to examine the transition process from one steady state to another.

III. Dynamic Simulation Analysis

The dynamic paths for inflation and real balances for the base-simulation parameters appear in Figure 1[2].

FIGURE 1

BASE SIMULATION: REAL BALANCES AND INFLATION



Following the increase in monetary expansion, there is a slight decline, then a large jump, in inflation. In succeeding periods, inflation comes down, but there is a burst between period 20 and 30. Inflation converges to its long-run value of five percent. Real balances show a similar pattern. There is a temporary increase after period 20, but the long-term effect is a decline to a value slightly more than one-fourth of the initial value. The capital stock, not shown in Figure 1, also increases, but due to the relatively larger transactions costs on capital accumulation, the change is only slight. Thus, a persistent deficit financed by monetary expansion leads to an increase in inflation and demonetization.

Figure 2 shows the adjustment of both variables when there is a slight change in the currency-substitution parameter, from $\rho = .99$ to the case of no currency substitution, $\rho = 1.00$. The graph shows that there is a marked jump (explosion) in the inflation path, stronger than in the case of slight currency substitution, and a very rapid demonetization. However, there is no secondary explosion as pronounced, relative to the initial surge, as in the case of slight currency substitution. These paths illustrate the extreme sensitivity of the simulation results to alternative values for ρ.

FIGURE 2

REAL BALANCES AND INFLATION WITHOUT CURRENCY SUBSTITUTION

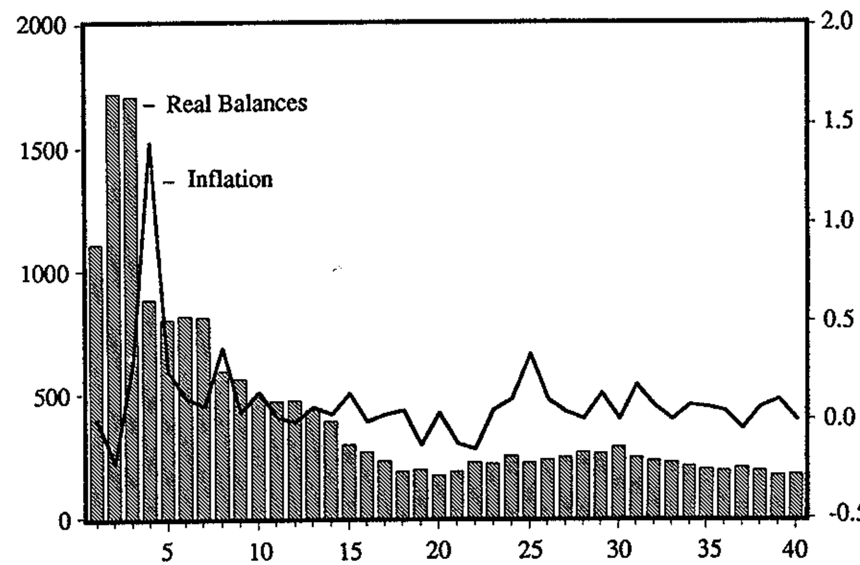


Figure 3 shows the adjustment paths for inflation and real balances when there is slight currency substitution, hence $\rho = .99$, but lower transactions costs on foreign asset accumulation, with $\theta_1 = .7$. Again, there are two sets of inflationary explosions before inflation converges to its long-run value.

Further changes in the currency-substitution parameter ρ or in transactions costs on foreign currency, θ_1 produce increasing instability in the adjustment paths of both inflation and real balances.

FIGURE 3

REAL BALANCES AND INFLATION WITH LOWER TRANSACTIONS COSTS

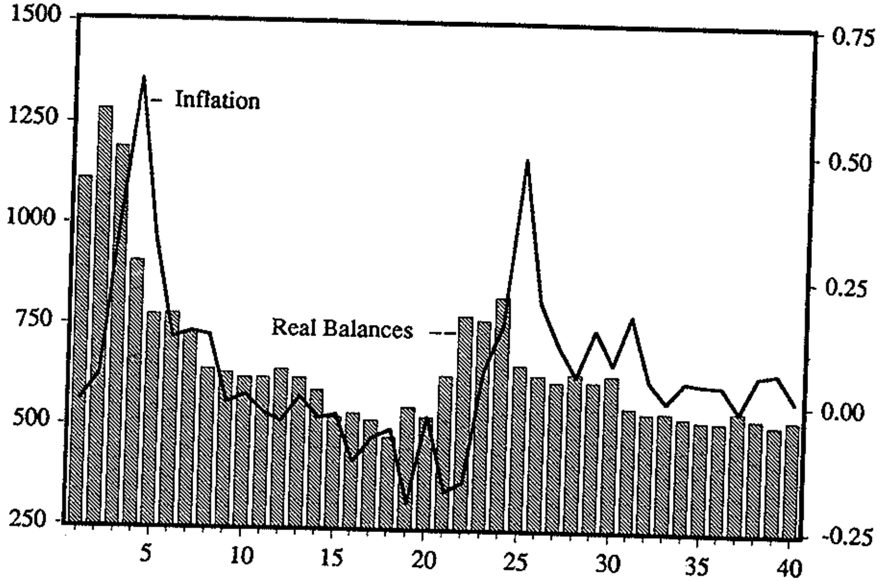


Table 1 summarizes the effects of alternative parameter values for the stability of the inflation paths generated by the model. We measure stability by the ratio of the standard deviation of succeeding simulation to the standard deviation of the base simulation.

