DEPOSIT DOLLARIZATION DYNAMICS IN A MODEL OF NETWORK EXTERNALITIES AND HYSTERESIS: THE CASES OF ARGENTINA AND BOLIVIA

by

Zaid Jamal Albarzinji

A dissertation submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Economics

The University of Utah

May 2011

STATEMENT OF DISSERTATION APPROVAL

The dissertation of Zaid Jamal Albarzinji

has been approved by the following supervisory committee members:

Lance Girton	, Chair	3/4/2011 Date Approved
Kenneth P. Jameson	, Member	3/4/2011 Date Approved
David M. Kiefer	, Member	3/4/2011 Date Approved
Matias Vernengo	, Member	3/4/2011 Date Approved
Farid Ul Islam	, Member	3/4/2011 Date Approved

and by Peter Philips, Chair of

the Department of Economics

and by Charles A. Wight, Dean of The Graduate School.

ABSTRACT

The shift from a domestic currency (peso) to dollar denominated deposits (deposit dollarization) in Argentina and Bolivia is explained with a nonlinear model that incorporates ratcheting effects, hysteresis and network externalities. There are two principal factors behind these effects: holding and transacting costs. The depreciation rate of a local currency versus an international monetary standard (peso versus dollar) is a reasonable proxy for the holding cost of the local currency. Strong depreciation of a currency imposes a substantial holding cost on its users and increases or "ratchets up" how high agents predict future depreciation rates will be. A transaction cost is incurred whenever an agent transacts outside his/her currency network of buyers and sellers. The model assumes there are two currency networks; one is based on the peso and the other on the dollar. A transaction network externality arises when relative returns or savings to using a given currency increase as the size of that currency's network of users expands. This externality makes the currency choice of an individual partially dependent on the choices others in his/her reference group or network make. Hysteresis, the persistence of high dollarization, happens when the expected holding cost of the dollar is less than the peso due to ratcheting effect, and/or converting back to the peso imposes a substantial transaction cost due to the large size of the dollar network. Under certain network dynamics and behavioral assumptions, dollarization levels can follow a nonlinear path to rest at an either high or low-equilibrium point. Resting at either high or low dollarization equilibria depends on the presence and location of an unstable third intermediate

equilibrium point. A shock to the holding cost of at least one currency is needed to establish a new equilibrium position. For example, a spike in peso's depreciation ratchets up its expected holding cost and establishes a new nonlinear path that leads to higher dollarization equilibria, which the model expects the economy to start moving towards. The opposite outcome can happen if a strong contractionary policy appreciates the peso and reduces its holding cost.

To Zahra.

TABLE OF CONTENTS

Appendices

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Prof. Lance Girton and Prof. David Kiefer for helping me to think like an economist and for their extensive guidance in the research and writing of this dissertation.

CHAPTER 1

INTRODUCTION

The importance of the “dollarization” phenomenon emanates from its impact on the ability of central banks to effectively conduct monetary policy by controlling domestic money supply, inflation and interest rates. Ineffective domestic monetary policy can mean substantial general welfare losses, disruption to local prices and financial asset valuations, and financial crises. General welfare can also be negatively impacted as domestic money supply conditions become strongly linked to the monetary policy of foreign authorities like the Federal Reserve Bank (FRB) or the European Central Bank (ECB). At any given time the prevailing policies of these authorities may or may not be in harmony with what is optimal for the macro conditions at a dollarized economy. A foreign central bank may undertake contractionary policies like raising interest rates to cool off a rapidly growing economy and rising prices while local conductions in a dollarized economy need lower interest rates to spur a stagnant economy.

While policy makers may decide that stopping or reversing dollarization is good for the country, an individual agent or an economic sector may be better off using strong and popular foreign currencies like the dollar or the Euro instead of a weak local currency. At a very basic level, a product or service is substituted or preferred over a rival one because an agent expects to derive more utility. The choice to substitute a foreign currency for a local one requires these two currencies to be rivals that offer similar benefits. It is commonly stated that money has three main benefits or functions: store of value, medium of exchange and unit of account. An agent needs to decide which currency offers more of these benefits among rival currencies. Therefore currencies have to be seen as rivals or competitors for substitution to take place.

Dollarization results from competition between different currencies, where a foreign one competes over the market share and functionality of a local one. Agents' choices determine the outcome of this currency competition based on their needs, market constraints and legal barriers or official policies that can either encourage, discourage or be neutral. Under reasonably free market conditions, agents are expected to choose the money brand that will best serve their needs today and in the future. It is a reversed Gresham law outcome where good money drives bad money out of circulation (Cohen, 2004).

In any given open economy, it is normal for some sectors to use foreign currencies regularly, like the export and import, and financial services sectors for example. These sectors can play a vital role in introducing foreign currencies to the rest of the economy as viable alternatives to the local currency. As the presence and circulation of foreign currencies takes hold, partial or full foreign currency networks may develop where buyers and sellers deal primarily or only in foreign currencies. The immediate benefit of a currency network is the reduction in transaction cost because deals are conducted directly in the same medium of exchange, dollars, without having to exchange them into pesos. The initial development of user base for a currency network can be hard and driven by certain incentives; subsequent users may be attracted for other reasons. All other things being constant, as a network increases in size, it becomes more beneficial to join because of the increased chance of transacting with users in the same network. In other words, as a network increases in size it creates a positive spillover or externality effects that can encourage more to join.

In the literature, the general term of dollarization can be associated with the substitution of foreign currencies for local ones as: medium of transaction (currency substitution or dollarization), store of value (deposit/asset substitution or dollarization,) and unit of account (dollarization of liabilities and contracts: denominating contracts, liabilities and prices in foreign currencies). In this research the terms asset substitution, deposit substitution, dollarization, and deposit dollarization are used synonymously.

McKinnon (2001) observes that the dollar started to be used widely in Latin American domestic markets, first as a store of value and next as the preferred medium of exchange (see also Feige, Faulend, Sonje, & Sosic, 2003). The shift from local currencies to dollar denominated deposits in Argentina's and Bolivia's banking sectors provides an excellent view of the gradual erosion of the store of value function of the Argentine peso and the Bolivian Boliviano (see Figures 1 and 2).

In Argentina's case, Figure 1 shows a succession of hyperdepreciation episodes[1] that drove the deposit dollarization ratio (DDR)[2] to higher levels. After the peso's 280%

---

[1] Exchange Rate Increase = Depreciation (*e*) = the log of (the Argentine Peso (or Bolivian Bolivano) / U.S. Dollar) quarterly market exchange rate, $e = 100 * \ln (Xt / Xt\text{-}1)$. Exchange Rate Increase and Depreciation Rate will be used as synonyms.

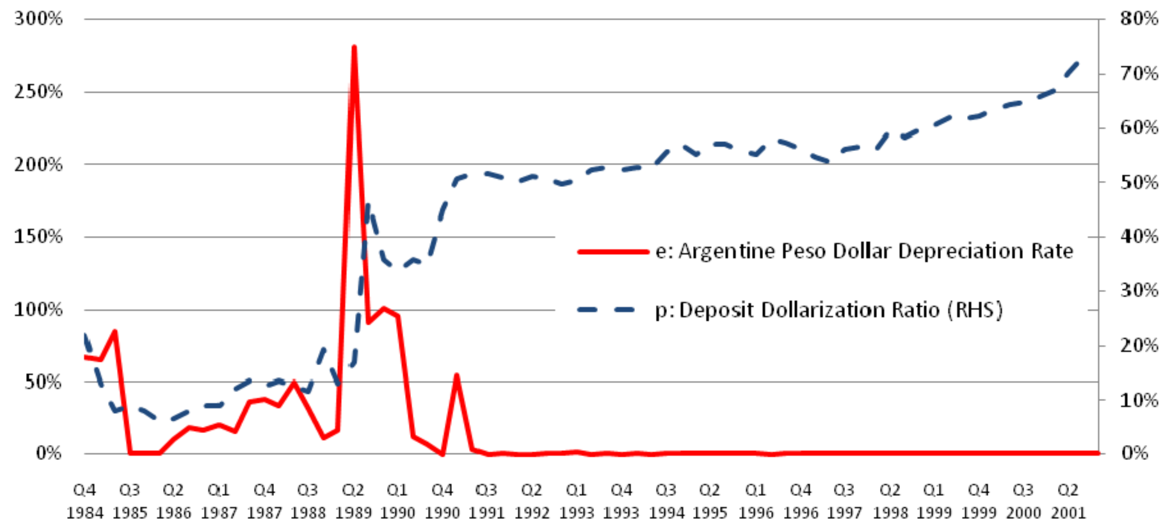

Figure 1: Argentina's exchange rate depreciation and dollarization history.

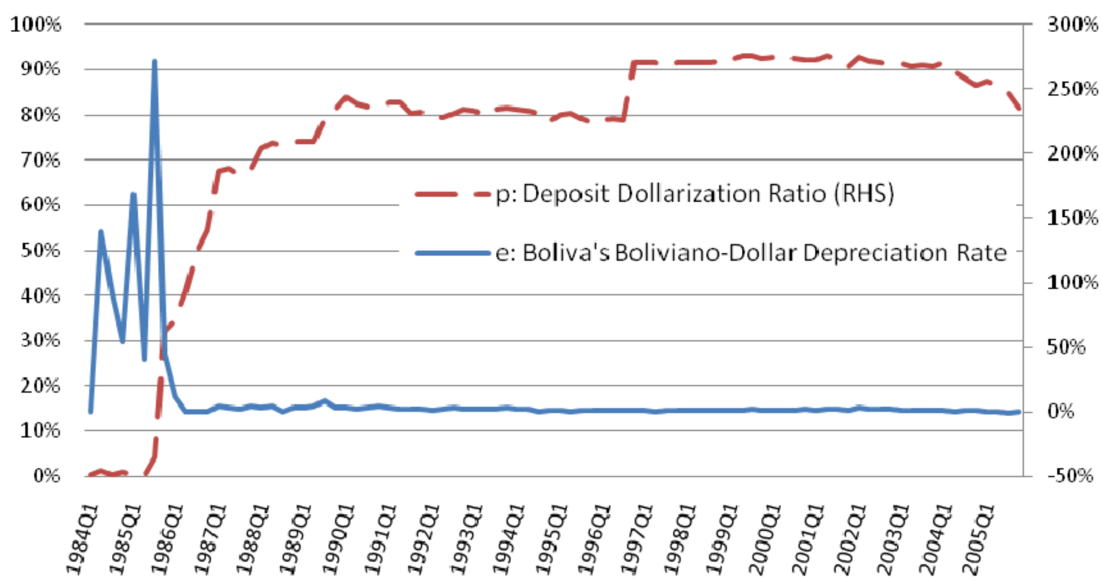

Figure 2: Bolivia's exchange rate depreciation and dollarization history.

---

[2] DDR = Foreign currency denominated deposits / total deposits, see Appendix A for an explanation of data sources and formulas.

depreciation free fall (exchange rate increase) in Q2 1989, deposit dollarization rose from about 13% at the time to 47% by the end of 1989. Dollarization subsided to around 35% afterward under a better controlled peso exchange value. However, in the Q1 1991, the Argentine peso (the peso) dropped again by 54% against the dollar. The drop was accompanied by a sharp increase in dollarization to over half of all deposits in the banking system. After this latest bout with depreciation, the Argentine government declared an official commitment to the stability of the peso. This commitment was lent credibility by the establishment of a currency board regime under the supervision of the International Monetary Fund (IMF). Despite this commitment, financial dollarization in Argentina did not reverse course. In fact, dollarization continued to climb, up to 70%, before the government forcibly converted all foreign deposits into pesos in early 2002.

In this dissertation, Oomes' (2003) model is modified and employed to explain Argentina's and Bolivia's experiences with deposit dollarization. Figure 3 graphically simulates the model,[3] which relates asset dollarization in the previous period (p_{t-1}) to its predicted level currently (p_t). Deposit dollarization is at an equilibrium (p^*) along the 45 degree line, where ($p_t = p_{t-1}$) and the dollarization path intersects the 45 degree line from above.

The main interesting outcome is that under the right circumstances and with the help of a logistic function, more than one steady dollarization state can exist in an

---

[3] The equation used to generate the simulation is $p_t = (1 + \exp\{-1/\varphi\,[e_t - \sigma_t + 2\,\sigma\,p_{t-1}]\})^{-1}$. Parameter values are $\varphi = 0.05$, $\sigma_t = 0.25$ and $e_t = 0.08$, 0.13 and 0.17. These values were used for illustrative purpose only.

