A Micro-foundations Model of Dollarization with Network Externalities and Portfolio Choice: The Case of Bolivia*

John T. Cuddington, Rose Mary R. Garcia,

and Daniel M. Westbrook
Georgetown University

January 24, 2002

Abstract

Recent experience from Latin America, Eastern Europe, and countries of the Former Soviet Union suggests that the ratio of foreign-denominated to total deposits in the domestic banking system – called the dollarization ratio – grows sharply during periods of high inflation. When inflation subsides, however, the dollarization ratio often remains high - a phenomenon that some describe as hysteresis.

There are two main competing explanations for these observed patterns in dollarization. Models of hysteresis claim that there are network externalities in transactions. They imply that agents may continue using foreign currency even when relatively higher rates of return on domestic-denominated deposits prevail. On the other hand, dollarization may be caused by movements in rates of return. Sahay and Vegh (1996) reveal that positive real rates of return in domestic-denominated assets are correlated with the recent drop in dollarization in Eastern Europe. Battaile (1996), also finds dollarization rates for post-inflationary Bolivia and Peru to be well explained by standard 'portfolio balance' variables.

The primary aim of this paper is to present and test a monies-in-the-utility function model that includes domestic and foreign-denominated interest-bearing assets and network externalities. The model, which reflects portfolio balance and hysteresis considerations, is empirically estimated using Hansen's generalized method-of-moments procedure. The results show that network externalities are insignificant in explaining post-stabilization dollarization patterns in Bolivia.

---

* This paper closely resembles Chapter 5 of Rose Mary Garcia's Ph.D. dissertation. For further details, contact garciar@georgetown.edu

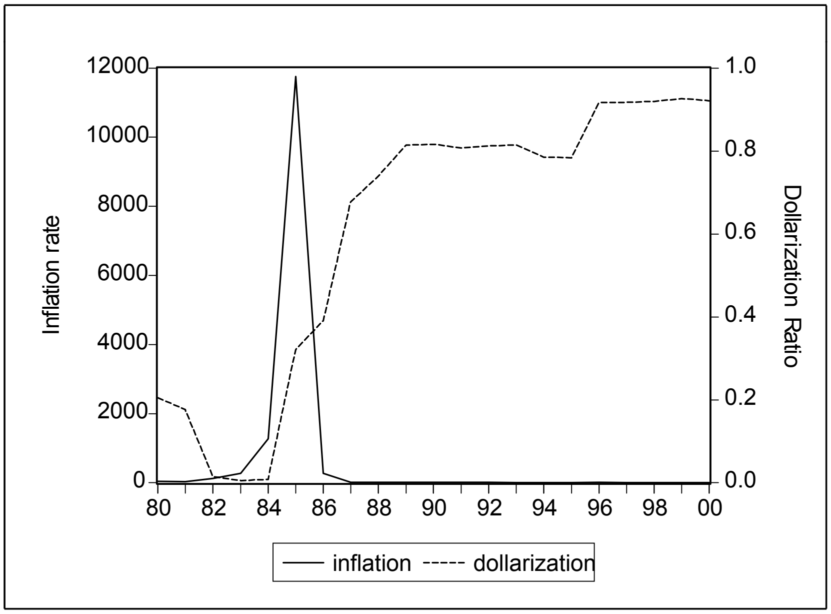

Figure 1: Inflation and Dollarization: Bolivia

A Micro-foundations Model of Dollarization with Network Externalities and Portfolio Choice: The Case of Bolivia

Prolonged periods of high and volatile inflation can lead to an erosion of demand for domestic money. Foreign money displaces unstable domestic currency as a store of value, unit of account and/or medium of exchange. Naive models predict that the process would be reversed if price stability were restored. But this does not always occur. In the case of Bolivia, inflation has subsided through credible and long-lasting stabilization programs but dollarization remains high — a phenomenon that some have described as hysteresis. Figure 1 shows the evolution of dollarization and its relationship to inflation, before, during and after hyperinflation.[1] After stabilization, the ratio continued an upward trend through out the 1990s.[2]

---

[1] The dollarization figures for 1982-1984 are missleading, since during this period the government outlawed foreign currency deposits.

[2] The empirical analysis is confined to the post-stabilization period because of lack of data on dissagregated foreign currency deposits.

The literature does not yield a consensus explanation of the behavior of post-stabilization dollarization. Some economists propose that network externalities create apparent hysteresis in dollarization. Others argue that portfolio balance considerations drive high levels of post-stabilization dollarization.

There are two formal models that link network externalities to dollarization. Uribe (1997) argues that dollarization persists because domestic agents have accumulated knowledge on how to use foreign currency in transactions. In his model, high inflation motivates agents to hold and transact in foreign currency. As inflation becomes acute the marginal cost of holding domestic currency increases and a greater proportion of goods are bought with foreign currency. The marginal cost of using foreign currency is reduced as more agents learn how to use it. This knowledge remains even if inflation subsides, so agents do not switch back to their domestic currency. Peiers (1994) postulates that these same network effects occur when the number of contemporaneous foreign-currency borrowers and lenders increases. As the proportion of foreign currency users becomes large, agents are more willing to accept the foreign currency. This acceptance prevails after inflation subsides.

The hypothesis of externalities in the use of money is not new. Giovannini and Turtelboom (1993, p. 4) refer to the unit of account function of money as follows:

> *calculating relative prices in different units of measurement can be a very cumbersome task... We suspect that habit, both in spatial and temporal dimensions, is an important factor determining substitutability of unit of account services. The more people are used to operating in different currencies to settle transactions, the more these currencies' unit of account services will be substitutable . . . In discussions*

> *of money's transaction services, externalities are often mentioned. A currency is more acceptable when more individuals use it as a means of settlement of private transactions.*

Referring to the transaction services provided by money, Calvo and Vegh (1992, p. 11) observe that

> *[h]igh inflation forces a gradual development of new financial instruments…Creating new financial products is costly and requires a learning process. Once this investment has taken place, the public will continue using these new financial instruments even if inflation falls.*

There is some empirical evidence supporting the hysteresis hypothesis. Kamin and Ericsson (1993) study dollarization in Argentina and conclude that inflation produces a significant "ratchet effect" on money demand. In addition, Peiers (1994) and Peiers and Wrase (1997) test for the significance of network externalities and document the degree to which transactions costs of using US dollars decline as the network of US Dollar borrowers and lenders increases. Using data from the informal credit market in Bolivia, they find coefficients for externality proxies that are statistically significant.

On the other hand, several papers focus on portfolio considerations as driving post-stabilization dollarization. Sahay and Vegh (1996) observe that Eastern European dollarization dropped when real rates of return in domestic-denominated assets increased. Battaile (1996), after incorporating ratchet and asymmetric effect terms, found that dollarization rates for post-inflationary Bolivia and Peru were well-explained by standard portfolio variables: rates of return, prices, income and wealth. Alami (1996) relates portfolio considerations to dollarization in Egypt.

Both theories are plausible, and could, in fact, operate jointly. If this were the case, any empirical model that incorporates only one theory might be subject to omitted-variable bias. This paper presents a model that embodies both the network externalities and portfolio considerations. The generalized-method-of-moments (GMM) technique is used to estimate the model using Bolivian data and to test the significance of externality and portfolio balance variables.

The paper presents a money-in-the-utility-function model with a network externality. Two currencies enter the utility function and provide liquidity services. In addition, the country's accumulated knowledge in using foreign currency enters the utility function. This additional factor may enhance liquidity services and reflects a simple form of network externalities postulated by Uribe (1997).

In the case of Bolivia, since we do not have data on foreign cash in circulation, we assume that liquidity services are provided by foreign and domestic demand deposits.[3] To incorporate the portfolio balance motive, we model foreign and domestic currency deposits in the form of Certificates of Deposit (CDs) for the non-liquid interest bearing assets, after testing for perfect substitutability.[4]

The model assumes that quantities demanded of the non-liquid assets depend on uncertain domestic and foreign rates of return. The uncertainty about interest earnings generally prevails in emerging economies because of financial instability.[5] Frequently, promised

---

[3] Savings deposits may also be yielding liquidity services. We hope to examine this possibility in the future and test for it. There is a conceptual problem in including savings deposits, since they yield interest earnings and we would no longer be separating the two roles of money.

[4] The derivations, for Chapter 5 in the dissertation, include savings deposits as portfolio balance assets, since they earn interest and are considered less liquid than demand deposits. But little is gained from adding these assets in the portfolio consideration framework. See discussion in Section 3.

[5]

interest rates are not realized because of the relatively large number of bank failures and incomplete Deposit Insurance Systems (DIS). The Economist Intelligence Unit Country Reports provide evidence for several countries. For example, in Paraguay, 38 financial companies collapsed between 1995 - 1999. Small depositors received their principal on a timely basis, yet interest payments were not delivered. In Honduras, Venezuela and The Russian Federation many depositors did not receive either principal or interest in 1999. Only in The Russia Federation was settlement of interest payments being negotiated. In Ecuador, when a series of bank failures turned into a banking crisis in 1999, the government took over 16 of the 65 failed commercial banks and "froze" savings and CDs deposits. Many emerging economies are now implementing DIS which may help to remedy this situation. Gillian Garcia (1999), however, provides evidence that many countries still do not include foreign-currency deposits (FCDs) in their DIS.

For the 1989 - 1997 sample period, the Bolivian DIS was not yet in existence and the Bolivian Central Bank acted as a lender of last resort to mitigate banking crises. However, this failed to protect many depositors and an average of ten percent of assets were frozen with no hope of earning interest payments.