What is surprising about Table 1 is that no clear pattern emerges. When we eliminate currency substitution, with ρ = 1, there is a slight but insignificant increase in volatility. However, with a lower value of ρ, there is a marked increase. Similarly with transactions costs on foreign currency and changes in the discount factor β, the inverse of the gross social discount rate: with a slight fall in θ_1, volatility decreases, but with a further decline, there is a major increase in volatility.

Figures 1 and 2 and Table 1 show that dynamic equilibrium paths can be characterized by sharp changes in inflation and continuing drastic demonetization, when money-financed deficits persist, and opportunities exist for currency-substitution or accumulation of foreign currency at lower costs. The analysis also shows that small changes in the degree of currency substitution, transactions costs, and the social discount rate can affect the volatility of the adjustment, although in ways that cannot be easily

TABLE 1

EFFECTS OF ALTERNATIVE PARAMETER VALUES ON INFLATION VOLATILITY

Nº	Parameter Values:	Volatility Measure ($\sigma(\pi)$ / $\sigma(\pi_{base})$)
1.	Base simulation ($\rho = .99, \theta_1 = .8, \beta = .9, \tau_1 = 4.0$)	1.00
2.	No currency substitution ($\rho = 1.00$)	1.08
3.	More currency substitution ($\rho = .98$)	5.96
4.	Lower transactions costs on foreign currency ($\theta_1 = .7$)	.73
5.	Lower transactions costs on foreign currency ($\theta_1 = .4$)	11.4
6.	Higher discount rate ($\beta = .8$)	.82
7.	Higher discount rate ($\beta = .4$)	1.05
8.	Lower transactions costs on capital accumulation ($\tau_1 = 2.0$)	23.2

predicted, since the dynamic process is complex and dependent on initial conditions and the array of initial parameter settings. The implication of this analysis is that we cannot be clear about the effects of financial openness on overall stability in an inflationary setting: while there is a chance that it may reduce volatility, there is also a chance that further openness may magnify overall instability. Until macroeconomic fundamentals are correct -money-financed deficits are eliminated- financial liberalization and other policies which increase the change of currency substitution should be put on hold.

IV. Simulated and Actual Inflation in Latin America

Table 2 presents GARCH (generalized autoregressive conditional heteroskedastic) estimates for the two simulated inflation processes, for the case of currency substitution, with ρ = .99, and for the case of no currency substitution, with ρ = 1.00, and for the case of lower transactions costs, with $\theta_1 = .7$.

The GARCH estimates come from maximum-likelihood procedures developed by Bollerslev (1986). We assume a random walk for inflation in both the simulated data and in the actual data, and model the GARCH as the process for the conditional variance of the forecast error[3]. Unit-root tests failed to reject the random-walk hypothesis for both the simulated and actual data. Given Campbell and Perron's recent warning about unit-root analysis, we make no claim about the validity of these tests. We only wish to show that currency substitution with persistent money-financed deficits can generate inflation paths with GARCH process in a dynamic equilibrium framework.

TABLE 2

GARCH MODELS OF INFLATION
(t-statistics in parentheses)

$$\Delta p = \Delta p_{t-1} + \varepsilon_t,\ \varepsilon_t \sim N(0, \sigma_t^2)$$
$$\sigma_t^2 = \alpha + \beta\, \hat{\varepsilon}_{t-1}^2 + \delta\, \sigma_{t-1}^2$$

Data Set	Period	Parameter Estimates α	β	δ
Artificial data:				
Figure 1: Base Run (ρ = .99)	1 - 100	0.0027 (2.67)	.9090 (3.27)	.219 (2.77)
Figure 2: No Currency Substitution (ρ = 1)	1 - 100	0.0064 (0.02)	.2124 (0.08)	0 (0)
Figure 3: LowerTransactions Costs (θ_t = .7)	1 - 100	0.0025 (1.99)	1.048 (2.87)	0.077 (.963)
Latin America data:				
Argentina, monthly inflation	1980-90	.488 (.49)	1.008 (1.12)	.2782 (0.28)
Argentina, monthly devaluation	1980-90	.003 (1.12)	.358 (2.59)	.556 (4.28)
Bolivia, monthly inflation	1980-88	.028 (2.26)	.47 (12.56)	1.11 (24.47)
Perú, monthly inflation	1980-89	.143 (6.2)	.80 (11.56)	.53 (24.78)
México, monthly inflation	1983-89	.198 (12.10)	.34 (4.83)	.26 (5.50)

Table 2 shows that one of the GARCH parameters turns out to be "significant", under the case of currency substitution, and for the case of currency substitution with lower transactions costs, but not for the case of no currency substitution (ρ = 1). Thus, the equilibrium model, in its simplest form, with slight currency substitution, can give the appearance of a GARCH process governing the evolution of inflation. For the case of lower transactions costs but no currency substitution, the stochastic simulation path shows no such appearance.