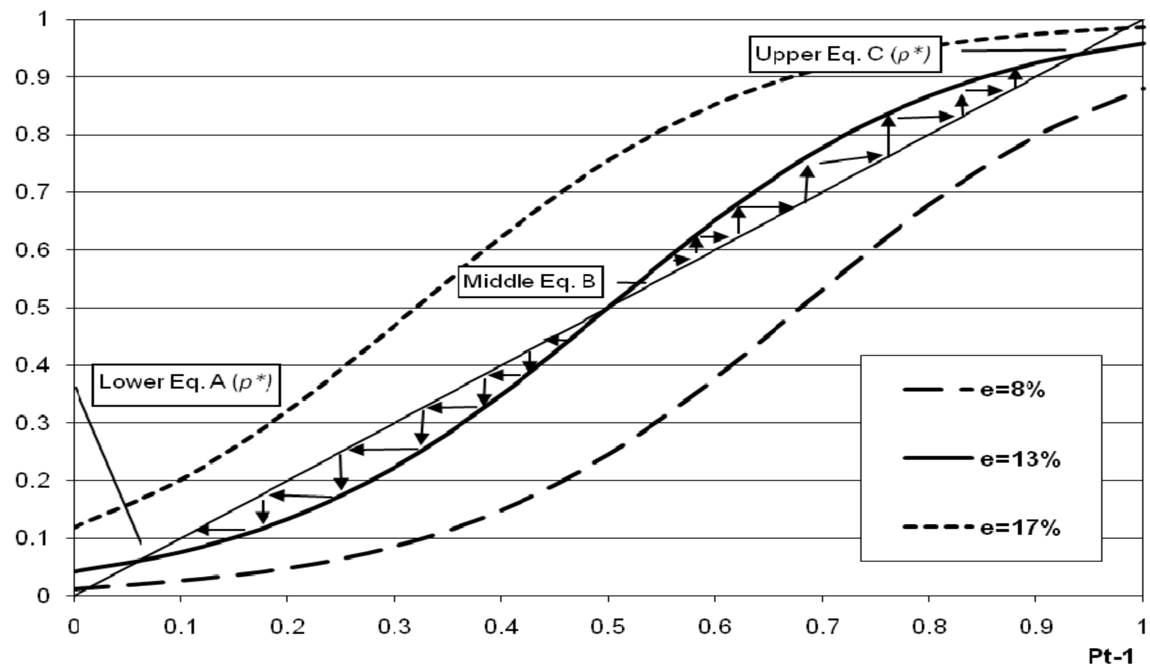

Figure 3: Modeling deposit dollarization with network and hysteresis effects.

economy. The empirical evidence supporting the model indicates that steady dollarization levels (*p*'s*) may not have a linear relationship with the rate of depreciation and other factors as typical portfolio balance models suggest. Also, successive deteriorations in a local currency's exchange rate diminish the value of peso denominated balances and increase the cost of holding or using the peso as a store of value. Concerns about further purchasing power losses drive people to switch their savings to dollars. This is captured in the model by upward shifts in the dollarization path curves e = 8%, 13% and 18% in Figure 3. The model predicts that when the depreciation rate (e) increases from 8% to 13%, the dollarization curve jumps from the lower curve (e = 8%) to the intermediate one (e = 13%). However it does not fall back when the peso's depreciation returns to a 8% rate. This is because previous depreciation spikes can have a lingering impact that “ratchets up” how high future depreciation rates are expected to be.

This ratcheting effect directly increases the expected holding cost of pesos and can induce peso users to convert their holdings into a foreign currency. Risk-averse agents may not adjust their depreciation expectation downward quickly for fear of getting caught in another hyperdepreciation episode. This conversion can produce an increased popularity for the foreign currency and extend its use from a store of value, because of its lower holding cost relative to the local currency, to being used as a unit of account and a medium of exchange. In other words, the number of agents holding and using dollars increases, thus increasing the dollar network. The main result from the expansion of any currency network is to reduce the expected transaction cost to the users of that currency as these agents do not have to do any currency switching to conclude transactions. This encroachment on the monetary functions of the local currency can further increase the use of the dollar and the dollarization levels in the economy and may not be easily reversible. The short run increase in dollarization during or after a currency crisis (induced by a financial or balance of payment troubles) can become a status quo, even after crisis conditions have passed, thus producing a “hysteresis” outcome. Dollarization hysteresis describes a situation when agents do not have an incentive to switch back to the local risky currency because a combination of high holding cost expectations and a decrease in the cost of transacting with the dollar may not make it worthwhile.

The middle curve in Figure 3 also has three extreme values. While the upper and lower values (points A and C) are always stable the intermediate one (point B) is not.[4] Point B acts as a tipping point in the balance between the strength of rival currency networks that determine the transaction cost associated with using a currency. A currency network is made up of all those agents deciding to hold and transact primarily in that currency, with the possibility of transacting with other agents belonging to other currencies as needed. When intracurrency- network transaction takes place, a transaction cost is imposed. Transaction cost is a term that can include many different costs that may arise when two currencies are in use, like government fees, switching cost (the cost of exchanging one currency for another), "shoe leather" cost of finding a currency exchange facility, etc. In this dissertation transaction cost and switching cost will be used synonymously. If the dollarization ratio passes point B (DDR > 55%) in the previous period, it will be expected to continue to rise until the upper equilibrium point (A) is reached. This is because the dollar "network externality" effect is expected to continue to increase the reward of converting away from the peso network by lowering transaction cost for new users until the dollar network is the dominant one.

This research examines Argentina's and Bolivia's history with deposit dollarization and finds that it can explain a good deal of the pattern in Figures 1 and 2. In the next chapter, I will discuss the literature on currency substitution and dollarization, and the

---

[4] The arrows depict how the upper and lower equilibriums are arrived at. For example, if dollarization at P_{t-1} is below point B but above point A, the level today will trend downward until it rests at point A.

evolution of different modeling approaches over the past four decades. In Chapter 3, I will discuss the theoretical approach of this dissertation and the model that generates the dynamics in Figure 3. In the final chapter, Chapter 5, the data and empirical results used in Argentina's and Bolivia's case studies are analyzed and several policy simulations are discussed.

CHAPTER 2

LITERATURE REVIEW

Development of the Currency and Asset Substitution Literature

This chapter will present a literature review of research done principally in the area of currency and asset substitution. The presentation will track the growth and development in this field over the past 60 years. The story that emerges shows how ideas ignored at one time may regain popularity later due to subsequent theoretical development elsewhere. The reincarnation of the transaction-cost focused models of the 1950s again in the late 1990s and early 2000s was made possible by the introduction of network dynamics research. For a long spell from the 1970s until the 1990s, the rival portfolio approach to money demand and currency substitution was the dominant one.

The excitement that network based research brought relates to the use of nonlinear functions that incorporate, among other things, cost functions. Nonlinear cost functions helped slow down the substitution process, especially at the extremes of either full or no dollarization. This is a considerable departure from the typical corner or extreme outcomes of portfolio based work. Furthermore, the spectrum of issues examined or incorporated has widened to include the further development of currency and asset substitution concepts, the use of cash-in-advance simplifying assumption, the use of intertemporal dynamic analysis, and the development of econometrically estimable models.

As mentioned, the first part will discuss the earliest foundational theoretical work of the 1950s and 1960s, followed by the pioneering contributions of the 1970s. The second part of this literature survey will discuss the continued interest and developments in the portfolio approach between the 1980s and early 2005. The last part discuses the market view, a term used to describe the body of work that pays close attention to the role of market mechanism to explain currency and asset substitution.

Early Approaches to Money Demand

The building blocks for the currency substitution literature may be traced back to money demand research in the 1950s of the last century. Money demand discussion in turn maybe traced as far back as the 19th century. The issue then was centered around the nature and makeup of money demand and its impact on monetary policy in a framework of: one nation one money. Even then, it was recognized that some currencies play a vital international role in facilitating global trade and finance, like the British pound (Eichengreen, 2005). Baumol (1952) and Tobin (1952) built the early structure of what can be termed the "transaction cost approach to money demand." Soon after, Tobin (1958) developed a significant alternative to understand money demand by suggesting a portfolio based approach. These two approaches are discussed next. The discussion will pay special attention to the pioneering work of those who developed the theory of substitutable monies on the portfolio approach like Girton and Roper (1976, 1986), Calvo and Rodriguez (1977) and Miles (1978).

Baumol and Tobin Transaction Cost Approach

The work of Baumol (1952) and Tobin (1956) formally introduced transaction costs in optimization models, along with payments practices and foregone interest. Baumol and Tobin's early work was influenced by mathematical inventory theory. This theory assumes the presence of two assets, money and interest earning investment. Agents choose "the optimal frequency for money-security transfers so as to maximize interest earnings net of transaction costs" (McCallum & Goodfriend, 1986, p. 13).

The transaction approach was largely ignored in the 1970s due to the difficulty of deriving practical application as compared with the portfolio approach. The transaction approach was purely theoretical and technical in nature and on its own did not lend itself easily to real life issues. The predictions of models utilizing this approach tended to strict relationships and very precise interaction. At the time, it was not readily clear how the transaction cost approach could contribute to currency substitution discussion and the present research. The substitution that was discussed in this early transaction cost approach was focused on various asset types or assets versus an official money brand. In a world of one currency per country and globally fixed exchange rates through the Bretton Wood system of fixed exchange rates, currency competition was simply not relevant.

Currency competition is a prerequisite for substitution to take place. If two currencies were assumed to be rivals, a slight cost advantage for one over the other will leave only one currency standing. No stable money demand equilibrium for a currency can be found if it is not cost effective and competitive enough versus other assets or currencies. The pessimistic view about the usefulness of the transaction cost approach persisted until the introduction of network effects much later.

Tobin's Portfolio Approach

Tobin pursued a different approach to money demand by using a portfolio allocation structure. In his 1958 paper, Tobin's stated "what needs to be explained is not only the existence of a demand for cash when its yield is less than the yield on alternative assets but an inverse relationship between the aggregate demand for cash and the size of this differential in yields" (p. 65). Cash money demand exists to satisfy transaction and investment needs. The transaction need depends on the synchronization between the inflow and outflow of money balances or to cover possible gaps between expenditures and receipts, especially when credit is not allowed. The investment cash money demand exists "because of expectations or fears of loss on other assets. It is here, in what Keynes called the speculative motives of investors, that the explanation of liquidity preference and of the interest elasticity of the demand for cash has been sought" (Tobin, 1958, p. 67). Agents need to decide how much cash money to hold as an investment versus other monetary assets that pay variable interest rates. Tobin considered money as just another monetary asset that is riskless and pays zero interest rate. All monetary assets share the characteristics of being marketable, fixed in money value and free of default risk. Tobin's (1958) "liquidity preference theory" attempts to explain how a given amount of wealth is allocated among various alternatives of monetary assets (p. 66).

The portfolio makeup of monetary assets is assumed to happen under conditions of uncertainty regarding interest rates and price fluctuations. Uncertainty of returns on some classes of assets, like consoles, produce risk of capital gain or loss. In this situation, an agent will form expectations about the risk and return of certain monetary assets according to a probability distribution with an expected value of zero (Tobin, 1958).

In a further development, Tobin (1963) discussed the substitutability option among different financial and nonfinancial assets in a portfolio. A portfolio owner is thought to have a range of options of asset as well as credit instruments to hold. The mix of assets and credit depends on how each asset contributes to the overall riskiness of the portfolio. Savings deposits, for example, are perfect substitutes for demand deposits in every respect except as a medium of exchange. Savings deposits can overcome, to certain extent, the high liquidity advantage of checking accounts by differences in yield. People can have a choice between a riskless asset (money) and an asset with a return that exceeds that of money. “Tobin shows how the optimal portfolio mix depends, under the assumption of expected utility maximization, on the individual’s degree of risk aversion, his wealth, and the mean-variance characteristics of the risky asset’s return distribution” (McCallum & Goodfriend, 1986, p. 15).

Some of the prominent critiques of Tobin’s new approach focused on his assumption that money is riskless, once inflation is considered, and ignoring the possibility of having a rival asset that is as riskless as money but with a higher average return[5] (Barro & Fischer, 1976). Another critique is that Tobin seems to put aside

[5] This is especially true when Treasury Inflation-Protected securities (TIPs) are considered.

nonpecuniary returns on money, like liquidity and transactions services. Liquidity demands for cash money was mentioned in Tobin's 1958 paper but was not the focus of his interest there. He just assumed that other monetary assets are reasonably marketable or liquid. The ability of the portfolio framework to handle variations in risk and return specifications made it possible for subsequent research to account for the earlier criticisms, as extensions to Tobin's work showed in the 1970s.