The model implies a set of stochastic Euler equations that must be satisfied in equilibrium. The parameters of the Euler equations are estimated using the GMM technique introduced by Hansen (1982). Data for Bolivia are used to estimate the model and to test whether network effects and/or portfolio considerations explain post-inflationary dollarization. Bolivia is chosen because a long period of hyper-inflation in the early 1980s was followed by a decade of macroeconomic stability, yet the dollarization process was not reversed. The country

---

This assumption is rather critical for the formulation of the model. See a detailed discussion in the Appendix.

continues to be highly dollarized with the US Dollar circulating equally as the Boliviano.

This paper finds no evidence to support the network externalities hypothesis. And although the CDs are found to be imperfect substitutes, the structure of the model does not yield clear conclusions regarding the portfolio balance framework.

The remainder of this paper is organized as follows. Sections 1 tests whether the uncovered interest parity condition holds between national-currency and foreign CDs in the Bolivian banking system. Section 2 and 3 present the model and Euler equations. Section 4 presents the results, including those from estimating restricted models, one without network externalities and without portfolio considerations. Section 5 concludes this paper.

1 Domestic and Foreign CDs: Imperfect Substitutes

Imrohoroglu (1994), Canzoneri and Diba (1993), and Uribe (1997) present dollarization models with foreign and domestic money in transactions and one financial asset, a "bond", yielding a world rate of return, i.e., they assume domestic and foreign bonds are perfect substitutes. With portfolio balance considerations, financial assets denominated in different currencies would offer typically different rates of return. Thus, an imperfect asset substitutability assumption is needed. For developing countries, this latter assumption may be valid. Lizondo (1983) and Phylaktis (1988) find that domestic and foreign assets are imperfect substitutes in Mexico and Argentina, respectively. To date, no such evidence exists for Bolivia.

Under perfect asset substitutability, expected nominal returns on domestic and foreign-currency denominated CDs are equal, $E_t\{(1+i_{cd,t})\} = E_t\{(1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right)\}$ where $(1+i_{cd,t})$ and $(1+i^*_{cd,t})$ are the uncertain gross nominal interest rates, $\left(\frac{e_{t+1}}{e_t}\right)$ is the gross-nominal depreciation of the national currency in the upcoming period. In other words, under perfect asset substitutability, the investor expects to realize equal returns on foreign and domestic identical assets. If there are systematic discrepancies, they are taken to reflect risk premia and one can reject the perfect asset substitutability assumption.

The discrepancies between the realized interest rates can be characterized as $(1+i_{cd,t}) - (1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right)$. Under imperfect asset substitutability a term, κ_t, accounts for the risk premium, so $(1+i_{cd,t}) - (1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right) = \kappa_t + \varepsilon_t$ where ε_t is the expectational error with a mean equal to zero, $E_t(\varepsilon_t) = 0$. While under perfect asset substitutability, $(1+i_{cd,t}) - (1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right) = \varepsilon_t$. If errors are serially correlated, they are evidence for a time-varying risk premium or for irrational investor behavior.

Figure 2 shows graphically the relationship between the two CD rates of return. The top panel is a graph of the interest rate series $(1+i_{cd,t})$ and $(1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right)$. The domestic rate is higher than the foreign rate for the entire sample. The bottom panel in the figure shows the difference between the rates, $(1+i_{cd,t}) - (1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right)$, which is greater than zero for the entire sample period.

The average risk premium is estimated by regressing $\left\{(1+i_{cd,t}) - (1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right)\right\}$ on a constant κ_t and testing if the constant is significantly different from zero.[6] Running an OLS regression results in an estimated risk premium of 0.08 with a t-statistic of 16.94, after correcting for serial correlation.[7] From these regressions, we conclude that foreign and domestic CDs in Bolivia are imperfect substitutes and that there exists a risk premia in equilibrium. This evidence shows strong support for modeling portfolio considerations to

---

[6] An Augmented Dickey-Fuller test *was applied* to the differential term $(1+i_{cd,t}) - (1+i^*_{cd,t})\left(\frac{e_{t+1}}{e_t}\right)$ rejecting the unit-root hypothesis at a 5% MacKinnon critical value. The test included a constant.

[7] Both the Breusch-Godfrey Lagrange multiplier test and the Q-static test showed autocorrelation of order two in the residuals of the original OLS regression.

explain Bolivian dollarization.

2 The Model

Our model is an extension of the monies-in-the-utility-function in a small open economy literature developed by Imrohoroglu (1994), and Canzoneri and Diba (1993). Individuals balance the proportions of foreign and domestic interest-bearing deposits in their portfolios.

The critical difference between the model presented here and those by Imrohoroglu (1994) and Canzoneri and Diba (1993) is that Uribe's (1997) network externality is incorporated and domestic and foreign-currency CDs are introduced. Individuals already know how to use their domestic currency, but must learn how to use foreign currency. As a country's knowledge of foreign currency accumulates, foreign money provides money services more effectively.

The model characterizes an economy with many identical infinitely-lived individuals who obtain utility from consumption and from money services (for estimation purposes, domestic and foreign demand deposits). Individuals maximize their expected discounted sum of instantaneous utility as expressed by:

$$E\sum_{t=0}^{\infty}\beta^t\{u(c_t)+v(\frac{e_t dd_t^*}{p_t},\frac{dd_t}{p_t},\overline{k}_t)\}. \tag{1}$$

β is the subjective discount factor; u is an increasing and strictly concave instantaneous utility function of consumption of a perishable good, c_t; v is the instantaneous utility of holding real domestic and foreign demand deposits, $\frac{dd_t}{p_t}$, and $\frac{e_t dd_t^*}{p_t}$, respectively; $\overline{k}_t$ is the average knowledge (across domestic residents) of using foreign currency. Functions u and v are assumed to be additively separable.

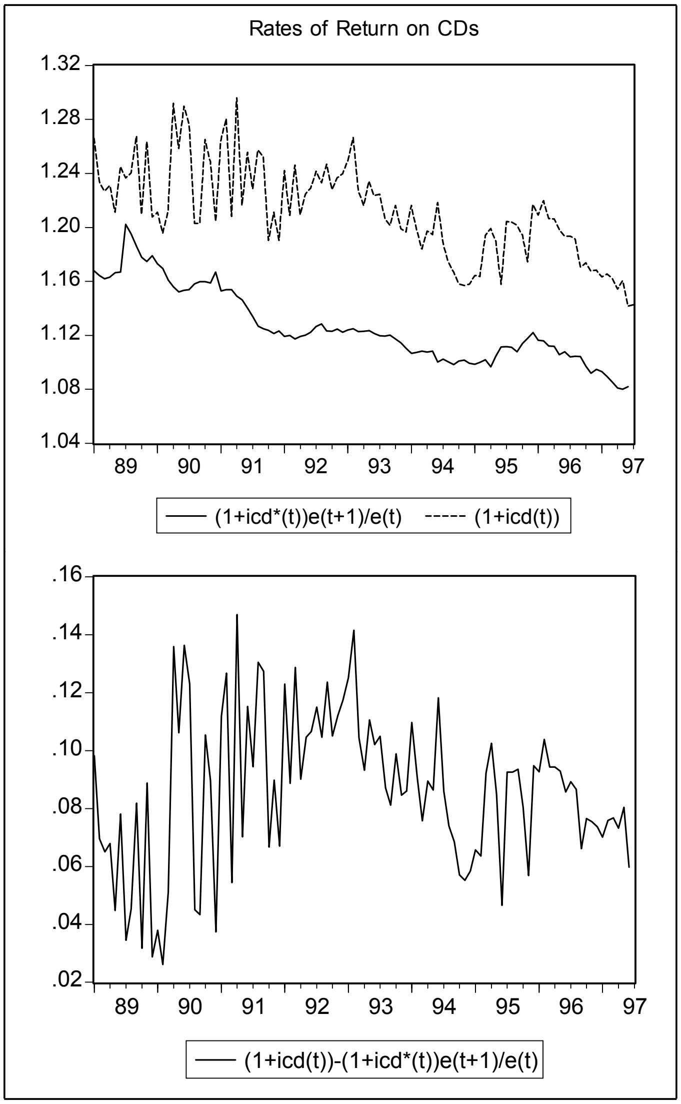

Figure 2: Interest Rates: Bolivia

We assume that v reflects the direct liquidity services obtained from currencies and the services provided by the stock of knowledge where v is ≥ 0, $\frac{\partial v}{\partial dd_t} \geq 0$, $\frac{\partial v}{\partial dd_t^*} \geq 0$, $\frac{\partial v^2}{\partial dd_t \partial dd_t} < 0$, $\frac{\partial v^2}{\partial dd_t^* \partial dd_t^*} < 0$, $\frac{\partial v^2}{\partial dd_t \partial dd_t} \frac{\partial v^2}{\partial dd_t^* \partial dd_t^*} - \frac{\partial v^2}{\partial dd_t \partial dd_t^*} < 0$. Under these conditions the money demand equations are well behaved. In particular, both currencies have positive, but diminishing marginal utilities.