GARCH estimates for three Latin American countries where currency substitution has been an issue in policy discussion, Bolivia, Perú, and México, show significant GARCH statistics. For Argentina, where currency substitution is also a policy issue, the GARCH statistics for inflation turn out to be insignificant. However, estimates for the rate of devaluation in the parallel market in Argentina, taken by many to be a proxy for expected inflation, show significant GARCH statistics[4].

While significant GARCH statistics for the inflation process are by no means unique to countries which experience currency substitution, since volatility in inflation may reflect a myriad of sources, the ease with which a model with a slight degree of currency substitution produces the appearance of a GARCH process in inflation leads one to suspect that a GARCH process may be an expected outcome when money-financed deficits are coupled with currency substitution.

V. Conclusion

While the analysis of this paper has been simple, based on the optimization of a linear-quadratic objective function with linear constraints, the results produce sharp breaks in inflation which give the appearance of a GARCH process. Such processes have characterized the inflation experience in Argentina, Bolivia, México, and Perú, where currency substitution has been an issue.

This model has neglected external adjustment, through exchange rates, debt service, and changes in the international interest rate, all of which have further effects on inflationary expectations and on the supply of foreign currency. A more elaborate model should take into account the ways in which the volatility in different financial variables spills over onto the inflation process and into other financial markets.

Nevertheless, we believe that more elaborate models will come to the same conclusions regarding money-financed deficit spending in financially more-open environments. Rather than be rare, inflationary explosions may be the normal expected outcomes in such situations.

APPENDIX 1

ESTIMATION OF GARCH PARAMETERS

We define the residual $e_t = x_t - x_{t-1}$. In the GARCH process, the following equation governs the evolution of the conditional variance s:

$$s_t^2 = \alpha + \beta\, e_{t-1}^2 + \delta\, s_{t-1}^2 \quad \text{(A.1)}$$

For a starting value of s_t, s_0, we maximize the following log-likelihood function, with respect to α, β, δ:

$$\log(L) = -.5 \sum_{t=1}^{N} s_t^2 - .5 \sum_{t=1}^{N} (e_t^2/s_t^2) \quad \text{(A.2)}$$

The inverse of the Hessian matrix is used to compute the standard errors for the maximum likelihood estimates. There are also non-negative restrictions on the values of α, β, and δ, to ensure that the conditional variance is greater than or equal to zero.

Notes:

1 Hansen and Sargent (1991) point out that these models, with linear quadratic objective functions and linear restrictions, have the advantage of combining good dynamic economics with good econometrics, since VAR and state-space representations are now the accepted empirical approaches for econometric analysis of dynamic systems. One can then proceed to estimation by simulation: compare the estimates of simulated data with estimates of actual data, and then alter the values of the "deep parameters" of the objective function until convergence.

2 A copy of the Matlab (1990) program for these models, for use with the Hansen-Sargent (1991) solution algorithms, is available upon request.

3 A copy of the Matlab program for estimating the GARCH parameters is available from the first author upon request.

4 Data for Argentina were obtained from Hildegard Ahumada at the Central Bank of Argentina. A copy of the Matlab (1990) program for estimating the GARCH models, as well as the data sets, are available upon request.

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CURRENCY SUBSTITUTION AND INFLATION IN PERU

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Abstract:

This paper shows that there is a long-run relationship between the expected rate of depreciation in the black-market-exchange rate and the ratio of domestic to foreign money in Perú; that is, the hypothesis of currency substitution can explain the behavior of real holdings of money in Perú. The paper also shows that, while, the importance of currency substitution as a transmission mechanism through which domestic policies affected the dynamics of inflation was relatively small during a period of high but relatively stable inflation (January 1978-85), it became an important factor in the inflation process during the recent hyperinflation episode.

I. Introduction

This paper deals with currency substitution–the substitution of foreign money for domestic money by domestic residents–and its role in the dynamics of inflation in Perú during the period January 1978-December 1990. As documented in a number of studies[1], currency substitution is a widely spread phenomenon in many developing countries. In the context of high levels of inflation and expectations of exchange rate depreciation, residents in many developing countries have attempted to protect the real value of their wealth by increasing their holdings of foreign currency[2]. As the severity of economic

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