Friedman's restatement of the quantity theory, in a 1956 book chapter, supported and generalized Tobin's idea that the principal role of money is being a form of wealth that needs to be allocated optimally. Friedman's contribution emphasized margins of substitution between money and a broader range of financial assets other than bonds and even real assets and durable goods (see McCallum & Goodfriend, 1986). Friedman (2005) suggested that money demand yields a stream of benefits to the holder along three principal factors: wealth constraint, return on money versus other financial and real asset, and asset holder's preferences. Friedman's followers "argue that money is a substitute for a wide range of real and financial assets, and that no single asset or group of assets can be considered to be a close substitute for money" (Snowdon & Vane, 2005, p. 168). This opinion may be true as long as there is one medium-of-exchange in circulation. The presence of more than one money brand will further lower the substitution margin as currencies start to compete with each other.

The Girton and Roper Currency Substitution Extension

The earliest use of the term "currency substitution" appeared in a 1974 working paper by Girton and Roper, published in 1981. Miles's 1978, and Calvo and Rodriguez's

1977 papers were among the other early significant contributions to the currency substitution literature. These papers used portfolio models to discuss the role of currency substitution in an economy. One common concern is the interaction between currency substitution on one hand, monetary policy and exchange rates on the other hand. Real rates of return, measured as the nominal interest rate minus inflation, play a pivotal role in determining what currency people will hold. Overall, the discussion is slanted to debating different exchange rate policies. Transaction cost consideration in these early writings appears as a constant coefficient across different asset types and is implicitly estimated by other macro variables. No specific functional form was assumed for transaction cost. Following is a more detailed discussion of these early contributions.

Girton and Roper (1981) introduced a "pure theory of multiple currencies" to discuss money demand independently of the number of countries or regions. The theory combines ideas from both domestic and international monetary economics. It also introduces the concept of currency substitution and formalizes it in a portfolio model of asset demand. Currency substitution assails the notion that national economies work with only one money brand in circulation. The choice to hold a portfolio of more than one currency used to be the narrow concern of international business and frequent travelers. After the demise of the Bretton Woods system that coordinated exchange rates around the world, currencies exchange rate values fluctuated widely. The culprit behind the fluctuation, in the most part, was inflationary financing measures. These measures had a direct negative impact on the purchasing power of currency holders. Thus, it made sense to replace a local currency with another asset that has reasonable medium of exchange functionality and a better rate of return.

The asset portfolio model of Girton and Roper included an exchange rate term. The model used a coefficient of substitution that depended on the difference in expected real return on various currencies and a coefficient of substitution between a currency and nonmonetary assets. The share of a currency in a portfolio depends on the difference between expected real return on a currency and nonmonetary assets.

Under conditions of rational expectations and perfect currency substitution, the model exhibited dynamic instability and the exchange rate end up being indeterminate. The model predicted that for a given shock, the higher the degree of substitutability the larger the jumps required to get to a new equilibrium (a result also explicitly and independently argued by Kareken and Wallace in 1981). Among the important assumptions behind the instability is exogenously supplied money and nominally fixed rates of return on money. Currency arbitrage was also assumed to maintain stable purchasing power for the currencies. However, small differences in anticipated inflation rates can sway real return leading to large exchange rate movement or corner solutions.

When the authors modified the model by using bond exchange rate to study bond substitution, stability was achieved (Kareken & Wallace, 1981). This outcome is attributed to the denomination of the return on bonds in terms of money and not some more bond units. This distinction in the terms of return between currency and bond substitution is fundamental to understanding the difference in the nature of the two categories of assets. This is a departure from Tobin’s assertion that the essential difference between money and bonds is the exogenously fixed nominal interest on money.

The bond analysis helped explain what happens when substituting money is an option by highlighting the store of value function of money. When more than one currency option presents itself, people can put a price on one currency in terms of another. An exogenously imposed negative return on a currency (e.g., from inflation) will depreciate its value in terms of other currencies. Agents concerned about the store of value property of a depreciating currency will switch to another one to protect their wealth.

Girton and Roper also argued that rational central banks will not over supply money if people can substitute one currency for another easily. Central banks' profit maximization consideration changes radically when agents have currency choices and no longer can they run the press until the value of a currency is equal to the paper it is printed on as Friedman (1968) suggested. The authors asserted that there is no positive spillover effect in the production of money. Competitive pressure among currencies is real and will force efficient allocation of resources as long as the issuing authorities do not collude to maintain market share. When monetary authorities do not have sole monopoly over money supply, agents can quickly switch to another currency leaving the inferior one behind. "Money holders choose between monies on the basis of anticipated real rates of return, consequently banks compete on the basis of anticipated real rates of real return" (Girton & Roper, 1981, p. 22).

When the model was modified to admit endogenous money supplies, instability in exchange rates under perfect currency substitution disappeared. The endogenous supply process implies the need for active management of real return on money and thus the maintenance of demand and market share. Consequently, if only one issuing authority actively manages the supply of its money, it will gain market share at the expense of a nonmanaged brand of money. Hence, Friedman's argument for the superiority of money supplied at a fixed rate was put into serious doubt (see Friedman, 1968).

The currency substitution concept picked up steam with subsequent contribution that also used the portfolio framework. Calvo and Rodriguez (1977) note that "The same argument of portfolio diversification and transaction cost which can be used to justify the demand for domestic money are also applicable to foreign exchange" (p. 617). The authors used a two-sector model of exchange rate determination to analyze the impact of currency substitution on monetary policy. They used a liquidity preference function to determine the optimal proportion of holding two assets in a portfolio. Currency substitution, defined as the ratio of domestic to foreign currency holdings, is assumed to be a function of the expected difference in the rates of return on both assets. Under perfect foresight conditionality, currency substitution levels change in equal proportion to the actual change in the exchange rate. The main policy implication of the model is to argue that if one accounts for currency substitution, monetary expansion will directly lead to an increase in the accumulation of foreign currencies.

Miles's (1978) paper represented another early important work that benefited from the development of currency substitution concept. Miles addressed the common argument that a flexible foreign exchange regime can insulate domestic economies from foreign financial shocks. This insulation allows central banks to exercise monetary independence and freedom to pursue activist policies. The author thoughtfully observes that flexible rates can achieve this with the assumption that currencies are not perfect substitutes on the supply side as is the case under a regime of fixed exchange rates.

However, if currencies are substitutable on the demand side, this perceived advantage of flexible rates disappears.

Miles uses a real cash balance portfolio that varies in size with the level of real income and the rate of return on other types of assets. The make-up of the portfolio will vary with the relevant opportunity costs of holding real balances of different brands of money. Rising inflation increases the opportunity cost of holding a currency. People will reduce their holdings of the riskier (inflation prone) currency by switching to another one. Real balances, denominated in terms of both domestic and foreign currencies, from an individual's cash balance portfolio are combined in a production function for money services. Given the relative efficiencies of domestic and foreign currencies in producing money services (defined by a production function) and the relative opportunity costs of holding different currencies (reflected in the asset constraint), an individual tries to maximize production of monetary services to where marginal costs equal marginal benefits. The determinant for the mix of the portfolio depends principally on changes in the relative opportunity cost of different currencies. The production function directly associates the amount of real balances with the amount of money services received from a currency. The amount of service a currency generates is inferred by the size of real balance holdings. Real balances are measured in terms of a standard commodity. To simplify the model, an exchange rate is used to determine the value of currency holdings. Changes in inflation affects real returns to holding a particular currency and increases its opportunity cost. People respond by reducing their portfolio's exposure to the weakening currency.

The "Denationalization of Money" book by Hayek (1978) addressed the supply side monopoly over money by central banks. He used the currency substitution idea to advocate giving private banks the freedom to issue their own currencies. He suggested that people will agree to hold private banks' notes if they are backed, for example, by an index of goods. Many currencies may coexist at market-determined exchange rates. At the end of the day, the better currency will drive away the other(s). Banks are expected to have responsible money supply policies or risk loss of confidence in their money brands. Loss of confidence will drive the holders of a currency to convert their holdings into other ones or into real goods, thus producing a bank-run like outcome. Hayek saw in deregulating money production a chance for people to escape depreciating, government issued, money. Hayek hoped that government's oppressive ability to finance its expenditure by taxing money holders would diminish when currencies compete for people's trust and acceptance (see Holmes, 1977).

This line of logic touched off intense discussion about the merits and demerits of ceding domestic monopoly over money supply and with it a great deal of monetary policy power over the domestic economy (see Calvo, 2002; Ize & Levy-Yeyati, 1998). It is also not clear in Hayek's book what will happen if a currency issuing bank abused its money supply ability and its customers (those holding the currency that bank issued) and caused a systemic failure in financial markets. Should the central bank continue to act as a lender of last resort to bail out failing banks? Maybe a currency insurance agency can be established to protect private currency holders after the model of the Federal Deposit Insurance Corporation. Nevertheless, Hayek's theoretical construct of free and competitive money supply is very useful in assessing currency substitution under such extreme conditions. The next section will discuss the most significant theoretical contribution in the 20 plus years that followed the end of the 1970s.

Contemporary Currency Substitution Research

The creation of the European monetary union was essentially a political project that used Mundell's optimal currency area theory to provide economic doctrine legitimacy (McKinnon, 2002; Mundell, 2000, 2003; Padoa, 2003; von Furstenberg, 2001). Beside the political aspirations of policy makers in Europe, the real economic challenge was to stand up to the increasing competitiveness of the U.S. dollar. Globally, the dollar plays a premier role as a reserve currency in foreign central banks, including European and communist ones, and as the currency of choice to price and conduct international trade, including most of Europe's transactions with the rest of the world (see Kenen, 2002; Portes, Ray, De Grauwe, & Honkapohja, 1998; Rogoff, 2004).

Globalization of finance further extended the dollar's domain beyond international trade. The lure of the dollar touches even the domestic domain of national currencies, just as Girton and Roper (1981) theorized and Calvo and Rodriguez (1977) predicted. The dollarization term became the new face of the wide substitution of national currencies in Latin America and elsewhere with the dollar, a currency perceived superior to local ones. Modeling work in the 1980s and 1990s increasingly paid more attention to dollarization as a process initiated and propagated by individuals. As the following discussion will show, the portfolio model continued to play an important role during this time period. However, the cash-in-advance framework, international currency competition theory, network and irreversibility or hysteresis effects were among the significant new contributions in the field.

As the dollar penetrated the local financial markets of Latin America and elsewhere, new portfolio based models emerged to specifically deal with this new reality that required fresh treatment. The term financial dollarization emerged to refer to the wide acceptance of the dollar as the denomination of deposits, securities, loans and in the pricing and fulfillment of local contracts. In short, financial dollarization refers to the dollarization of assets and liabilities (Ize & Levy-Yeyati, 1998). Generally, portfolio based models explained the emerging dollarization as the optimal portfolio choice for a given distribution of real returns in each currency. Even under an unstable exchange rate regime, individuals may assign low chance to a devaluation actually taking place. If devaluation materializes they expect the local currency (for example the peso) to collapse. This small risk probability of large loss broadens the peso-dollar spread. The size of the spread may grow to a point at which the default risk of a peso borrower indebted at a high interest rate exceeds the risk of a dollar borrower that faces a sure loan default only in the unlikely devaluation scenario (Levy-Yeyati, 2005). Specified functions for money supply shock and future growth rate expectations played an important part in modeling work during this period and still do today.

The capital asset portfolio model of Ize and Levy-Yeyati (1998) put the focus on the banking sector's role in encouraging dollarization. In their financial intermediation model, money choice is decided by hedging decision on both sides of a bank's balance sheet. Hence, the two sides of financial dollarization, assets and liabilities, interact through the loanable funds market. This interaction brings about financial equilibria that gravitate around interest rate parity and minimum variance portfolio allocations. The use of minimum variance portfolio allocation provides a natural benchmark to estimate the degree of deposit and loan dollarization, given macroeconomic uncertainty. At equilibrium, asset substitution is explained by the volatility of inflation (the second moments) instead of the usual and simpler expected inflation rate (the first moment). This is an important variation, not usually encountered in the literature.

A pass-through coefficient of exchange rate changes with prices in the model and helps link the financial with the real sector. This makes it hard for exchange rate policy to reverse dollarization once it is deeply ingrained. The displacement of local currencies by a foreign one can exhibit hysteresis symptoms, or in other words become irreversible, if the expected volatility of the inflation rate is excessive in relation to that of the real exchange rate (or inflation abroad). This implies that dollarization should be seen, at least partially as, "a natural consequence of trade liberalization and international economic integration. Hence, attempts to limit it can be ill-advised" (Ize & Levy-Yeyati, 1998, p. 4).