Knowledge, $\overline{k}_t$, is accumulated through the use of foreign currency by domestic agents. A proxy for such knowledge at time, t, is represented by the maximum past dollarization ratio or:

$$\overline{k}_t = \max_j dr_j, \; j = 0, ..., t-1, \tag{2}$$

where dr_j is the dollarization ratio. The numerator of the dollarization ratio is FCDs (i.e., the sum of foreign demand deposits, dd_t^*, savings deposits, sd_t^*, and CDs, cd_t^*, held in domestic banks); and the denominator is M3. The idea behind this proxy is that knowledge of foreign currency is proportional to the largest amount of foreign currency previously used. We assume that knowledge accumulates equally from all foreign deposits.[8]

Each individual maximizes expected utility, choosing how much to consume of the perishable good, c_t, how much to save in the form of domestic and foreign CDs, and how much to hold for transactions at the end of the period, dd_t, and dd_t^*, subject to the budget constraint:

$$\begin{aligned} & c_t + \frac{dd_t}{p_t} + \frac{e_t dd_t^*}{p_t} + \frac{e_t cd_t^*}{p_t} + \frac{cd_t}{p_t} \\ \leq \; & y_t - \tau_t + \frac{dd_{t-1}}{p_t} + \frac{e_t dd_{t-1}^*}{p_t} + (1 + i_{cd,t}^*) \frac{e_t cd_{t-1}^*}{p_t} + (1 + i_{cd,t}) \frac{cd_{t-1}}{p_t}. \end{aligned} \tag{3}$$

The terms $y_t - \tau_t$ represent (exogenous) labor income after taxes in real terms. Domestic

---

[8] One may argue that knowledge depends only on the portion of FCDs used for transactions. In this case, knowledge would be the maximum of a narrow definition of the dollarization ratio (i.e., $\frac{e_t dd_t^*}{e_t dd_t^* + dd_t}$). We expect to examine this possibility in future research.

and foreign CDs, represented by cd_t, cd_t^* differ in terms of expected nominal returns $i_{cd,t+1}$, $i_{cd,t+1}^*$, respectively. Note that savings deposits, sd_t^*, are left out of the budget constraint. A derivation with savings is presented in Appendix C of the dissertation, but including these additional deposits fails to yield any additional insight in the model.

The budget constraint can be rewritten in real-deflated terms following Cuddington (2000):

$$\begin{aligned} & c_t + \frac{dd_t}{p_t} + \frac{e_t dd_t^*}{p_t} + \frac{e_t cd_t^*}{p_t} + \frac{cd_t}{p_t} \\ \leq \; & y_t - \tau_t + \left(\frac{p_{t-1}}{p_t}\right)\frac{dd_{t-1}}{p_{t-1}} + \left(\frac{e_t}{e_{t-1}}\right)\left(\frac{p_{t-1}}{p_t}\right)\frac{e_{t-1} dd_{t-1}^*}{p_{t-1}} \\ & +(1+r_{cd,t}^*)\frac{e_{t-1} cd_{t-1}^*}{p_{t-1}} + (1+r_{cd,t})\frac{cd_{t-1}}{p_{t-1}}. \end{aligned} \tag{4}$$

The period t values remain as before. The period, $t-1$, as real domestic money, $\frac{dd_{t-1}}{p_t}$ is multiplying by $\frac{p_{t-1}}{p_{t-1}}$ resulting in $\left(\frac{p_{t-1}}{p_t}\right)\frac{dd_{t-1}}{p_{t-1}}$. To deflate real domestic CDs, for example, $\frac{cd_{t-1}}{p_t}$ is multiplied by $\frac{p_{t-1}}{p_{t-1}}$, again. Using the definition for gross real return on domestic CDs at time $t-1$, $(1+r_{cd,t}) \equiv (1+i_{cd,t})(\frac{p_{t-1}}{p_t})$, the deflated expression is $(1+r_{cd,t})\frac{cd_{t-1}}{p_{t-1}}$. Deflating foreign currency real-lagged money, $\frac{e_t dd_{t-1}^*}{p_t}$, multiplication by $\frac{p_{t-1}}{p_{t-1}}$, and $\frac{e_{t-1}}{e_{t-1}}$ yields $\left(\frac{e_t}{e_{t-1}}\right)\left(\frac{p_{t-1}}{p_t}\right)\frac{e_{t-1} dd_{t-1}^*}{p_{t-1}}$. And finally, deflating real foreign currency CDs, $\frac{e_t cd_{t-1}^*}{p_t}$, entails multiplying by $\frac{p_{t-1}}{p_{t-1}}$, $\frac{e_{t-1}}{e_{t-1}}$, $\frac{p_{t-1}^*}{p_{t-1}^*}$ and $\frac{p_t^*}{p_t^*}$, where p_t^* is the foreign price level at time t. Using the definition of the real exchange rate at time t, $s_t \equiv \frac{e_t p_t^*}{p_t}$, we define the gross-real return on foreign CDs at time $t-1$, $(1+r_{cd,t}^*) \equiv (1+i_{cd,t}^*)(\frac{p_{t-1}^*}{p_t^*})(\frac{s_t}{s_{t-1}})$. These substitutions yield the deflated real foreign CDs, $(1+r_{cd,t}^*)\frac{e_{t-1} cd_{t-1}^*}{p_{t-1}}$. The same is done for savings deposits.

3 Functional Forms and Euler Equations

To parameterize the model, functional forms are chosen for the utility functions, u and v. Utility from consumption is assumed to be a constant relative risk aversion or constant intertemporal elasticity of substitution function:

$$u(c_t) = \frac{c_t^{1-\delta} - 1}{1-\delta}, \tag{5}$$

where $\delta > 0, \delta \neq 1$; for $\delta = 1$, $u(c_t) = \ln c_t$; and for $\delta = 0$, $u(c_t) = c_t$. The basic economic property of this function is that the elasticity of substitution in consumption between any two points in time is $\frac{1}{\delta}$.

Utility from money services, v, is assumed to be a Constant Elasticity of Substitution function (CES):

$$v\left(\frac{e_t dd_t^*}{p_t}, \frac{dd_t}{p_t}, \overline{k}_t\right) = \left[\alpha(\overline{k}_t)\left(\frac{e_t dd_t^*}{p_t}\right)^{\rho} + (1-\alpha(\overline{k}_t))\left(\frac{dd_t}{p_t}\right)^{\rho}\right]^{\frac{1}{\rho}} \tag{6}$$

where $-\infty < \rho < 1$, $0 \neq \rho$, and $0 \leq \alpha \leq 1$. This specification follows Imrohoroglu (1994), but modifies the coefficient on the share of foreign currency, α, by making it a function of $\overline{k}_t$, the country's accumulated knowledge of foreign currency.[9]

The logistic function is specified for $\alpha(\overline{k}_t)$:

$$\alpha(\overline{k}_t) = \frac{1}{1+\exp(-\gamma_2 \overline{k}_t - \gamma_1)}; \qquad \overline{k}_t \; \epsilon \; (0,1) \; . \tag{7}$$

This functional form has desirable properties. First, it is bounded by zero and one, which is sensible for modelling shares. Second, the first derivative is positive, which implies that the share of foreign currency increases with knowledge. Third, the function looks like a typical

---

[9] In subsequent work, we hope to explore $\rho(\overline{k}_t)$.

cumulative density function which means that marginal effects at the tails are small. Thus, at very low and high levels of knowledge the marginal effects on the way money is used are small. But for the central values, there may be decreasing or increasing marginal effects of knowledge on the share α (i.e. the second derivative, $\frac{d\alpha^2}{d^2\overline{k}}$, can be > 0, $= 0$, or < 0).

Note that if the network externality coefficient, γ_2, is zero then $\alpha(\overline{k}_t)$ is a constant, $\frac{1}{1+\exp(-\gamma_1)}$, and the function v reverts to a CES form with no network externality (as in Imrohoroglu (1994)). $\gamma_1 \neq 0$ allows for the arbitrariness of the starting date when defining $\overline{k}_t$.

The Euler equations below characterize the interior solution of the consumer's maximization problem in terms of five unknown parameters $\{\beta, \delta, \rho, \gamma_1, \gamma_2\}$:[10]

$$E_t \left\{ \left[\beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} (1 + r_{cd,t+1}) - 1 \right] |I_t \right\} = 0, \tag{8}$$

$$E_t \left\{ \left[\beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} (1 + r^*_{cd,t+1}) - 1 \right] |I_t \right\} = 0, \tag{9}$$

$$E_t \left\{ \left[(1-\alpha(\overline{k}_t)) c_t^{\delta} A_t (\frac{dd_t}{p_t})^{\rho-1} + \beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} \left(\frac{p_t}{p_{t+1}} \right) - 1 \right] |I_t \right\} = 0, \tag{10}$$

$$E_t \left\{ \left[\alpha(\overline{k}_t) c_t^{\delta} A_t (\frac{e_t dd^*_t}{p_t})^{\rho-1} + \beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} \left(\frac{p_t}{p_{t+1}} \right) \left(\frac{e_{t+1}}{e_t} \right) - 1 \right] |I_t \right\} = 0, \tag{11}$$

where

$$A_t = \left[\alpha(\overline{k}_t) (\frac{e_t dd^*_t}{p_t})^{\rho} + (1-\alpha(\overline{k}_t)) (\frac{dd_t}{p_t})^{\rho} \right]^{\frac{1}{\rho}-1}.$$

Note that the expectations, denoted by E_t above, are conditional on all variables that are in the consumers' information set, $i_{cd,t}$. This includes lags of all past variables in the model, among other things. β is the subjective discount factor, and $(1 + r_{cd,t+1})$ and $(1 + r^*_{cd,t+1})$ are the random gross-real rates of returns on domestic and foreign currency financial assets,

---

[10] For derivations of the Euler equations, see Appendix C of the dissertation.

respectively. $\left(\frac{c_t}{c_{t+1}}\right)^{\delta}$ is one plus the growth in marginal utility of consumption, $\frac{e_{t+1}}{e_t}$ denotes one plus the nominal depreciation rate of the domestic currency, $\frac{p_t}{p_{t+1}}$ denotes the inverse of one plus the inflation rate.

For ease in estimation, equations (10) and (11) are used to construct a ratio of monies, as in Imrohoroglu (1994). The second and third terms in both equations are moved to the right hand side. A_t is then isolated in equation (11), and substituted to the altered (10). These Euler equations can be rewritten as:

$$\left\{ \begin{array}{c} \left[(1-\alpha(\overline{k}_t))(\frac{dd_t}{e_t dd_t^*})^{\rho-1}\left[1-E_t\left\{\beta\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\left(\frac{e_{t+1}}{e_t}\right)\right\}|I_t\right]\right] \\ -\alpha(\overline{k}_t)\left[1-E_t\left\{\beta\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\right\}|I_t\right] \end{array} \right\} = 0 \tag{12}$$

where all variables are as described above.

In the current model, the random variables that form the basis for GMM estimation are ex-post deviations from optimal consumption and money balances paths expressed in the Euler equations. These deviations are expressed as equations (8), (9) and (12):

$$\beta(1+r_{cd,t})\left(\frac{c_t}{c_{t+1}}\right)^{\delta}-1=\varepsilon_{1,t+1}, \tag{13}$$

$$\beta(1+r^*_{cd,t})\left(\frac{c_t}{c_{t+1}}\right)^{\delta}-1=\varepsilon_{2,t+1}, \tag{14}$$

$$\left\{ \begin{array}{c} \left[\left(1-\frac{1}{1+\exp(-\gamma_2\overline{k}_t-\gamma_1)}\right)(\frac{dd_t}{e_t dd_t^*})^{\rho-1}\left[1-\beta\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\left(\frac{e_{t+1}}{e_t}\right)\right]\right] \\ -\left(\frac{1}{1+\exp(-\gamma_2\overline{k}_t-\gamma_1)}\right)\left[1-\beta\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\right] \end{array} \right\} = \varepsilon_{3,t+1} \tag{15}$$

where the Euler equation errors are denoted by $\varepsilon_{1,t+1}$, $\varepsilon_{2,t+1}$, and $\varepsilon_{3,t+1}$. These expectational errors can be interpreted as shocks to technology, preferences or prediction errors due to uncertainty. They can also reflect measurement error for consumption, since exports are used to generate the consumption series Note that these expressions contain unknown parameter values and data. The Euler equations imply that the unconditional expectations of these random variables are zero.

Since there are five unknown parameters $(\beta, \delta, \rho, \gamma_1, \gamma_2)$ in this set of three unconditional expectations, the corresponding sample means of the "residuals" are insufficient to identify the parameters; additional moment conditions are required. Additional moment conditions can be secured by defining appropriate instrumental variables. Take z_t as the realization of an instrumental variable that is in the consumers' information set at time, t, and define a new variable, $\varepsilon_t z_t$. If z_t is an appropriate instrument, the moment condition on $\varepsilon_t z_t$ is $E[\varepsilon_t z_t] = 0$. GMM selects parameter estimates that make $\frac{1}{T}\sum \varepsilon_t z_t$ as close to zero as possible. Note that $z_t = 1$ is a possible instrument.

If the number of moment conditions is identical to the number of unknown parameters, then the parameters are exactly identified and the sample moments can be made to hold exactly. If the number of moment conditions exceeds the number of unknown parameters, then the parameters are over-identified and weighted averages of the sample moments are minimized.

In the current work, if we select a single instrument (not 1) we secure an additional moment associated with the product of that instrument with each of the three stochastic errors. With six conditions, the five variables are overidentified and estimation is feasible. However, availability of additional instruments and their corresponding conditions would enhance the efficiency of estimation. Recall that the expectations in (8), (9) and (12) are conditional on the relevant consumer information set, I_t, which is composed of all past values of the variables in the model:

$$I_t = \left\{ \begin{array}{c} r_{cd,t-i+1}, r^*_{cd,t-i+1}, \frac{c_{t-i}}{c_{t-i+1}}, \frac{dd_{t-i}}{e_{t-i}dd^*_{t-i}}, \\ \frac{e_{t-i+1}}{e_{t-i}}, \frac{p_{t-i}}{p_{t-i+1}}, \overline{k}_{t-i}, \frac{e_{t-i}cd^*_{t-i-1}}{p_{t-i}}, \frac{cd_{t-i-1}}{p_{t-i}} \end{array} \right\}_{i=1}^{\infty}. \tag{16}$$

Tauchen (1986) and Kocherlakota (1990) provide Monte Carlo evidence that instrument sets with variables lagged a fewer times perform better than if many lags are included. This is consistent with Fair's (1970) prescription for two-stage-least-squares applications involving systems of equations with AR(1) errors. Thus, the instrument set we use contains the one period lagged values of all seven variables in the Euler equations and constant:

$$I_t = \left\{ 1, r_{cd,t}, r^*_{cd,t}, \frac{c_{t-1}}{c_t}, \frac{dd_{t-1}}{e_{t-1}dd^*_{t-1}}, \frac{e_t}{e_{t-1}}, \frac{p_{t-1}}{p_t}, \overline{k}_{t-1} \right\}. \tag{17}$$

This instrument set provides twenty-four moment conditions, so the parameters are overidentified.

Hansen's (1982) J test statistic is used to test the overidentifying restrictions. The J statistic is asymptotically chi-square with degrees of freedom equal to the degree of overidentification. If the value of J is "large" the overidentifying restrictions are rejected.

Hansen (1982) establishes the properties of the GMM estimator under the assumption that the variables involved are strictly stationary. This motivated to test for deterministic trends and unit roots, see Appendix. Time-series graphs of the data can be found in Figures 4 - 6. All the variables were found to be integrated of degree zero, but some possessed deterministic trends. These series were de-trended in the usual way prior to GMM estimation, following Ogaki (1993), and Eichenbaum and Hansen (1990). Both the trended and detrended series are used in the estimation.

The GMM estimates are found by minimizing a quadratic form in the deviations from the sample moment conditions. The optimal weighing matrix for the quadratic form is the inverse of the estimated error covariance matrix, as shown by Hansen (1982). This estimator has to account for autocorrelation among the errors, when the autocorrelation order is unknown. The error covariance are estimated as weighing averages of the successive order of autocorrelations. These weights are empirically determined by kernel density functions. We follow Andrews (1991) in using a quadratic spectral (QS) kernel with an empirically determined bandwidth parameter. This estimation procedure is one of several that may be automatically executed using EViews© Software.

4 Estimation Results and Hypothesis Tests

This section reports GMM estimation results. For time-series graphs of the data, see Figures 3 - 6.

Table 1 presents results from estimating the model using starting values of $\{\widehat{\beta}$=0.83, $\widehat{\delta}$=0.02, $\widehat{\rho}$=0.99, $\widehat{\gamma}_1$=-0.83, $\widehat{\gamma}_2$=0.24 $\}$.[11] We begin by examining the magnitude of the J statistic to determine if the model might be mispecified. The J statistic is close to zero, and we fail to reject the overidentifying restrictions.

The estimated value for the subjective discount factor, β, is 0.83 and is highly significant. This estimate is smaller than the 0.99 estimate obtained by Imrohoroglu (1994) for Canada or Finn, Hoffman, and Schlagenhauf (1990) and Eichenbaum and Hansen (1990) for the United States. The estimate of the risk aversion parameter $(1-\delta) = 0.992$ is estimated to be less than one. But $\delta = 0$ can not be rejected with a t-statistic of 0.67. Imrohoroglu's (1994) estimates for $(1-\delta)$ range from 0.005 to 0.89 for Canada, depending on the specification

---

[11] Starting guesses were obtained from non-linear least squares estimations. One hundred other initial starting values were used to check the robustness of the parameter estimates.

Table 1: Estimation Results: Bolivia

Bolivia, 1989:01 - 1997:07				
Bandwidth	1.85			
J statistic	0.227			
Parameter	coefficient	standard error	t-statistic	p-value
β	0.832	0 .002	321.65	0.00
δ	0.008	0.013	0.67	0.50
ρ	1.018	0.051	19.91	0.00
γ_1	0.316	0.879	0.37	0.71
γ_2	-1.020	0.990	-1.03	0.30

Estimations used: Prewhitening, QS Kernel and Andrews bandwidth.

of the model. The estimate for ρ is 1.01 and not significantly different than one. This implies and infinite elasticity of substitution, $\frac{1}{1-\rho}$, between the US Dollar and the Boliviano. Imrohoroglu's (1994) estimates of the elasticity of substitution between the Canadian and US Dollars, range from 0.229 to 0.303. The other two parameters, γ_1 and γ_2, have estimates of 0.31 and -1.02, respectively.

4.1 Testing for Network Externalities

There are several ways to test if the parameter estimate for the network externality, γ_2, is significantly different from zero. One of them is Wald test (t-statistic) and another one is a likelihood-ratio (LR) test. The simple t-statistic in the original model (Table 1) suggest the network externality effect is statistically insignificant. Moreover it does not have the positive sign that the network externality hypothesis predicts. In this subsection, we use the Eichenbaum, Hansen and Singleton (1988) LR test the restriction $\gamma_2 = 0$ in order to get new parameter estimates with the imposed restriction.

The estimation equations for the restricted model are given by:

$$\beta(1 + r_{cd,t+1}) \left(\frac{c_t}{c_{t+1}}\right)^{\delta} - 1 = \varepsilon_{6,t+1}, \tag{18}$$

$$\beta(1 + r^*_{cd,t+1}) \left(\frac{c_t}{c_{t+1}}\right)^{\delta} - 1 = \varepsilon_{7,t+1}, \tag{19}$$

$$\left\{ \begin{array}{c} \left[\left(1 - \frac{1}{1+\exp(-\gamma_1)}\right) (\frac{dd_t}{e_t dd_t^*})^{\rho-1} \left[1 - \beta \left(\frac{c_t}{c_{t+1}}\right)^{\delta} \left(\frac{p_t}{p_{t+1}}\right) \left(\frac{e_{t+1}}{e_t}\right)\right]\right] \\ - \left(\frac{1}{1+\exp(-\gamma_1)}\right) \left[1 - \beta \left(\frac{c_t}{c_{t+1}}\right)^{\delta} \left(\frac{p_t}{p_{t+1}}\right)\right] \end{array} \right\} = \varepsilon_{8,t+1} \tag{20}$$

and the Euler equation errors are denoted by $\varepsilon_{6,t+1}$, $\varepsilon_{7,t+1}$, and $\varepsilon_{8,t+1}$.