In a more recent paper, de Freitas and Viega (2006) discuss the dynamic optimization of money demand and its impact on currency substitution. Portfolio decisions in the foreign versus local currency denominated bonds guide the demand for domestic money. Portfolio composition is influenced by hedging and speculative incentives. It changes based on return differentials subject to maximizing a flow budget constraint. The expected exchange rate depreciation term in the demand for domestic money provides a test for the presence of currency substitution. de Freitas's empirical results also suggest that in countries facing monetary instability and currency substitution, restricting the availability of interest-bearing assets denominated in foreign currency can destabilize money demand.

However, introducing transaction cost leads to imperfect substitutability of competing moneys as in Uribe (1997) and Engineer (2000). These models use a "transaction technology" framework to avoid restricting money holding to one unit or good. This an improvement on other currency substitution models like that of Matsuyama, Kiyotaki, and Matsui (1993). This technology allows part of the market to use either local or foreign money in transactions.

The Market and Institutions View and the Reemergence of Cost Functions

The market-mechanism view explains financial dollarization by considering on market frictions, sluggishness and official barriers against currency and asset substitution. These factors include switching and transaction costs, network externalities, cash-in-advance assumption, expectational adjustment periods, the presence of multiple equilibria and hysteresis or irreversibility. The focus is generally on an individual optimization problem that is aggregated to the macro level. The institutional view emphasizes how policy can foster financial dollarization, either by introducing new distortions or by reinforcing the market dynamics in play. Policies like dollar pegs, taxing of foreign currency transactions, confiscation of foreign currencies, liberalization of trade and finance (especially dual currency banking systems), and providing inflation indexed assets can all have serious impact on dollarization levels.

Another area of focus, for example in Sturzenegger (1992, 1997) and Levy-Yeyati (2004) work, is

> on the relationship between the rate of inflation and the degree of currency substitution. On the one hand, they emphasize the direct effect the average rate of inflation has on currency substitution as private agents substitute out of the domestic currency to hedge against the erosion of its value, which intensifies currency substitution. On the other hand, they stress the feedback effect of the degree of currency substitution on the inflation rate as the base of the inflation tax shrinks and a financially constrained government monetizes its budget deficit, which, in turn, leads to higher inflation. (Neanidis & Savva, 2006, p. 2)

Furthermore, the interaction of rapid money supply and currency substitution is also present in studies that examine the irreversibility of currency substitution. Theoretical explanations of this phenomenon have mainly focused on the transaction costs involved in switching between two currencies when randomly matched agents have differing currency preferences (de Freitas & Viega, 2006; Guidotti & Rodriguez, 1991; Oomes, 2003; Uribe, 1997). Evidence of hysteresis has been accounted for by using a ratchet effect function. This function usually depends on current and lagged inflation or depreciation rates as in Kamin and Ericsson (1993).

Dollarization hysteresis can also exist due to factors such as the sizable transactions costs involved in switching money holdings from foreign currency back to domestic currency (Guidotti & Rodriguez, 1991; Uribe, 1997) or the gradual development of financial instruments and institutions that depends on using foreign currencies during sustained high-inflation episodes, which then become permanent parts of the landscape even after inflation subsides (Dornbusch & Reynoso, 1989; Dornbusch & Wolf, 1990).

Transaction Cost and Network Based Models

Early transaction cost based models focused on the cost of switching back and forth between currencies and predicting the need for incurring such cost. The expected return from switching must more than compensate for the cost of staying with a depreciating money brand, for example.

Guidotti and Rodriguez (1991) built a transaction cost model with a neutral band for inflation; within it there is no incentive to de-dollarize. Switching back to a domestic currency following dollarization will occur only if domestic inflation is low enough to overcome a transaction cost difference between using dollars and a domestic currency. This transaction cost threshold for reversing established dollar holdings is a form of 'ratchet effect' of inflation on money demand. The ratchet effect reduces money demand for a local currency when inflation rises, but increasing this demand by a lesser extent when inflation falls. Sturzenegger (1992) extends Guidotti and Rodriguez work by emphasizing scale economies and financial adaptation as forces behind hysteresis effects driven by transactions costs. These papers are good examples for the modeling path that explains dollarization through transaction cost, network externalities and hysteresis associated with currency use.

One of the early efforts to understand network externality, is Farrell and Saloner's (1985, 1986) papers on the effect of 'Installed Base and Compatibility' of various technological standards on competition and the introduction of new products. Farrell and Saloner explained network externality as an increase in the usefulness, or value of a good to any user, as more users choose compatible goods. If an installed base exists and transition to a new standard must be gradual (not mandated by the government,) early adopters will bear higher costs than late adopters. This can cause “excess inertia.” If the transition is mandated, then delaying the conversion to the new standard may be costly. The high cost of procrastination can create “excess momentum” as agents attempt to minimize cost by adopting the new or mandated technology (see Farrell & Saloner, 1986, p. 940). Farrell and Saloner’s (1985) earlier model considered only the decision to switch to a new technology as one time opportunity, while the 1986 paper introduces more flexibility allowing the participants to switch at different times. The authors found that “excess inertia” can exist even under “complete information” conditions if large networks are present. Large networks can have two externalities affecting a user’s adoption decision: the stranding or lock-in effect on the installed base that can produce negative returns by delaying new technology adoption, and an increasing return effect on late adopters that may encourage procrastination.

Dowd and Greenaway’s (1993) modeling work represents one of the earliest efforts at introducing the role of agent interaction and currency network into currency competition literature. The model examines currency competition and substitution with network externalities and switching constraint factors. Network effect is explained as the increase in the value of a particular currency to a user as the number of users of that currency increases. The network effect influences the agent’s decision to switch from one currency to another depending on his/her expectations about what other agents will do. The scale of currency networks has a direct impact on the value of money holdings and as a consequence on people’s money demand for various currencies. In this model, agents have the choice to hold only one of two currency types. The model’s network externalities exhibit increasing returns under conditions of perfect foresight, where agents know the currency preferences of the others. However, the perfect foresight assumption leads to corner solutions. It also does not allow a currency to be used as a store of value only without also being used as a medium of exchange. The switching decision uses a simple utility function and produces instant corner solutions. Money is not presumed to have a store of value function. See also Dean (2000) for an expanded discussion of the role of transactional networks in currency competition.

The presence of multiple equilibria that supported the co-existence of multiple currencies gained strong momentum with the widely cited paper of Matsuyama et al. (1993). The authors employ a model of two countries with their own respective currencies. Agents are randomly matched in a semi "cash-in-advance" setup, where agents can only trade with fiat money without requiring a particular money brand to be used. Generally, random matching models assume a random process in which agents are matched uniformly in pairs, where the opportunity of any agent to transact with another is the same. Matsuyama et al. "divide agents into two groups and assume that a pair of agents that belong to the same group is more likely to be matched than a pair of agents that belong to different groups" (p. 284). The model demonstrates the possibility of multiple equilibria in the usage of the two currencies. Agents are allowed to hold only one unit of one currency type per-period and to conduct one transaction with that money. By using discrete time periods and a transaction mechanism, equilibria are generated through a search based evolutionary process (see also Kiyotaki & Wright, 1993). The transaction mechanism or technology is in the form of a 2 x 3 matrix of the probability that an agent with a particular preference set will meet another agent who is similar, different or meets nobody. When one currency brand gains market share at the expense of the other, those who use that currency will gain too due to the expanded network of users that makes transactions easier. Economic integration between two countries is an important facilitator for one local currency to be used internationally and to compete with the local currency of other countries.

Peiers and Wrase (1997) related currency hysteresis in Bolivian financial markets to network externalities. “The probability of observing a dollar-denominated loan in a particular region of Bolivia is shown to be positively related to various proxies capturing positive network effects on agents from dollar usage” (p. 1). Transaction cost, in the form of borrowing fee, increases with the size of the loan and decreases as network externalities for a currency increases. Peiers and Wrase further explain this by saying “a network of dollar users increases the marginal cost of lending Bolivian currency and decreases the marginal cost of lending dollars” (p. 4). Political credibility as a factor is also included in five different variables to try to isolate hysteresis from network externalities effects and to identify ratcheting events. Ratcheting events are those that follow a shock to exchange rates that lead to a strong rise or ratcheting in the dollarization level of domestic financial markets and the economy at large. Hysteresis or the persistence of a new higher dollarization level after a ratcheting event takes place when the population does not credibly trust the political will of the government in stabilizing the local economy. This lack of trust can be born out of historical experience with the current ruling party or previous economic reform and stabilization attempts and/or contradictions in the current macroeconomic policies of the various authorities in the country. Controlling for ratcheting and hysteresis effects can help identify the pure role of positive currency network externalities in gradually driving currency and asset substitution levels. Peiers and Wrase also tried to make their model more flexible by allowing multiple holdings of money and goods. Households maximize utility by ordering their preference of consumption goods subject to their currency holdings.

A different approach to understanding competition among international currencies was provided by Lyons and Moore (2005). Their paper addresses currency competition from a transaction information perspective. In traditional models, transactions do not convey information. Therefore, transaction costs, the driver of competition outcomes, are influenced by market size. By adding the information aspect, it is possible to understand currency trade patterns with the help of the concentrating force of the market. Transaction channel type, direct or through a vehicle, actually makes a difference in prices because different trading methods do not convey homogenous information. Finally, the model formally demonstrates a currency arbitrage process and shows that arbitrage transaction quantities and price levels are jointly determined. The information model predicts that transactions should affect prices across markets, albeit at various degrees in the short run.

Cash-In-Advance Models

Lucas (1980), Lucas and Stokey (1987), and Svensson (1985) pioneered the cash-in-advance class of models. In cash-in-advance models, there is an upper limit to agents' purchases capped by the money held at the beginning of the period. The cash-in-advance constraint (sometimes known as the Clower constraint[6]) is used in economic theoretical development to capture monetary phenomena. In the most basic economic models (such as the Walras model or the Arrow-Debreu model) there is no role for money. These models are not sufficiently detailed to consider how people pay for goods. To be able to say anything about the money supply, inflation monetary policy and so on, the cash-in-advance constraint is used. This assumption requires each consumer or firm to have sufficient cash available before they can buy goods. This assumption also justifies the medium of exchange role of monetary assets. Hellwig (2000) explains that

> all agents trade twice to acquire what they want to consume: once to obtain the medium of exchange (sell their production), and once to buy their consumption good. Effectively, a cash-in-Advance constraint for transactions with intermediaries is introduced, i.e., market participants have to use the common medium of exchange to be able to trade with intermediaries. (p. 4)

It can be regarded as an extreme special case of the shopping-time approach, where extra consumption through shopping is possible but increasingly expensive in terms of time or other resources (McCallum & Goodfriend, 1986). Cash-in-advance models provide a conducive framework to discuss network, transaction cost and hysteresis factors.

Uribe's (1997) cash-in-advance model with network externality and hysteresis effects provide an important foundation to much of the research work that followed, including that of Oomes (2003). A unique twist is Uribe's modeling of hysteresis as a human experience factor with a currency that can be slowly accumulated and lost overtime. The cost of buying goods with a foreign currency is decreasing in the

---

[6] After economist Robert Clower (1965) who suggested an evolutionary mechanism until "goods buy money and money buys goods, but goods don't buy goods" (p. 6).

economy's accumulated experience in transacting in the foreign currency. This experience is shown to display hysteresis in money velocity, that is, a temporary increase in expected inflation can cause a permanent increase in velocity. In addition, the model implies that the domestic currency does not have to dominate the foreign currency in rate of return to induce agents to stop using the foreign currency. Finally, inflation rates that trigger currency substitution need not be associated with steady states in which the domestic currency disappears from circulation. More than one brand of money can coexist in a persistent equilibrium. Uribe's model demonstrates the role of learning by doing in currency substitution. He uses a law of motion for the accumulated experience of agents with the foreign currency, which can also depreciate if not used. A human experience factor is not easy to quantify in empirical models, but the law of motion part of it turned out to be useful in Oomes' (2003) work.

In an extensive empirical study of the spread and persistence of dollarization, Kamin and Ericsson (1993) focused on macroeconomic factors, such as domestic inflation as well as behavioral factors. Agents' learning to transact in a new currency and their use of banking services for transactions, just as in Uribe's model discussion above, were found to be instrumental in driving dollarization. Of particular interest is their discussion of hysteresis and menu cost problems in transition between different currencies. They found, for example, that the maximum past domestic inflation rate affects its expected future value. This relationship between past and future inflation rates was found to have a statistically significant "ratchet" effect on dollarization. The larger the maximum past inflation, the more likely it is for dollarization to persist. This is explained partially by the lack of timely and cheap information about inflation adjusted nominal interested rates (real Interest rates) on Peso deposits. The authors also found that using past maximum depreciation rates as ratchet variables worked well in predicting hysteresis outcomes. But realizing that a total irreversibility of dollarization is not very realistic, the authors expanded their model to include prices, interest rates on bank deposits and savings, exchange rates and dollar holding in the banking sector.