The estimates of the restricted model, using the same instrument set and initial parameter values, are presented in Table 2. The J statistic is once gain small, implying a non-rejection of the overidentification of the model.

The parameter estimates for most coefficients are similar to the ones found in the previous sections, but their significance has improved. The estimate for the subjective discount factor, β, is economically significant and close to 0.89, with very small standard errors. The estimate for the parameter for elasticity of risk aversion, $(1-\delta)$, is less than one, but with a t-statistic of 0.05, a linear utility function in consumption is not ruled out. Testing $\delta = 1$ would specify a logarithmic utility function which is rejected. The parameter estimate for ρ is 0.99 with a t-statistic of 61.58, implying a very high elasticity of substitution. The parameter estimate for γ_1 is -0.65 with an increased significance compared to previous estimations. This estimated parameter value translates to an estimated α value of 0.34, lower than the Bolivian average dollarization ratio in demand deposits. The estimation of α has not changed very much with the parameter restriction.

The Eichenbaum, Hansen and Singleton (1988) LR test statistic is 0.05. This implies that the null hypothesis that contains the restriction $\gamma_2 = 0$ is not rejected[12] . Thus, the network externality term, γ_2, appears to be unimportant for explaining post-inflationary

---

[12] The appropriate likelihood-ratio statistic is $LR = T(Q^r - Q^{ur})$, where T is the total sample size, Q^{ur} is the minimand from the original model, while Q^r is the minimand on the model with parameter restrictions.

Table 2: Estimation Results for the Model without Network Externalities: Bolivia

Bolivia, 1989:01 - 1997:07				
Bandwidth	2.10			
J statistic	0.17			
LR test[1]	0.05			
Parameter	coefficient	standard error	t-statistic	p-value
β	0.897	0.005	175.88	0.00
δ	0.001	0.001	0.05	0.95
ρ	0.990	0.016	61.58	0.00
γ_1	-0.650	0.009	-66.18	0.00
γ_2	0	imposed	-	-

1- Eichenbaum, Hansen and Singleton (1988) Likelihood Ratio test statistic.
Estimations used: Prewhitening, QS Kernel and Andrews bandwidth.

dollarization in Bolivia.

4.2 Assessing the Importance of Portfolio Considerations

This subsection presents evidence from estimating a model without portfolio choice by counterfactually assuming perfect asset substitutability. New Euler equations are derived assuming that interest-bearing assets in domestic and foreign currency are perfect substitutes. Individuals are assumed to choose a sum of CDs holdings, $F_t^* \equiv (cd_t^* + \frac{cd_t}{e_t})$, rather than the individual foreign and domestic currency CDs, $e_t cd_t^*$, cd_t, respectively. The relevant real rate of return is denoted by $r^*_{cd,t+1}$.[13] The new budget constraint is characterized by:

$$\begin{aligned} & c_t + \frac{dd_t}{p_t} + \frac{e_t dd_t^*}{p_t} + \frac{e_t F_t^*}{p_t} \\ \leq \; & y_t - \tau_t + \left(\frac{p_{t-1}}{p_t}\right)\frac{dd_{t-1}}{p_{t-1}} + \left(\frac{e_t}{e_{t-1}}\right)\left(\frac{p_{t-1}}{p_t}\right)\frac{e_{t-1}dd^*_{t-1}}{p_{t-1}} \\ & +(1 + r^*_{cd,t+1})\frac{e^*_{t-1}F^*_{t-1}}{p_{t-1}}. \end{aligned} \tag{21}$$

The agent chooses how much to: consume of the perishable good, c_t, save in the form of CDs, F_t^*, and hold cash, dd_t, and dd_t^*. Assuming the same functional forms for preferences,

---

[13] The weighted average of the foreign and domestic CD rates was used in these estimations.

u and v, the Euler equations below characterize the interior solution of the maximization and contain unknown parameters $\{\beta, \delta, \rho, \gamma_1, \gamma_2\}$:

$$E_t \left\{ \left[\beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} (1 + r^*_{cd,t+1}) - 1 \right] | i_{cd,t} \right\} = 0, \tag{22}$$

$$E_t \left\{ \left[c_t^{\delta} A_t (1 - \alpha(\overline{k}_t)) (\frac{dd_t}{p_t})^{\rho - 1} + \beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} \left(\frac{p_t}{p_{t+1}} \right) - 1 \right] | i_{cd,t} \right\} = 0, \tag{23}$$

$$E_t \left\{ \left[c_t^{\delta} A_t \alpha(\overline{k}_t) (\frac{e_t dd_t^*}{p_t})^{\rho - 1} + \beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} \left(\frac{p_t}{p_{t+1}} \right) \left(\frac{e_{t+1}}{e_t} \right) - 1 \right] | i_{cd,t} \right\} = 0, \tag{24}$$

where

$$A_t = \left[\alpha(\overline{k}_t) (\frac{e_t dd_t^*}{p_t})^{\rho} + (1 - \alpha(\overline{k}_t)) (\frac{dd_t}{p_t})^{\rho} \right]^{\frac{1}{\rho} - 1}.$$

The estimation equations for the restricted model are:

$$\beta (1 + r^*_{cd,t+1}) \left(\frac{c_t}{c_{t+1}} \right)^{\delta} - 1 = \varepsilon_{4,t+1}, \tag{25}$$

$$\left\{ \begin{array}{c} \left[\left(1 - \frac{1}{1 + \exp(-\gamma_2 \overline{k}_t - \gamma_1)} \right) (\frac{dd_t}{e_t dd_t^*})^{\rho - 1} \left[1 - \beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} \left(\frac{p_t}{p_{t+1}} \right) \left(\frac{e_{t+1}}{e_t} \right) \right] \right] \\ - \left(\frac{1}{1 + \exp(-\gamma_2 \overline{k}_t - \gamma_1)} \right) \left[1 - \beta \left(\frac{c_t}{c_{t+1}} \right)^{\delta} \left(\frac{p_t}{p_{t+1}} \right) \right] \end{array} \right\} = \varepsilon_{5,t+1} \tag{26}$$

where the Euler equation errors are denoted by $\varepsilon_{4,t+1}$, and $\varepsilon_{5,t+1}$. The number of Euler equations is reduced by one since there one less choice variable.

The results of this restricted model, using the previously used instrument set and initial parameter values, are presented in Table 3. The J statistic is once gain small, implying we fail to reject the overidentification restrictions. The estimate for the subjective discount factor, β, is economically significant and is 0.89, with very small standard errors. The estimated parameter for elasticity of risk aversion, $(1 - \delta)$, is 1 and has a p-value of 0.95. The parameter estimates for ρ is 1.11, the t-statistic to test if $\rho = 1$ is 1.66 implying a very large elasticity of substitution between the Boliviano and US Dollar in transactions.

Table 3: Estimation Results for the Model Assuming Perfect Capital Mobility: Bolivia

Bolivia, 1989:01 - 1997:07				
Bandwidth	2.16			
J statistic	0.140			
LR test[1]	0.086			
Parameter	coefficient	standard error	t-statistic	p-value
β	0.89	0.005	175.58	0.00
δ	-0.00	0.012	-0.06	0.95
ρ	1.11	0.066	16.97	0.00
γ_1	1.57	1.227	1.27	0.20
γ_2	-2.50	1.37	-1.82	0.07

Estimations used: Prewhitening, QS Kernel and Andrews bandwidth.

1- Eichenbaum, Hansen and Singleton (1988) Likelihood Ratio test statistic.

The other two parameter estimates, γ_1 and γ_2, have relatively higher standard errors and consequently higher p-values at 0.20 and 0.07, respectively.

The Eichenbaum, Hansen and Singleton (1988) likelihood ratio test statistic is 0.086. This implies that the null hypothesis that imposes all the moment conditions (as the general portfolio balance model does), as specified in Section 2, is not rejected.[14]

5 Conclusion

This paper presented a model that embodies two competing theories that explain dollarization after price stabilization: the network externalities hysteresis hypothesis and portfolio balance theories. This monies-in-the-utility-function model with a network externality has two currencies that provide liquidity services. In addition, a proxy for a country's average accumulated knowledge in using foreign currency enters the utility function. This additional

---

[14] The appropriate likelihood-ratio statistic is $LR = T(Q^r - Q^{ur})$, where T is the total sample size. Q^r is the minimized value of the objective function for the **original model**, when all the Euler equations are used. This is considered econometrically a more restrictive model since the data must satisfy additional moment conditions. Q^{ur} is the minimized value of the objective function for the model with no portfolio choice. The value Q equals $\frac{J}{T}$.

factor may enhance liquidity services and reflects a simple form of network externalities postulated by Uribe (1997). In order to incorporate the portfolio balance theory, non-liquid foreign and domestic currency deposits, or CDs, are included such that their demand is based on the uncertain domestic and foreign rates of return.

The empirical estimations yield support for modeling dollarization with two different roles for money. This setup enabled us to find that US Dollar CDs behave differently from US Dollar demand deposits in Bolivia. The US Dollar CDs, the portfolio asset, are found to be an imperfect substitutes for the Boliviano CDs, while the US Dollar demand deposits is almost interchangeable with the Boliviano demand deposits. The GMM estimations yielded strong support for the over-identifying restrictions, and thus to specified model. Two estimated preference parameters were consistently significant, the discount factor and the parameter to construct the elasticity of substitution between the two currencies (p-values of 0.00). The estimated coefficient for the discount factor was similar to those found in estimations for other countries. The calculated elasticity of substitution is positive and very large, much larger than others find for other developed countries. It is possible that this would differ if we included cash in the estimations. In testing for network externalities, we find no evidence to support the theory, at least not using this proxy during this sample period. The p-value of the coefficient estimate is 0.30 when we estimate the complete model. Likelihood-Ratio tests confirm these results. We hope to examine, what happens if we had assumed knowledge in transactions to be accumulated only from the use of foreign currency in transactions. It is more difficult to directly assess the role of portfolio balance considerations since these are imbedded in the preference parameters. The GMM estimations did not reject the model which distinguishes between domestic and foreign currency CDs.

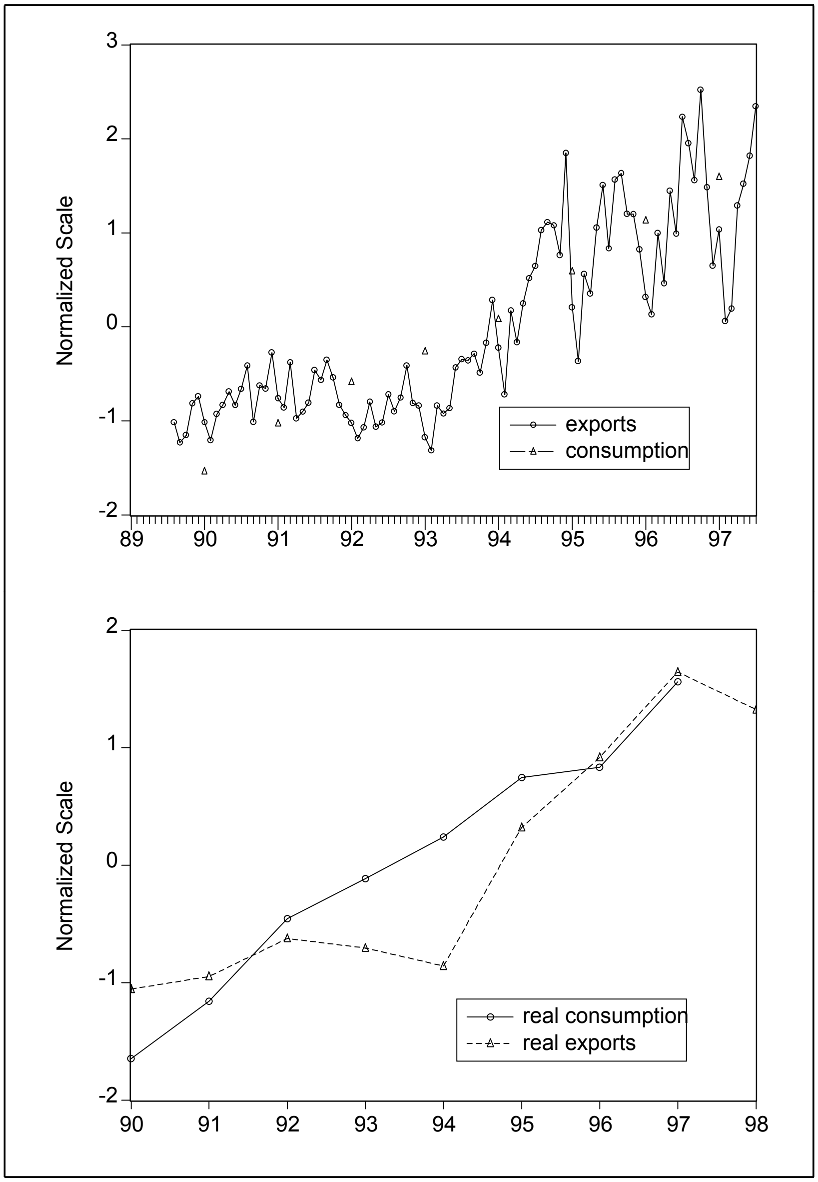

Figure 3: Real Consumption and Exports: Bolivia

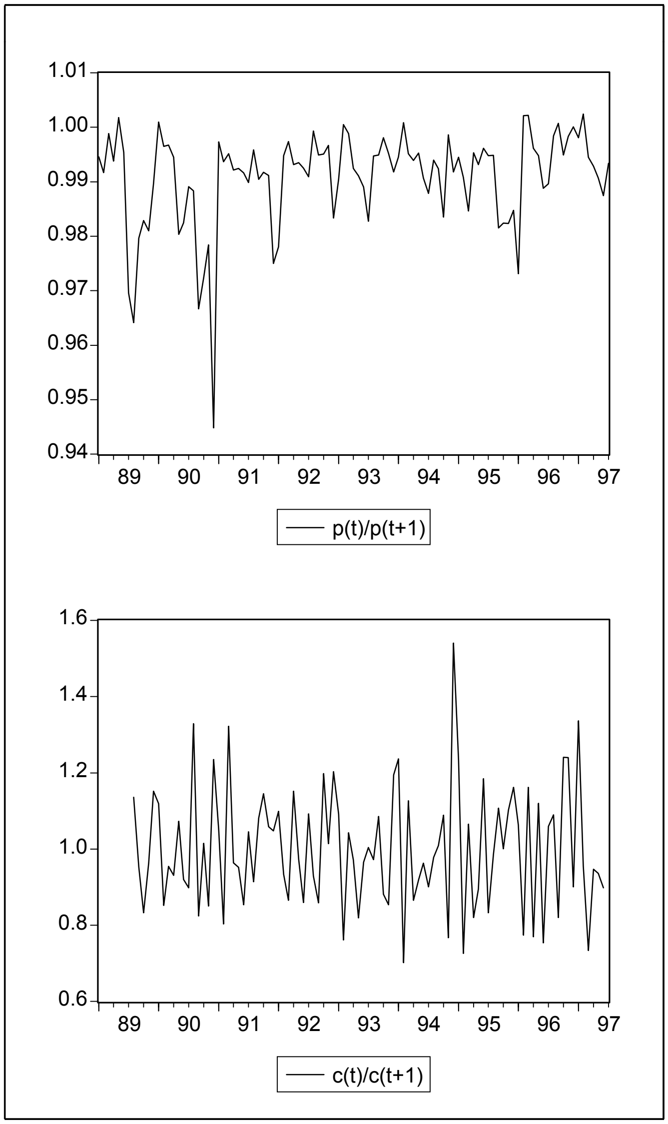

Figure 4: Gross Inverse Inflation and Consumption Growth: Bolivia

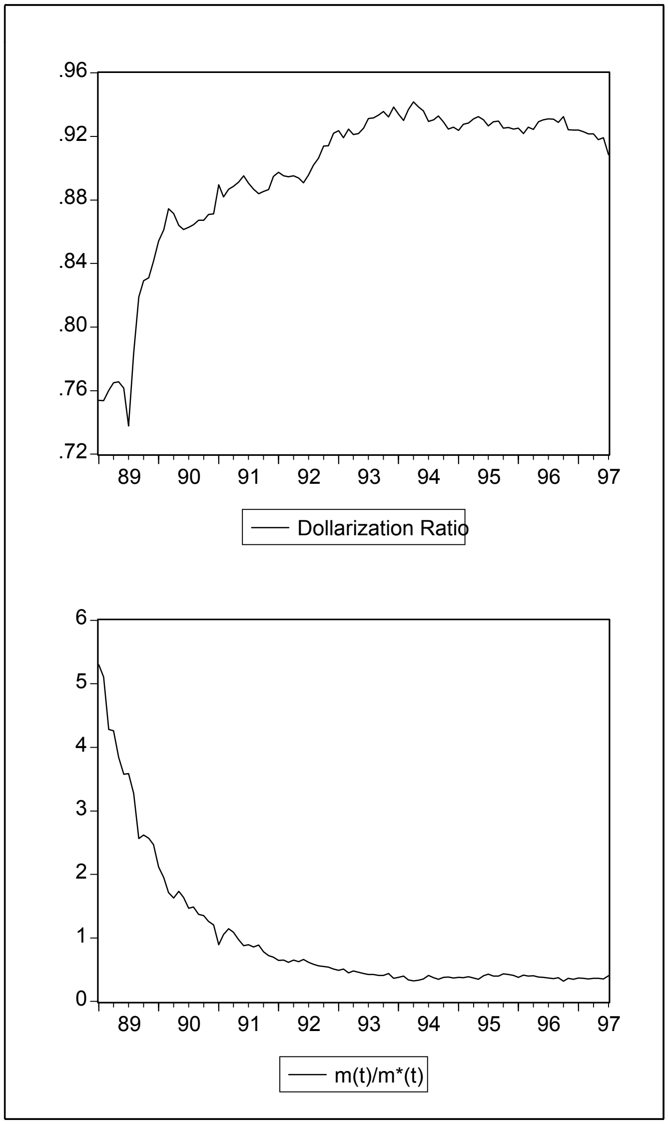

Figure 5: Dollarization Ratio and Ratio of Monies: Bolivia

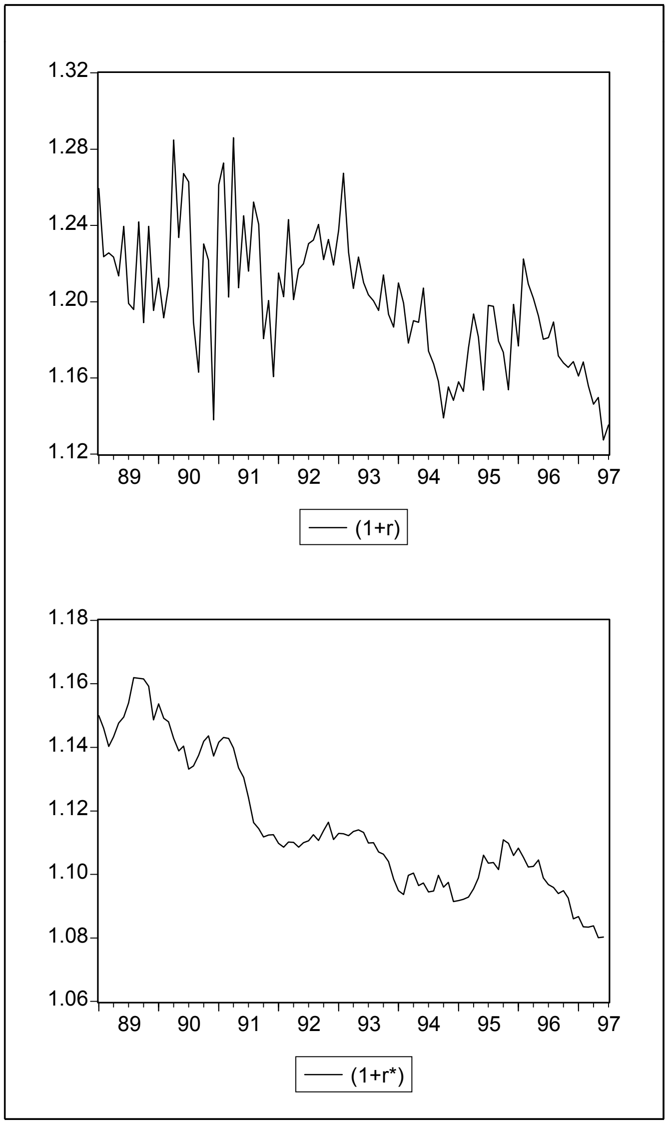

Figure 6: Domestic and Foreign Interest Rates: Bolivia

References

[1] Alami, Tarik. 1996. Dollarization and Money Demand in Egypt, Ph.D. dissertation, American University.