Another variation of the cash-in-advance class of models was provided by Engineer (2000). Again in Engineer's model two competing fiat currencies, domestic and foreign, may coexist as media of exchange. Unlike in Uribe and Oomes' models, agents are allowed multiple holdings of money and goods along with a stochastic consumption demand, and high and low uncertainty levels in forming expectations. The domestic currency has lower transaction cost but a higher growth rate than the foreign currency. This currency is used in everyday transactions and has a higher velocity of circulation at equilibrium. In contrast, the foreign currency is hoarded for occasional high consumption shocks and precautionary consumption. It has high transaction cost but considered a strong store of value and thus used for occasional large purchases. The different endogenous roles for the currencies provide an explanation for the nondisappearance of the hyperinflating domestic currency in the presence of a stable foreign currency.

Money specialization leads to nonsubstitution, which is useful for analyzing hysteresis and defacto optimal/maximum saturation levels of dollarization. Though the presence of the foreign currency lowers the value of the domestic currency, it may increase welfare when large amount of seigniorage[7] is to be generated. The foreign currency's transaction cost is assumed to increase as the size of its network increases. Despite the unrealistic nature of this assumption, Engineer makes this compromise to keep his model internally consistent. The increasing circulation of a currency is accompanied by decreasing transaction cost, thus the expanding network of users produce positive spillover benefit.

Camera, Craig, and Waller (2004) use two factors--currency risk and trade frictions--to model how fiat currencies compete in an open market and obtain equilibrium values. Agents look at the utility they derive from spending one currency versus another. The risk involved is that of sudden confiscation of the local currency via inflationary measures, while the foreign currency is assumed to be free of such risk. The category of agents who hold both local and foreign money need to decide which money to spend first, given the risk involved and the expected utility that can be generated over time. Agents prefer to transact in the safe currency, unless trade frictions and the currency risk are low. Trade friction is also dependent on the risk factor without specifying an interaction function. As the relative risk of two currencies changes, their values also change leading to market price disturbances. Buyers' spending strategies are affected by price disturbances to the effect of altering economy-wide transaction patterns and the relative transaction velocities of the currencies.

---

[7] Seigniorage can be defined as the real return on printing money.

Camera et al. (2004) find that dollarization threat is more serious to poorly functioning economies with risky currencies. They conclude by stating that “our analysis is consistent with the view that the local currency sustains internal trade if the purchasing power risk is kept very low, but once that risk gets too high substantial currency substitution kicks in” (p. 542).

Feige et al. (2003) who employ Oomes’ modeling approach in their paper also note the impact of hyperinflations and severe exchange rate depreciations in radically reducing the rates of return on local domestic currencies relative to U.S. dollars. Under falling local currencies’ purchasing power, individuals flee to the perceived safety of the dollar or other strong foreign currencies. Asset substitution is usually the primary motive to avoid the costs of a depreciating store of value. However, currency also represents an important medium of exchange, and the extent of currency substitution depends upon the relative transaction costs of foreign and local currency.

Relative transaction costs are, in turn, determined by the network externalities enjoyed by the users of each alternative medium of exchange and the costs of switching between them. For any expected rate of depreciation of the domestic currency, it is more likely that agents will substitute into a foreign currency if other agents already use it as a co-circulating medium of exchange in the domestic economy. When severe exchange rate depreciation induces unofficial dollarization, network externalities tend to reinforce the rewards of holding the stronger currency. Switching costs inhibit a return to the local currency even after a successful stabilization effort. “These well known incentive effects give rise to the conjecture that once de facto dollarization has reached a threshold, it may well persist, leading to the observation of dollarization hysteresis" (Feige et al., 2003, p. 12).

Present Work and Future Extensions

Oomes' model can be regarded as a representation of an augmented cash-in-advance model by including network effects, and served as the foundation of my work. One important feature in Oomes' paper is the use of a logistical function to model a more realistic depiction of network effects and switching cost. This function also provides a mechanism that slows asset substitution at the extreme. Brock and Durlauf's (2001) suggestion that there are positive complementarities in joining a network made this crucial feature in Oomes' model possible.

David and Greenstein's (1990) work on the nature of industrial standards competition contained some interesting explanation of the dynamics of network externalities, especially what they termed the "bandwagon effect" (p. 7). Their discussion was beneficial in providing theoretical support to Oomes' work and the present work.[8] Further examination of both Oomes' model, and David and Greenstein's insights will be presented later as part of discussion of the theoretical approach of my work.

---

[8] Also, among the new exciting possibilities is the application of the network approach in currency substitution to other fields of research. Network effects can improve the understanding of the substitution dynamics between products and services, especially in duopolistic and oligopolistic competitive settings.

CHAPTER 3

THE MODEL

Theoretical Approach

In the area of currency competition, asset substitution refers specifically to the competition between local and foreign currencies (pesos versus dollars) over fulfilling the store of value function for money users. Currency substitution models, on the other hand, focus on how currencies compete to fulfill the medium of exchange function. The model I present takes into consideration both types of substitution by considering two types of costs associated with the holding and the use of money. These factors, under the right circumstances and functional form, produce network dynamics that favors one currency over another in a path determined fashion and persistent dollarization or hysteresis.[9] This section provides a literature discussion of these factors and ties this discussion with the model I present formally afterward.

As stated above, cost factors are of two types, holding cost and transaction cost. Holding cost captures the impact of peso's diminishing purchasing power, especially when it is held or saved for a long time. The holding cost to individuals or firms that rely

[9] Hysteresis is not a true theoretical explanation, rather an observed outcome that the model explains.

heavily on the store of value quality of a currency is higher versus those who carry only short-term transactional balances. The loss is positively related to peso's depreciation rate, and the size and the length of time a stock of pesos is held. According to Edmunds and Marthinsen (2003), agents experiencing hyperinflation may willingly keep on using small amounts of the local currency in daily purchases. However, the holding cost of a large amount of such currency may be too much to bear for some agents. Agents experiencing frequent hyperinflation episodes can adapt by converting their savings into safer stores of value, be it gold, dollars or Euros (see also Melvin, 1988). While a decision to convert savings into a safer asset may help protect against purchasing power losses, it also may make it inconvenient to make purchases later if the safer assets cannot easily be used for transactional purposes.

Transaction cost looks at the economic burden associated with moving money between two different denominations to pay for products and services. This cost exists whenever the preferences of buyers and sellers to transact with a certain brand of money differ. In other words, there is a cost when transacting parties belong to different transactional networks. In these instances, a transaction must also include the cost of converting currency from one denomination to another. In general, belonging to a network produces external gain to its members. The gain is in the form of savings on currency switching cost. The gain increases as the size of the currency network expands and so does the opportunity cost of opting out. Network externalities influence is strongest on agents who place more weight on the transaction cost of a currency, which is a function of other agents' choice to dollarize or not. Brock and Durlauf (2001) argue that thanks to external effects “payoff for a particular action is higher for one agent when others behave similarly” (p. 235).

New in my research is the use of the “bandwagon effect,” from industrial standard rivalry literature, to lend stronger theoretical support to the network and cost factors in the model. David and Greenstein (1990) describes the bandwagon effect as “the processes by which decision makers overcome coordination problems in planning how to adopt a new standard, starting with those with largest private gain to those with largest network gains” (p. 7). In the context of this dissertation, the bandwagon effect suggests that those who have the highest prospect of loss due to private holding cost consideration will be the first to dollarize their savings. Those who do so later are motivated mainly by the size of the dollar’s transactional network. Thus, under the right conditions of holding and transaction cost, there is a strong path-dependence element in the wide circulation of international money brands like the dollar, Euro and yen (see also Bergsten, 2002; Eichengreen, 2005; Greenspan, 2001; Jameson, 2003; Matsuyama et al., 1993; Ritter & Rowe, 2000). Furthermore, the expansion or contraction of a network is not an open-ended process. Network size tends to stabilize as Brock and Durlauf (2001) explain:

> the presence of social interaction will induce a tendency for conformity in behavior across members of a reference group. When social interactions act as strategic complementarities between agents, multiple equilibria may occur in absence of any coordination mechanism. (p. 235)

Oomes’ (2003) currency substitution model and the Feige et al. (2003) minor variation and application of the same model provide the underpinnings of the mechanism and econometric methodology for this dissertation. However, in order to analyze asset substitution problems, Oomes' framework was modified to admit multiple economic sectors, financial intermediation and different timing sequence to assure alignment between assumption and conclusions at the theory level. The model itself was enhanced by adding an interest rate differential variable and a radically different switching cost function to better reflect the constraints on deposit accounts and the behavior of switching cost as dollarization increases. The result is an Oomes' model variation that is theoretically and empirically adapted to analyze deposit dollarization case studies. The rest of this section will explain the above in more detail.

This chapter will present a model of currency substitution. The following section will discuss the model's foundation, assumptions, best response equations and theoretical treatments that enable the model to address network effects and hysteresis in currency competition. The next section discusses the expected values in the model and produces an econometrically estimable equation. This equation is tested on the case studies in Chapter 3.

Cost Functions

In Oomes' (2003) currency substitution model, the starting point is a group of general assumptions to build a cash-in-advance framework. Seller and buyer agents decide to hold either a local or a foreign currency today according to the expected cost associated with each currency. By combining the cost equations, buyers and sellers face a cost minimization constraint.

A major departure from Oomes' model is replacing the seller and buyer categories with agents being either in the domestic or the foreign currency network. There is also no need to use three time periods to build the model, during which a buyer at time *t*-1 becomes a seller at time *t* and again a buyer at time *t*+1. A buyer at time *t*+1 uses his previous buying experience at time *t*-1 to form his expectations and currency preference at time *t*+1. The model developed here does not require multiple time periods. An agent's currency preference, just as in Oomes' model, is based on expectations about the network value (the choices of other agents) and the holding cost (personal utility) of various currencies today (*t*) rather than tomorrow (*t*+1).

Oomes' cash-in-advance assumption has been relaxed to allow agents to hold different amounts of cash and own different amounts of a homogenous product. Since network size influences currency preferences of all agents, key market players (large currency holders/users) are allowed to have a bigger role in the model presented in this dissertation. It also helps justify the use of a logistic function in combination with the bandwagon effect to explain why certain agents may decide to dollarize ahead of others due to putting different weights on the holding and transacting costs.[10] However, agents still need to have money in advance and to make decisions regarding denomination of their currency holdings. As in a typical cash-in-advance model, agents are also restricted to conducting one transaction per period (see Dowd & Greenaway, 1993; Matsuyama et al., 1993).

There are two currency networks, one for the local (peso) currency and one for the foreign (dollar) currency. An agent can hold only one kind of currency at any time.

---

[10] The empirical testing did not differentiate between various agents. The "bandwagon effect" is used as a useful theoretical explanation of the behavior of various agents.

If an agent decides to hold his money in pesos it automatically becomes part of the peso currency network. In a similar manner, if an agent decides to hold dollars, he/she will automatically become part of the dollar network. Belonging to a network is beneficial when both sellers and buyers prefer to transact in the same money brand and thus avoid switching costs.[11]

At time *t* agents form expectations about the cost of holding and transacting pesos versus dollars. Agents expect that the purchasing power of their currency holdings to deteriorate by the rate of inflation in prices of goods and services denominated in pesos or dollars. Inflation is a real concern for agents as it directly impacts their wellbeing and future consumption ability.

Countering the inflation cost, money holdings at financial institutions (banks) earn a nominal interest rate of (i_t) and (i_t^*), on domestic and dollar deposits respectively at time *t*. Agents also assess the benefit of transacting with various currencies by looking at the cost of switching (σ_t) from one to another. The chance of incurring a switching cost depends on the dollarization ratio (p_t) in the economy at time *t*. The dollarization

---

[11] One kind of transaction cost that was dropped from the model developed in this dissertation and was in Oomes' paper is Institutional barriers. Institutional barriers, like regulations, taxes and fees, can increase the cost of transacting in foreign currencies. Dollar holdings can face an institutional cost *q* if used in transactions or face other institutional or market barriers when shopping at small or remote markets where the dollar is less familiar and harder to exchange. Oomes used a foreign exchange fee imposed on switching from Russian Rubles to U.S. Dollars to represent this transaction cost. In the case studies of Argentina and Bolivia, which this research presents, data on such cost were not available and therefore it was dropped from the model. Institutional and market barriers are similar to the presence of barriers against entry and exit into industries and in adopting a technology standard in industrial organization literature. A decrease in these barriers is key to creating contestable markets, where monopolist or oligopolist firms price like perfect competitors for fear of market share loss due to ease of entry and exit by opportunistic entrepreneurs or currency arbitrage by typical agents.

ratio stands for percentage of agents choosing to hold dollars at time *t*. Even though different agents may belong to different currency networks, their chance of transacting with agents of a different network is equal to that network's share of the market, as represented by p_t.[12] The product of multiplying the switching cost factor by the probability of transacting with another dollar holding agent ($\sigma_t\ p_t$) then becomes the expected switching cost for peso holders at time *t*.

At time *t*-1, agents form expectations about the inflation rates on peso and dollar denominated prices by looking at the peso's and dollar's depreciation rates ($\hat{e}_t, \hat{e}_t^*$), interest rates on peso and dollar deposits ($\hat{i}_t, \hat{i}_t^*$), and the switching cost ($\hat{\sigma}_t$) at time *t*. The expected cost of holding and transacting with pesos $c(m_t)$, at time *t* becomes:

$$c(m_t) = \hat{e}_t - \hat{i}_t + \hat{\sigma}_t \hat{p}_t \tag{1}$$

And the expected cost for dollar users, $c\ (m_t*)$, becomes:

$$c(m_t^*) = \hat{e}_t^* - \hat{i}_t^* + \hat{\sigma}_t (1 - \hat{p}_t) \tag{2}$$

---

[12] One way to improve the model is to change the probability of agents having to transact out of their network from being proportional to the size of the network to having a higher probability to transact within one's chosen network. Agents in the second scenario can be assumed to belong to different economic sectors like financial versus agricultural, or urban versus rural markets, etc. Agents in a specific sector have a higher probability to transact with each other than with agents in other sectors, without precluding the chance for an intrasector transaction taking place.

Cost minimizing agents will hold dollars whenever *c* $(m_t^*) < c\ (m_t)$ and will hold pesos if the inequality is reversed. There is still a possibility that agents may continue to prefer a currency for noneconomic considerations that are observable to them only.[13] Let ε_t and ε_t^* represent these unaccounted and unobserved random utility (or disutility) factors influencing the currency preferences of agents. ε_t and ε_t^* influence the decision to hold pesos or dollars respectively by an agent at time *t*.[14] To arrive at the final form of the model and to produce S shaped curves, φ is introduced as a coefficient of ε_t and ε_t^*.[15] Now we can state the probability (p_t) that a given agent will hold dollars at time *t* to be

$$\begin{aligned} p_t &= \Pr\{\, \mathrm{c}\,(\mathrm{m}_t^*) + \varphi\,\varepsilon_t^* < \mathrm{c}\,(\mathrm{m}_t) + \varphi\,\varepsilon_t \,\} \\ &= \Pr\{\varphi\varepsilon_t^* - \varphi\varepsilon_t < [\hat{e}_t - \hat{i}_t + \hat{\sigma}_t\hat{p}_t - \hat{e}_t^* + \hat{i}_t^* - \hat{\sigma}_t(1-\hat{p}_t)]\} \\ &= \Pr\{\varepsilon_t^* - \varepsilon_t < 1/\varphi[\hat{e}_t - \hat{e}_t^* + \hat{i}_t^* - \hat{i}_t - \hat{\sigma}_t + 2\hat{\sigma}_t\hat{p}_t]\} \end{aligned} \tag{3}$$

If we assume that agents know ε_t and ε_t^* at time *t*, and that these random factors are identically and independently distributed (idd) then the difference in ε_t and ε_t^* can be

---

[13] Agents may hold pesos because of patriotic sentiment, believe the economy will improve soon, or want to comply with laws that prohibit transacting in foreign currencies among other reasons.

[14] Feige et al. (2003) explain that "In order to close the model and introduce a stochastic element that allows for noncorner solutions, Oomes uses the random utility terms ε_t and ε_t^* that account for unobserved variables effecting the cost or benefits of holding domestic and foreign currency" (p. 60).

[15] Brock and Durlauf (2001) developed φ as a coefficient that measures the overall role of ε_t and ε_t^* on the total expected cost. The term φ also incorporates the effect of social interaction and interdependencies of agents' decision. This term is used in this dissertation to easily arrive at the final form of the model without departing too much from the literature, which this model is based on. It probably can be simplified by including φ in ε_t and ε_t^* in future refinements.

assumed to be logistically distributed in the following manner:[16]

$$\text{If, } x = [\hat{e}_t - \hat{e}_t^* + \hat{i}_t^* - \hat{i}_t - \hat{\sigma}_t + 2\hat{\sigma}_t \hat{p}_t]$$
$$\text{and, } \Pr(\varepsilon^* - \varepsilon < x) = [1 + \exp(-\varphi x)]\text{-}1 \qquad (4)$$

$$\text{Then, } pt = \Pr(\varepsilon^* - \varepsilon < x) = [1 + \exp(-\varphi x)]\text{-}1$$
$$\text{or, } pt = [1 + \exp(-\varphi x)]\text{-}1 \qquad (5)$$

Brock and Durlauf (2001) use the logistic transformation in Equation 5 to create "a direct link between the theoretical model and its econometric implementation" (p. 239). This transformation into logistic distribution is instrumental in depicting the observed excess inertia and excess momentum that characterize currency competition. This behavior is sometimes termed as the "bandwagon effect"[17] described earlier.

The model becomes econometrically estimable when the standard discrete choice theory[18] is applied to Equation 5. The theory helps generate the following equation to describe the discrete choice of dollarizing.

---

[16] See Appendix B for further information on the probability and cumulative density functions of logistic distribution.

[17] Agents in different economic sectors may put varying values on the different cost components of the currencies they hold and use or plan to. Export and financial sectors may convert to a safer currency because they put a higher value on the stability of a currency. This stability is crucial for fulfilling long-term obligations or dollar denominated obligations as in foreign currency denominated liabilities. These type of agents will be among the early adopters of the safer currency regardless of what other local agents decide to do. Other agents at the local retail level may find it more convenient to hold and transact in a currency that their customers are paid in and are familiar with its look and purchasing power. These agents will adopt the safer currency only after enough agents have done so to justify the transaction costs involved.

[18] The theory uses a qualitative response model where the dependent variable is an indicator of a discrete choice, such as yes or no. In our case it is pesos or dollars (see Greene, 2003 for discussion on random utility models).

$$p_t = (1 + \exp\{-\tfrac{1}{\varphi}[\hat{e}_t - \hat{e}_t^* + \hat{i}_t^* - \hat{i}_t - \hat{\sigma}_t + 2\hat{\sigma}_t \hat{p}_t]\})^{-1} \quad (6)$$

Equation 6 contains the following important properties: The probability that a typical agent will choose to save dollars, given expected dollarization levels $\hat{p}_t$, increases with the increase in expected inflation $\hat{e}_t$, a decrease in dollar's inflation $\hat{e}_t^*$, and the gap between $\hat{i}_t^* - \hat{i}_t$.[19]

Interestingly, $\hat{\sigma}_t$'s influence changes depending on the value of $\hat{p}_t$. If the expected dollarization ratio at (*t*) is relatively low, an increase in expected switching cost $\hat{\sigma}_t$ will depress dollarization levels today p_t. If on the other hand $\hat{p}_t$ is relatively high, an increase in switching cost will encourage more agents to dollarize their money holdings. This happens because all agents are exposed to incurring transaction costs. However, the burden of this cost varies between the members of the two currency networks (the peso and the dollar) according to their sizes or the probability of having to transact within the network. So, when the dollar network is small, dollar holdings are more exposed to a transaction cost premium than peso holding and vice versa when the dollar network is large.[20] This behavioral pattern preserves the status quo, i.e., to keep agents in the peso

---

[19] The longer a stock of pesos is held (n time periods) and the higher the rate of depreciation is, the higher its holding cost. $\hat{i}_t^* - \hat{i}_t$ is expected to be a negative sum since rates of return on local currencies usually add a country risk premium. Thus, larger negative $\hat{i}_t^* - \hat{i}_t$ sums should lessen pesos account losses or make peso accounts more attractive and vice versa.

[20] This can impose market inefficiency due to the difficulty of coordinating agents' decision making process to arrive at a socially optimal outcome. This may justify the involvement of a

network when the peso is dominant and in the dollar network when it is dominant, thus producing hysteresis. This hysteresis outcome also captures the "bandwagon effect" of the agents who are more concerned about transaction costs rather than holding costs and thus are not interested in switching back. These agents hesitate to convert from one network to another, unless they can see obvious return.

Appendix C demonstrates, through simulations, the impact of manipulating the various parameters in Equation 6 and how the dollarization paths can change dramatically in response. The simulations in Appendix C are very useful in understanding what range of values can produce multiple dollarization equilibria and which ones do not.

Expectations and Functional Forms

From the above analysis, agents' currency choices are found to depend on the expected values of $(\hat{e}_t, \hat{e}_t^*, \hat{i}_t^* - \hat{i}_t, \hat{\sigma}_t \text{ and } \hat{p}_t)$. Also a functional form that is theoretically sound and lends itself to econometric estimation is needed for some of these variables. These issues are the subject of this section.

Starting with $\hat{p}_t$, buyers can predict that dollarization level today to be similar to the one they experienced in their last shopping trip or last period (*i*-1), so $\hat{p}_t = p_{t-1}$. "This assumption is considered reasonable in cases where agents repeatedly encounter similar situations" (Oomes, 2003, p. 16). With a sufficiently large pool of agents, p_t or the

---

governmental entity to make a decision whether to dollarize or not, or to adopt a new technological standard or not as the Federal Communication Commission (FCC) mandated the full conversion of TV broadcasting from analog to digital signal transmission.

overall dollarization ratio at time *t* is equal to the probability that a random agent is holding dollars at time *t*.

Second, the same assumption above will be used with $(\hat{i}_t^* - \hat{i}_t)$ so we have $(i_{t-1}^* - i_{t-1})$. In calculating the reward from holding a currency, agents look at the nominal interest rate paid on deposits in that currency in the previous time period (*i*-1). Citizens in financially vulnerable economies "frequently require extra compensation to voluntarily hold their own money in deposit because they view it as an inferior brand" (von Furstenberg, 2000, p. 21). Just paying interest rates on peso deposits may not be enough to convince people to let go from the safety of dollarized savings.

Third, switching cost ($\hat{\sigma}_t$) from one currency to another[21] will be assumed to depend on the dollarization level in the economy and to have a convex parabolic shape:[22]

$$\hat{\sigma}_t = -4(\gamma - 1)p_{t-1}^2 + 4(\gamma - 1)p_{t-1} + 2 \tag{7}$$

where, 0 < γ < 1.

---

[21] Good and well documented data on switching or transaction costs or a proxy for such costs are hard to find in general.

[22] Oomes (2003) assumed that switching cost ($\hat{\sigma}_t$) to depend on the prevailing dollarization level in the economy. The increasing demand for dollars encourages more foreign exchange kiosks and businesses to open, which will increase competition and reduce switching costs from pesos to dollars. The functional form she suggested as a proxy for switching cost is: $\sigma_t = 1 - \gamma\ p_{t-1}$. In this formulation, switching cost is at its highest when the dollarization ratio (p_{t-1}) at its lowest. Feige et al. (2003) used a slight variation of Oomes' switching cost function by specifying an intercept that will be estimated empirically. Their form is $\sigma_{t+1} = \gamma_1 - \gamma_2 p_{t-1}$.

In Equation 7, σ_t represent a switching cost index. Equation 7 implies that when dollar holdings at zero or at a maximum (p_{t-1} = 0 or 1), the transactional cost index will be at its highest where (σ = 2). The switching cost index will be at its lowest when p_{t-1} = 0.5 and the final value of index will depend on γ. Equation 7 suggests when there is a dominant currency it is costly to transact with a rival currency and when rival currencies share the market equally, the transaction cost will be the same for all currency holders.[23]

Fourth, expectations about peso's depreciation can be the product of a number of factors. Using the "expectational adjustment periods" approach,[24] agents will be assumed to predict peso's depreciation rate at time *t* by referring to the peso's depreciation rate at time *t*-1 and also its highest depreciation rate in the recent past. By referring to the peso's highest depreciation rate in the recent past, indicates a ratchet effect. The ratchet effect captures the impact of previous strong depreciation episodes, which led to strong purchasing power loses. The expected rate of peso's depreciation is assumed to be

$$\hat{e}_t = \alpha e_{t-1} + (1-\alpha) e_{t-n}^{\max} \qquad (8)$$

where, $0 < \alpha < 1$.

---

[23] The credit for devising this function goes to David Kiefer.