[2] Andrews, D. W. K. 1991. "Heterosckedasticity and Autocorrelation Consistent Covariance Matrix Estimation". *Econometrica*, 59 : 817-858.

[3] Battaile, William. 1996. Dollarization and Inflation Stabilization in Latin America, Ph.D. dissertation, Georgetown University.

[4] Calvo, Guillermo, and Carlos Vegh. 1992. "Currency Substitution in Developing Countries: An Introduction". *Revista de Analisis Economico*, 7 No.1 : 3-27.

[5] Canzoneri, Matthew, and Behzad Diba. 1993. "Currency Substitution and Exchange Rate Volatility in the European Community". *Journal of International Economics*, 35 : 351-365.

[6] Cuddington, John. 2000. Analyzing the Sustainability of Fiscal Deficits in Developing Countries. Mimeo, (30 April).

[7] Cuddington, John, and Robert E. Cumby. 1997. Macroeconomics Using EViews Software. Notes for the Learning and Leadership Center, A World Bank Course, October 10-17, 1997.

[8] Eichenbaum, M., and L. P. Hansen. 1990. "Estimating Models with Intertemporal Substitution using Aggregate Time Series Data". *Journal of Business and Economics Statistics*, 8 : 53-69.

[9] Eichenbaum, M. L. P. Hansen, and K. J. Singleton . 1988. "A Time Series Analysis of Representative Agent Models of Consumption and Leisure Choice under Uncertainty". *Quarterly Journal of Economics*, 103 : 51-75.

[10] Fair, Ray. 1970. "The Estimation of Simultaneous Equations Models with Lagged Endogenous Variables and First Order Serially Correlated Errors". *Econometrica,* 38: 507-516.

[11] Finn, M. G., D. L. Hoffman, and D. E. Schlagenhauf. 1990. "Intertemporal Asset-Pricing Relationships in Barter and Monetary Economies, an Example Analysis". *Journal of Monetary Economics,* 25 : 431-451.

[12] Garcia, Gillian. 1999. Deposit Insurance: A Survey of Actual and Best Practices. International Monetary Fund working paper, WP/99/54 (April).

[13] Giovannini, Alberto, and Bart Turtelboom. 1994. "Currency Substitution" in Handbook of International Macroeconomics, va der Ploeg, ed., Oxford: Blackwell.

[14] Hansen, L. P. 1982. "Large Sample Properties of Generalized Method of Moments Estimators". *Econometrica*, 50 : 1029-1054.

[15] Hansen L. P. , and K. J. Singleton. 1982. "Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models". *Econometrica*, 50 : 1269-1286.

[16] Imrohoroglu, Selahattin. 1994. "GMM Estimates of Currency Substitution between Canada and the U.S. dollar". *Journal of Money, Credit and Banking*, 26 No. 4 : 792-807.

[17] Kamin, Steven, and Neil R. Ericsson. 1993. Dollarization in Argentina. International Finance Discussion Paper, U.S. Board of the Federal Reserve. No. 460 (November).

[18] Kocherlakota, N. 1990. "On Tests of Representative Consumer Asset Pricing Models". *Journal of Monetary Economics,* 26 : 285-304.

[19] Lizondo, J. Saul. 1983. "Interest Rate Differentials and Covered Interest Arbitrage" in Financial Policies and the World Capital Market, Pedro Aspe Armella, Rudiger Donbusch, and Maurice Obsfeld, eds., Chicago: University of Chicago Press.

[20] Ogaki, Masao. 1993. "Generalized Method of Moments: Econometric Applications" in Handbook of Statistics, Vol 11., G. S. Maddala, C. R. Rao, and H. D. Vinod, eds., Elsevier Science Publishers.

[21] ________. 1999. "GMM Estimation Techniques" in Generalized Method of Moments Estimation., Laszlo Matyas, ed., Cambridge University Press.

[22] Parsley D. and S. Wei. 1993. "Insignificant and Inconsequential Hysteresis: The Case of US Bilaterial Trade". *The Review of Economics and Statistics*, 75 (November) : 606-613.

[23] Peiers, Bettina Marion. 1994. Two Essays in International Finance. Ph.D dissertation, Arizona State University.

[24] Peiers, Bettina, and Jeffrey Wrase. 1997. "Dollarization Hysteresis and Network Externalities: Theory and Evidence from an Informal Credit Market". Federal Reserve Bank of Philadelphia, Working Paper No. 97-21.

[25] Phylaktis, Kate. 1988. "Capital Controls: The Case of Argentina". *Journal of International Money and Finance, 7 : 303-320.*

[26] Sahay, Ratna, and Carlos Vegh. 1996. "Dollarization in Transition Economies: Evidence and Policy implications". in The Macroeconomics of International Currencies: Theory Policy and Evidence, Paul Mizen, and Eric Pentecost, eds., UK: Edward Elgar Publishing.

[27] Tauchen, G. 1986. "Statistical Properties of Generalized Method of Moments Estimators of Structural Parameters Obtained from Financial Market Data". *Journal of Business and Economics Statistics,* 4 : 397-425.

[28] Uribe, Martin. 1997. "Hysteresis in a Simple Model of Currency Substitution". *Journal of Monetary Economics*, 40 No. 1: 1299-1303.

Appendix A

This appendix contains technical components for the paper that are critical but can distract the reader from the main points of the analysis. It contains three sections. Section 1 describes the importance of the stochastic-interest-rate assumption. Section 2 discusses the data and its sources. Section 3 presents the results from unit-root tests.

1 The Stochastic Nominal Interest Rate Assumption

Note that there are three sources of uncertainty in real interest rates. The first stems from price uncertainty. The second arises from assuming that nominal interest rates are unknown. Third, there is no proxy for expected currency devaluation. The second assumption is crucial for the model. If we assume otherwise, algebraic manipulation of the Euler equations yields a deterministic ratio of money demands identical to those derived by Canzoneri and Diba (1993, p. 354). The only difference is that they do not have the network externality term and assume $\alpha = 0.5$.

Their derivation is as follows. Assume that nominal interest rates are known, but there is uncertainty about the price level. The Euler equations are derived using the non-deflated terms (i.e.; the deflation of Section 2 is not applied) resulting in:

$$\beta(1+i_{cd,t+1})E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)|I_t\right\}=1, \tag{1}$$

$$\beta(1+i^*_{cd,t+1})E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\left(\frac{e_{t+1}}{e_t}\right)|I_t\right\}=1, \tag{2}$$

$$\beta(1+i_{sd,t+1})E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)|I_t\right\}=1, \tag{3}$$

$$\beta(1+i^*_{sd,t+1})E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\left(\frac{e_{t+1}}{e_t}\right)|I_t\right\}=1, \tag{4}$$

$$c_t^{\delta} A_t(1-\alpha(\overline{k}_t))\left(\frac{dd_t}{p_t}\right)^{\rho-1} + \beta E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)-1\right\}=0, \tag{5}$$

$$c_t^{\delta} A_t\alpha(\overline{k}_t)\left(\frac{e_t dd_t^*}{p_t}\right)^{\rho-1} + \beta E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\left(\frac{e_{t+1}}{e_t}\right)-1\right\}=0. \tag{6}$$

The stochastic nature of the nominal interest rates has been eliminated, so we combine the last two equations in the following manner: place equations (1) into (5) by eliminating the one, do the same with equation (2) and (6); take the second term in both altered equations (5) and (6) to the right hand side, and divide them one by the other. The result is:[15]

$$\begin{aligned} &\frac{c_t^{\delta} A_t(1-\alpha(\overline{k}_t))\left(\frac{dd_t}{p_t}\right)^{\rho-1}}{c_t^{\delta} A_t\alpha(\overline{k}_t)\left(\frac{e_t dd_t^*}{p_t}\right)^{\rho-1}} \\ = \;& \frac{\beta E_t\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)-(1+i_{cd,t+1})\beta E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)|I_t\right\}}{\beta E_t\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\left(\frac{e_{t+1}}{e_t}\right)-(1+i^*_{cd,t+1})\beta E_t\left\{\left(\frac{c_t}{c_{t+1}}\right)^{\delta}\left(\frac{p_t}{p_{t+1}}\right)\left(\frac{e_{t+1}}{e_t}\right)|I_t\right\}}, \end{aligned} \tag{7}$$

further simplification yields:

$$\frac{(1-\alpha(\overline{k}_t))\left(\frac{dd_t}{p_t}\right)^{\rho-1}}{\alpha(\overline{k}_t)\left(\frac{e_t dd_t^*}{p_t}\right)^{\rho-1}} = \frac{i_{cd,t+1}/(1+i_{cd,t+1})}{i^*_{cd,t+1}/(1+i^*_{cd,t+1})}, \tag{8}$$

isolating for money demand results in:

$$\frac{dd_t}{e_t dd_t^*} = \left[\frac{\alpha(\overline{k}_t)}{(1-\alpha(\overline{k}_t))}\frac{i_{cd,t+1}/(1+i_{cd,t+1})}{i^*_{cd,t+1}/(1+i^*_{cd,t+1})}\right]^{1/\rho-1}, \tag{9}$$

and after replacing the functional form for $\alpha(\overline{k}_t)$,

$$\frac{dd_t}{e_t dd_t^*} = \left[\frac{1/(1+\exp(-\phi\overline{k}_t-\xi))}{1-(1/(1+\exp(-\phi\overline{k}_t-\xi)))}\frac{i_{cd,t+1}/(1+i_{cd,t+1})}{i^*_{cd,t+1}/(1+i^*_{cd,t+1})}\right]^{1/\rho-1}. \tag{10}$$

Relative money demand depends on current domestic and foreign interest rates, as in Canzoneri and Diba (1993).