[24] This approach stands for the realization that it takes time before agents become convinced that a present macroeconomic stability is of permanent nature (see Oomes, 2003; Peires & Wrase, 1997). Other explanations incorporate transaction and learning cost.

e_{t-1} is the depreciation rate in the previous period. $e_{t-n}^{\max} = \max\{e_{t-1}, e_{t-2},...e_{t-n}\}$ is the highest depreciation rate in the previous n periods and it is the source of ratcheting effect in the model.[25] Agents expect with a probability α that the depreciation rate this period will be equal to e_{t-1} and with a probability of $(1-\alpha)$ expect the depreciation rate to equal $e_{t-n}^{\max}$. The foreign currency is assumed to be a stable bench mark for value. Therefore, $\hat{e}_t^* = 0$.

After doing the required substitutions to Equation 6, we arrive at specifying the following law of motion:[26]

$$p_t = (1+\exp\{-\tfrac{1}{\varphi}[(\alpha\, e_{t-1} + (1-\alpha)\, e_{t-n}^{\max}) + (i_{t-1}^* - i_{t-1}) - (-4(\gamma-1)p_{t-1}^2 + 4(\gamma-1)p_{t-1} + 2) + 2(-4(\gamma-1)p_{t-1}^2 + 4(\gamma-1)p_{t-1} + 2)\, p_{t-1}]\})^{-1} \tag{9}$$

Equation 9 permits us to predict how the dollarization of assets will evolve over a certain time period, given the values of the variables $(e_{t-1}, e_{t-n}^{\max}, (i_{t-1}^* - i_{t-1}),$ and $p_{t-1})$. If these principal variables remain unchanged, the dollarization ratio of asset will converge to a steady state p^* that solves $p_t = p_{t-1}$ for all t. This also indicates that changes to

---

[25] Oomes' (2003) equation is $\hat{e}_t = \alpha e_t + (1-\alpha)e_t^{\max}$. Using the current depreciation rate in the equation raises issues of the presence dependent variable endogeniety. Endogeniety bias exists when your dependent variable and independent variable move in the same direction causing multicollinearity problem. Feige et al. (2003) explains Oomes' formula by saying "expectation formation is assumed to be a linear combination of perfect foresight and the ratchet effect" (p. 60).

[26] Oomes' equation is $p_t = (1 + \exp\{-1/\varphi\, [e_t - \sigma_t + (2\sigma + \tau_t - q_t)\, p_{t-1}]\})^{-1}$. In this equation, q_t stands for the risk of confiscation of a foreign currency if used in transactions and τ_t stands for a government tax on switching a local currency into a foreign one.

$(e_{t-1}, e_{t-n}^{\max}, (i_{t-1}^{*} - i_{t-1}),$ and $p_{t-1})$ will alter the asset substitution equilibrium as well. In this modification of Oomes' model we can also experiment with different values for the above variables to examine their impact on deposit dollarization equilibrium in an economy, as was done in the introduction.

Econometric Equation

The above logistic structural form equation of the model can be linearized by logistic manipulation in the following manner:

$$\text{Let x} = [(\alpha e_{t-1} + (1-\alpha) e_{t-n}^{\max}) + (i_{t-1}^{*} - i_{t-1}) - (-4(\gamma - 1)p_{t-1}^{2} + 4(\gamma - 1)p_{t-1} + 2) + 2(-4(\gamma - 1)p_{t-1}^{2} + 4(\gamma - 1)p_{t-1} + 2)\, p_{t-1}]$$

Then Equation 9 can be written as:

$$p_t = \frac{1}{1 + \exp\{-\tfrac{1}{\varphi}[x]\}}$$

$$\frac{1}{p_t} = 1 + \exp\{-\tfrac{1}{\varphi}[x]\}$$

$$\frac{1}{p_t} - 1 = \exp\{-\tfrac{1}{\varphi}[x]\}$$

So, $$\frac{1 - p_t}{p_t} = \exp\{-\tfrac{1}{\varphi}[x]\}$$

$$\ln\left(\frac{1 - p_t}{p_t}\right) = -\frac{1}{\varphi}[x]$$

to produce the linearized model below:

$$\ln\left(\frac{1-p_t}{p_t}\right) = -\frac{1}{\varphi}[(\alpha e_{t-1} + (1-\alpha)\, e_{t-n}^{\max}) + (i_{t-1}^{*} - i_{t-1}) - (-4(\gamma-1)p_{t-1}^{2} + 4(\gamma-1)p_{t-1} + 2)$$
$$+2\,(-4\,(\gamma-1)p_{t-1}^{2} + 4(\gamma-1)p_{t-1} + 2)\,p_{t-1}] \qquad (10)$$

While the dollarization ratio p_t have a range of 0 and 1 by definition, $\ln\left(\frac{1-p_t}{p_t}\right)$, the log odds ratio range of values is not restricted.

To estimate the principal parameters (*φ, α and γ* in Equation 10) of the model directly a nonlinear regression method is used with the two case studies in this research. Restrictions were imposed on the values of α and *γ* to confirm these parameters to their expected values (between 0 and 1). Finally, in Equation 8, $\hat{e}_t = \alpha\, e_{t-1} + (1-\alpha) e_{t-n}^{\max}$, a maximum lag will be set to six,[27] se we have $e_{t-6}^{\max} = \max\{e_{t-1}, e_{t-2}, e_{t-3}, e_{t-4}, e_{t-5}, e_{t-6}\}$.

---

[27] The ratchet effect $e_{t-6}^{\max}$ was chosen through an experimental process in which a range of lengths ($e_{t-2\ \dots 8}^{\max}$) were tested. The $e_{t-6}^{\max}$ was chosen because it had a good model fit (highest *R*-Square results) and produced significant parameters in the expected ranges of values in both of Argentina's and Bolivia's case studies. The nonlinear regression results of the experimental process can be found in Appendix A for Bolivia and Appendix D for Argentina.

CHAPTER 4

CASE STUDIES: ARGENTINA AND BOLIVIA

The Dollarization Phenomenon

Since the demise of the Bretton Woods system in 1973, neither fixed nor flexible exchange regimes have saved third world countries from experiencing severe financial upheavals. Rennhack and Nozaki (2006) narrates how:

> inflation in many Latin American countries during the period 1980-1995 was extremely high by historical standards and compared with other developing country regions. In the period 1980-2003, there were a total of 56 so-called free-fall events--defined as years when broad money or consumer prices rose or the currency depreciated by over 1,000% or when deposit or lending interest rates exceeded 100%. Three fourths of these events occurred in six Latin American countries (Argentina, Bolivia, Brazil, Nicaragua, Peru, and Uruguay). (p. 5)

Among the usually cited culprits behind these upheavals are balance of payment crises, inflationary finances, and contagious crises (see Krugman, 1993; Salvatore, Dean, & Willett, 2003). The common outcome of these two trouble filled decades was the emergence of the U.S. dollar as a global monetary standard. According to Jameson (2001, 2003), Latin America has been a dollar bloc since the 1970s. Ezrati (2004) and McKinnon (2000) considered Asia also as a dollar bloc and the U.S. currency as the foremost global monetary standard with the exception of the Euro area and its periphery. Latin America and Asia are considered dollar blocks because of the formal or informal exchange rate links between the individual currencies in the region and the dollar.

Financial dollarization, the dollarization of financial assets and liabilities, was also strongly encouraged by the globalization and liberalization of trade and finance (Ize & Levy-Yeyati, 1998). Since the United States is the main trading partner of most Latin American countries, the U.S. dollar is extensively used for international transactions, intra-South American trade (Latin America Research Group [LARG], 2005). Domestically, foreign currencies served as a portfolio diversification tool in the absence of other financial options (Havrylyshyn & Beddies, 2003; see also Baliño, Adam, & Eduardo, 1999). In this regard, conversion of assets to dollars helps hedge against a shaky exchange rate peg or expansionary monetary policies. However, this financial dollarization of assets and liabilities was a main factor behind dollarizing local trade and transactions.

Lack of trust in the future value of local currencies is often the most powerful driver of the extensive dollarization, as Singh et al. (2005) observe in Latin America (see also Cesarano, 1999; Feige et al., 2003; Melvin, 1988, for their observations in other parts of the world). A legacy of severe economic crises in the 1980s and 1990s destroyed confidence in economic policies and in holding savings in domestic currencies. In many instances "interest rates on deposits in domestic currency were unable to compensate depositors for inflation, leading to significant losses on savings held in domestic currency" (Singh et al., 2005, p. 80). Under these circumstances, citizens often required extra compensation to hold local money because they viewed it as an inferior brand. Even after inflation declines, suspicion of another sudden inflation bout can persist and the credibility of monetary policy to fight inflation may remain questionable. Under these circumstances, residents respond by converting their local currency deposits into foreign currency deposits to protect their purchasing power, measured in local currency, from the risk of an unexpected inflation episode. This fear is often reflected in witnessing yield curves in the six most dollarized South American countries in 2004, Bolivia, Paraguay, Peru, and Uruguay and Costa Rica. In these countries, the premium return on domestic over foreign currency deposits was in excess of inflation differentials. This excess reflects the presence of a country risk premium that local currency depositors need to be compensated for (Rennhack & Nozaki, 2006).

In early 2002, financial dollarization increased substantially over their levels in the 1990s in Argentina, Bolivia, Costa Rica, Nicaragua, Paraguay, Peru, and Uruguay. Dollar bank deposits and loans accounted for at least 40%, and in extreme cases more than 90%, of total loans and deposits (Singh et al., 2005).

Institutional and regulatory policies of local financial markets can also play a strong role to encourage or discourage dollarization. Governments often accept or encourage dollarization in the hope of remonetizing the economy after a crisis, accelerating financial development, and/or reversing capital flight (Savastano, 1996). Uruguay encouraged foreign currency deposit holdings as part of its efforts to promote the country as a regional financial center (Singh et al., 2005). Implicit guarantees for foreign deposits (Burnside, Eichenbaum, & Rebelo, 1999), foreign exchange pegs (de la Torre, Levy-Yeyati, & Schmukler, 2002, 2003) and currency-blind regulation and safety nets (Broda & Levy-Yeyati, 2003a, 2003b) all, expectedly or not, promoted currency and asset substation.

The resulting structure of the banking system became more conducive to financial dollarization of domestic markets. Prior to this, the credit market used to be segmented into large, high-quality firms with their own access to credit lines abroad and other borrowers (such as households and medium-sized and small enterprises) without such access. The use of the dollar increased efficiency from a micro perspective as it enhanced liquidity or generated greater efficiency in financial intermediation (Ize & Powell, 2004; see also Claasson & Martinez, 1994; von Furstenberg, 2001). Financial liberalization allowed more competition in the domestic banking market as banks started lending in foreign currency not only to high-quality firms but also to small firms and consumers. Another motive behind this expansion of dollar based credit is the alignment of the increasing share of bank liabilities denominated in foreign currency deposits with consumer and business loans that are denominated similarly (Catão & Terrones, 2000). This alignment is important for gauging banks' default exposure, managing their balance sheets or to just comply with bank regulations. All the highly dollarized economies of South America apply the same capital adequacy requirement to foreign and local currency assets and extend the same deposit insurance coverage to all deposits, regardless of currency denomination. Limitations on banks' net position in foreign exchange, and restrictions on the net long positions in foreign currency can also be a strong incentive to lend in foreign currency terms (Rennhack & Nozaki, 2006).

Faced with desperate economic challenges, governments may resort to abrupt change of rules, like the freezing of foreign deposits or even their forced conversion into local money at an exchange rate of their choice. For example, in August 1982 Mexico's government froze all dollar denominated deposits and nationalized all banks (Melvin, 1988). Or, governments can declare officially the adoption of the U.S. dollar as the official de-jure currency of the country, as El Salvador and Ecuador did in 2000 and 2001 respectively (Singh et al., 2005). Yet, another option can be to reaffirm trust in the national currency through various forms of credible and binding commitments by passing laws to protect the long term purchasing power of the local currencies, increase the independence of the central bank and its control over money supply and by bringing in international supervision to certify and monitor a government's commitment to a stable currency exchange rate. The first empirical case study of Argentina showcases the range of currency stabilization policies that successive governments have undertaken and the impact of these policies on the dollarization of its economy.

Argentina's Case Study

Argentina's dollarization history can be traced back to its inflation experience beginning in the mid-1970s. Annual rates of inflation of more than 100% became the norm in the late 1970s while the 1980s and 1990s yielded several hyperinflation episodes. It was common for the consumer price index in the early 1980s to rise at 20 to 40% per month. This trend abated somewhat in 1985 when Alfonso's government implemented the Austral plan that succeeded in controlling inflation by the end of that year. However, inflation rose steadily and in 1989, the inflation rate peaked at 190% per month. After a brief slowdown, inflation accelerated again to about 90% per month in 1990. In 1989 bank deposits were frozen as it was done in 1982 (Collyns & Kincaid, 2003). The government had, effectively, confiscated part of the savings of bank depositors to finance its expenses.