---

[15] The substitution is arbitrary since in Chapter 5, there are also Euler equations for savings deposits. But following Canzoneri and Diba the Euler equations for CDs are placed (they have foreign and domestic "bonds").

This deterministic expression is rejected when one inspects the data on $\frac{dd_t}{e_t dd_t^*}$, $i_{cd,t+1}$, and $i^*_{cd,t+1}$.

2 Description of the Data

In this section, we first describe the available assets and proceed to the specific sources.

The Bolivian Central Bank reports twelve different end-of-month balances held in the domestic banking system, see Table A.1. They are demand deposits, savings deposits, CDs and an addition broad category "Other." The latter constitutes balances held by the Central Bank belonging to depositors at defunct banks. Each deposit type is denominated in: domestic currency (Bolivianos), the US Dollar, and indexed-domestic currency.[16] Columns three and four of the table depict the distribution of assets for January 1989 and July 1997 which show that ignoring indexed and "Other" deposits is inconsequential. In this chapter, we use demand deposits in Bolivianos and US Dollars and CDs in Bolivianos and US Dollars.

We aim to conduct the empirical analysis on monthly data. Although, monthly data on private consumption are not available for Bolivia, monthly data on exports are available and used to proxy consumption. Figure 3 shows two graphs on the consumption-exports relationship. The top graph shows annual data on private consumption and monthly data on exports. The other presents real annual figures for both series. Both graphs yield support for the use of this proxy.

Monthly observations from January 1989 through July 1997 on posted nominal interest rates on foreign and domestic denominated CDs, end-of-month balances on foreign and do-

---

[16] The indexed deposits are called "Con mantenimiento de valor" which translates to "which maintains its value." The indexation is to the market rate of depreciation in the nominal exchange rate, but it is often called an indexation to inflation. An indexed account is compensated as accrued earnings.

Table 4: Banking Assets Available to the Bolivian Depositor

Bolivia, 1989:01 - 1997:07			
		1989:01	1997:07
Type of Deposit	Denomination	percent of M3	percent of M3
Demand	Bolivianos	8.00	4.00
	US Dollar	2.00	10.00
	Indexed	0.03	0.00
Savings	Bolivianos	8.00	1.00
	US Dollar	1.00	19.00
	Indexed	0.12	0.01
CDs	Bolivianos	1.00	0.50
	US Dollar	49.00	54.00
	Indexed	4.00	0.54
Other	Bolivianos	0.36	0.14
	US Dollar	0.14	2.00
	Indexed	0.01	0.01

mestic denominated CDs, and demand deposits were obtained from hard-copy issues dated January, April, August, and December from 1989 through 1997 of the *Boletin mensual*, published by the Banco Central de Bolivia. Nominal interest rates on Boliviano CDs, $i_{cd,t+1}$, come from tables labeled "Tasas de interes pasivas anuales negociadas en el sistema bancario nacional, promedios mensuales." Nominal interest rates on US Dollar-denominated CDs, $i^*_{cd,t+1}$, are obtained from tables labeled "Tasas de interes de certificados de depositos y letras del tesoro." Monthly balances on US Dollar and Boliviano demand deposits, dd^*_t and dd_t, respectively, are in tables labeled "Dinero y cuasidinero - depositos vista y cuentas corrientes."

Monthly data on end-of-period exchange rates (series ea), the Bolivian CPI (series 64) and exports (series 70..d) were obtained from the January 1998 issue of the *International Financial Statistics*.[17]

---

[17] The IFS Compact Disk-ROM is published monthly by the International Monetary Fund, Washington, D.C.

3 Unit Roots, Deterministic Trends, and Autoregressive Specification

Before estimating the model using Hansen's (1982) GMM estimation method, stationarity characteristics of variables must be determined because neither deterministic trends nor unit roots are permitted in the procedure. ADF and PP tests are used to test for the presence of unit roots in the data. The hypothesis that series are trend stationary conditional on unit roots is also tested.

Table A.2 summarizes the results from the ADF and PP tests. The unit-root hypothesis is rejected for all of the series. There is, however, evidence for the presence of deterministic trends, as shown in the fourth column.

The number of lags used in the ADF test was chosen as follows. The highest lag considered was seven following the $\sqrt{T}$ rule of thumb suggested by Enders (1995, p.227) If the t-statistic on the coefficient for the last lag was statistically insignificant (i.e. less than 1.9), it was dropped. The procedure was repeated sequentially by dropping the last lag, if insignificant, one at a time. Once a coefficient on the longest lag was found to be significant, that lag and all shorter ones were kept in the ADF regression. Then, the unit-root test statistic was compared to the MacKinnon critical values. Hall (1994) and Ng and Perron (1995) provide evidence for using this lag selection methodology.

The ADF testing procedure followed the general-to-specific methodology suggested by Enders (1995, pages 256-257). The "general" model includes a time trend, a constant and the highest lag considered in the ADF regression. Once the appropriate lag is found, as discussed above, the test statistic is compared to the MacKinnon critical values. If the unit-root hypothesis is rejected, we stop testing noting that the test included a time trend and constant. On the other hand, if the unit-root hypothesis is not rejected, the significance for the time trend is compared to the appropriate Dickey-Fuller critical values, which can be found in Table 4.1 of Enders (1995, p. 223). If the trend coefficient is significant, we stop testing and conclude that the series contains a unit root, time trend, and constant. On the other hand, if the trend coefficient is not significant, the ADF test is repeated after dropping the trend and the highest lag to be considered. Once the appropriate lag is found with this new specification, the test statistic for the unit root hypothesis is compared to the appropriate MacKinnon critical values. If the unit-root hypothesis is rejected, we stop and state that the test included a constant. If the unit root hypothesis is not rejected, we prefer not to drop the constant, since Hamilton (1994) cautions that this implies an alternative hypothesis where the variable has a steady state value of zero.

The PP testing procedure follows that of the ADF tests, except that the lag truncation reflects the Newey-West recommended value.

Table A.2 presents the results from the unit-root tests. Since the unit-root tests are rejected for all the series, explicit deterministic trend tests are presented in Table A.3. OLS regressions with a constant, time trend, and the appropriate autoregressive specification are estimated for each series. In every case, a first-order autoregressive specification suffices.[18]

The variables with significant trend coefficients are real domestic and foreign currency interest rates, gross expected depreciation, and the inverse inflation rate.

---

[18] The AR specification is determined by observing the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) in each series' correlogram.

Table 5: ADF and PP Unit-Root Tests: Bolivia

Bolivia, 1989:01 - 1997:07

variable	test	test-statistic	Unit-root test include trend (t), or constant (c)	lags/lag truncation
$r_{cd,t}$	ADF	-4.54***	t, c	0
	PP	-4.52***	t, c	4
$r^*_{cd,t}$	ADF	-4.54***	t,c	0
	PP	-4.53*	t,c	4
$\frac{e_{t+1}}{e_t}$	ADF	-6.15***	t, c	1
	PP	-6.13***	t, c	4
$\frac{dd_t}{e_t dd^*_t}$	ADF	-8.76***	c	4
	PP	-19.21***	c	4
$\frac{p_t}{p_{t+1}}$	ADF	-7.24***	t, c	0
	PP	-7.17***	t, c	4
$\frac{c_t}{c_{t+1}}$	ADF	-12.59***	c	0
	PP	-12.88***	c	3
dr_t	ADF	-3.67**	t, c	0
	PP	-3.84**	t, c	3

,* - significant at 5%, 1% of the MacKinnon critical values, respectively.

Table 6: Deterministic Trends: Bolivia

Bolivia, 1989:01 - 1997:07

	Coefficients on:		
variable	constant (t-stat)	trend (t-stat)	AR(1) (t-stat)
$r_{cd,t}$	1.24	-0.001***	0.26
	(171.60)	(-5.93)	(2.68)
$r^*_{cd,t}$	1.15	-0.001***	0.92
	(102.12)	(-4.12)	(24.22)
$\frac{e_{t+1}}{e_t}$	1.01	-0.0001***	0.44
	(767.08)	(-5.87)	(4.93)
$\frac{dd_t}{e_t dd^*_t}$	0.71	-0.004	0.90
	(1.84)	(-0.76)	(65.52)
$\frac{p_t}{p_{t+1}}$	0.98	$8.63\text{x}10^{-5}$**	0.37
	(380.76)	(1.99)	(3.96)
$\frac{c_t}{c_{t+1}}$	0.99	$6.23\text{x}10^{-6}$	-0.26
	(35.46)	(0.011)	(-2.62)
$\overline{dr}$	0.94	-0.0001	0.95
	(12.34)	(-0.20)	(38.15)

,* - significant at 5%, 1% of the z-statistic critical values, respectively.