When Carlos Menem was first elected president of Argentina in May 1989, the inflation rate was running at 78% per month. To put an end to the vicious effect of hyperinflation on the economy, the Argentine congress passed the convertibility law in March 1991, establishing the convertibility of the austral into the U.S. dollar at a rate of 10,000 australes per dollar. In January 1992 the peso replaced the austral, at a rate of one peso for 10,000 australes. In response to the above strong policy changes, inflation dropped to 1% a month (Velde & Veracierto, 2000).

Throughout the 1980s, many Argentines converted to the dollar in the form of longer-term bank deposits and loans. Current and checking accounts that are usually used for transactional purposes were largely denominated in pesos throughout this period. In 1992, dollar denominated current account deposits were allowed. In 1993, checking accounts denominated in U.S. dollars were also permitted for residents to use for local and foreign transactions (Daniel, 2001). The wider legalization of dollar based deposits significantly reduced the cost of transacting in dollars. Despite the stronger commitment by Menem’s administration to the dollar-peso-peg regime in the early 1990s, Argentineans actually increased their use and demand for dollars as the denomination of bank deposits, and for transactional purposes.

This process was encouraged by familiarity with and trust in the dollar and its purchasing power (Ize & Levy-Yeyati, 1998). Trust in the dollar’s value was an especially important factor since throughout the years of the Convertibility Plan worries continued to haunt the reliability of the currency board. Argentine citizens’ ingrained suspicion of their government’s commitment to reform and the persistence of corruption continued to bear down on their trust in the new peso currency. Despite stable economic conditions in Argentina in 1994-1995, the economic troubles of the Mexican peso caused international investors to pull their dollars not only from there but from Argentina’s financial sector as well. Argentina's ability to sustain the rigid currency board arrangement of a fixed peso to dollar exchange rate was put into sever suspicion.

Argentina took measures to promote dollarization of the banking system to ease the liquidity squeeze following the tequila crisis to enhance the credibility of the convertibility plan. In the Argentine scenario, the government encouraged dollarization by making it legal to write contracts in foreign currencies and allowing foreign currencies to be used as an alternative means of payment (Dominguez & Tesar, 2004). The resulting wide circulation of dollars in an economy makes it easy for local agents to adopt and use it, as Jameson (2003) also notes:

> Between December 1, 1994 and January 10, 1995 Argentine banks experienced significant peso deposit withdrawals and substitutions from peso to dollar accounts…After the Tequila crisis, the dollarization of deposits steadily increased, so that by 2001 over 80%[28] of time deposits were denominated in dollars. (Dominguez & Tesar, 2004, p. 2)

Worries about the stability of the Argentine currency board were fulfilled in January 2001 when the Argentine peso was officially devalued and all bank deposits and debts were "pesofied." "Dollar deposits were converted at 1.4 pesos to the dollar, while dollar loans were subject to one-to-one conversions, effectively imposing the bulk of the costs of pesofication on the banks rather than depositors" (Dominguez & Tesar, 2004, p. 14.)

As discussed above, the Argentine financial sector experienced a very tumultuous history in the 80s and 90s that was full of economic crises. These crises almost always

---

[28] This dollarization level calculation may not be consistent with the one this dissertation uses.

resulted in strong devaluation of the Argentine currency versus other foreign currencies. One byproduct of the local currency instability is the flight to the safety of foreign currencies, mainly the U.S. dollar (see Figure 1 in Introduction).

In the following sections, the model developed in this dissertation will be applied to Argentina's empirical data and the results of the statistical estimation of the model and its prediction as well as policy implications will be discussed.

Argentina's Data

The data cover the time span between Q1 1981 and Q4 2001. The International Financial Statistics (IFS) database of the IMF and Central Bank of Argentina' banking sector information was the main sources of regression data. Other minor sources were also used to obtain deposit dollarization readings. Appendix D provides further discussion on these other sources. Figure 1 in the Introduction plotted the deposit dollarization ratio and peso-dollar depreciation time series. Following are the plots for the rest of variables used in the model in Figures 4 and 5. Table 1 contains descriptive statistics of the variables.

Argentina's Model Estimation Results

The Gauss-Newton method of nonlinear regression was performed to estimate the parameters of Equation 10 using Argentina's data. Table 2 reports the regression results. The regression results suggest that about 92% of Argentina's dollarization behavior can be explained by the model as indicated by the *R*-square statistics. Also, all the

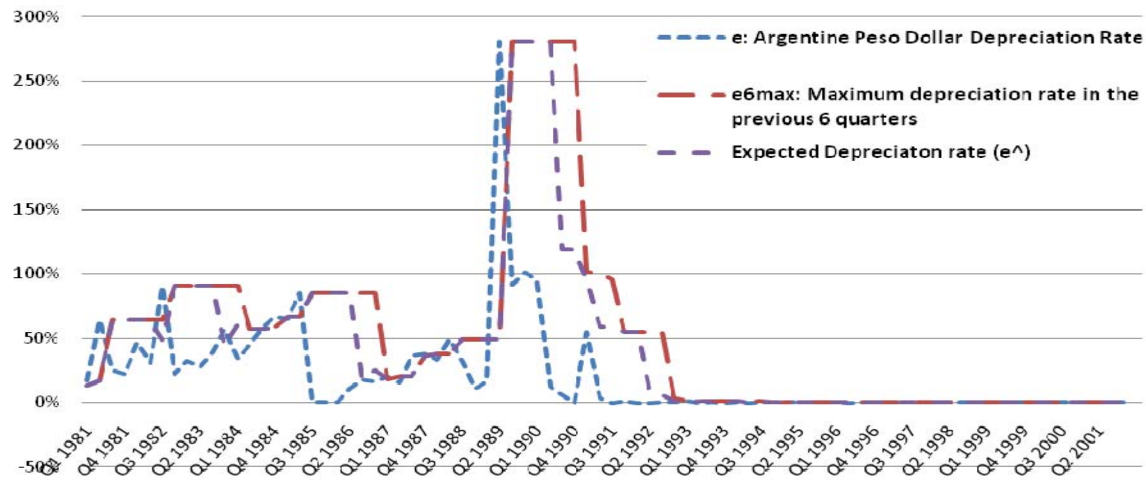

Figure 4: Argentine case study variables: peso-dollar depreciation rate.

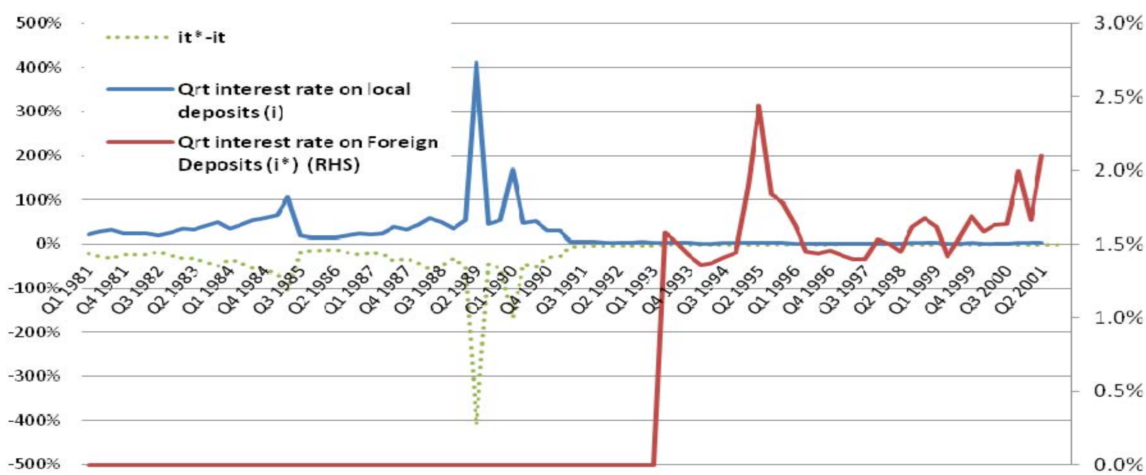

Figure 5: Argentine case study variables: interest rates on local and foreign denominated bank deposits.

Table 1

Descriptive Statistics of Argentina's Model Variables

Variable	***N***	**Mean**	**Std Dev**	**Minimum**	**Maximum**
Deposit Dollarization Ratio (p_t)	84	0.364	0.231	0.051	0.735
Argentine Peso Dollar Depreciation Rate (e_t)	84	0.211	0.392	-0.007	2.805
Maximum depreciation rate in the previous six quarters ($e_{t-6}^{\max}$)	84	0.512	0.73	0	2.805
Qrt interest rate on local deposits (i_t)	84	0.253	0.501	0.016	4.102
Qrt interest rate on Foreign Deposits (i_t^*)	84	0.007	0.009	0	0.029
$i_t^* - i_t$	84	-0.246	0.505	-4.102	-0.002

Table 2

Argentina's Regression Fit and Estimated Parameters' Results

R-Square	0.921	
Parameter	**Estimate**	***t*-Value**
φ	0.724	14.536
γ	0.634	1.975
α	0.904	15.422

parameters have the correct signs and are highly significant at a 95% minimum level of confidence as their *t*-values suggest. The value of γ produces a transaction cost index of $\sigma = 1.643$ at its lowest (when the dollarization ratio at 50%). This σ value suggests that there is a strong influence for transaction cost on dollarization levels and agents choices.[29] The value of α (.9) suggest that agents predict the depreciation rate by looking both at this rate in the previous quarter (with a 90% weight) and the highest such rate in the previous six quarters (with a 10% weight). This indicates that ratcheting effects are playing a role in the model and in general; agents do care about the holding cost of their preferred currency.

Table 3 shows the results for the Augmented Dicky Fuller (ADF) tests of time trend stationarity. The same tests were also conducted using the Phillips-Perron (PP) method. The two testing methods resulted in similar conclusions, so only the ADF results were reported here.[30]

The reported ADF test values suggest that the dollarization ratio (p_{t-1}) and its related variables ($\ln\left(\frac{1-p_t}{p_t}\right)$ and p_{t-1}^2) and $e_{t-6}^{\max}$ have a time trends (that the time series

[29] The estimated value of σ is also very high and cannot be interpreted readily. The functional term of this transactional cost term is an improvement over the original one that Oomes suggested. However, further improvement is still needed to develop a transaction cost term with a better range of values. Also, it will be very beneficial to find empirical sources to measure transaction cost more directly. The same comment applies to σ estimate in the Bolivian case study. A plot of σ is provided in Appendix D.

[30] Phillips and Perron (1988) have developed a more comprehensive theory and tests of unit root nonstationarity. The tests are similar to the Augmented Dicky-Fuller (ADF) test, but they incorporate an automatic correction to the Dicky-Fuller procedure to allow for auto-correlated residuals. The tests usually give the same conclusions as the ADF tests, and the calculation of the test statistics is complex. Main criticism of the Phillips-Perron and ADF test is that the power of the tests is low if the process is stationary but with a root close to the nonstationary boundary. See Appendix B for further discussion.

Table 3

Augmented Dickey-Fuller of Unit Root Tests With a Trend

Variable	Lags	Tau	Pr < Tau
Deposit Dollarization Ratio (p_t)	0	-2.68	0.2478
$i_t^* - i_t$	0	-7.29	<.0001
Argentine Peso-Dollar Depreciation Rate (e_t)	0	-6.54	<.0001
Maximum depreciation rate in the previous six quarters ($e_{t-6}^{\max}$)	0	-2.62	0.2734

are nonstationary). However, $(i_{t-1}^* - i_{t-1})$ and e_{t-1}, in the model have no time trends and are stationary at a 99% confidence level (see Tau test results in Table 3). It is normal to expect most financial time-series to be nonstationary and for these series to drift over time as the plot of the dollarization levels exhibited in Table 1. After all, the subject of this dissertation is the sustained increase of deposit dollarization in Argentina and Bolivia over a 20-year period. It is also sensible to expect the ratchet variable $e_{t-6}^{\max}$ to have a time trend since it maintains previous depreciation rates for as long as six quarters. Generally, regression results are not reliable and spurious if at least one of the independent variables exhibit nonstationarity. However, the Phillips-Ouliaris co-integration test values are strong enough to reject the null hypothesis of no co-integration. If two or more series are individually nonstationary but a linear combination of them has a lower order of integration, then the series are said to be cointegrated. This cointegration then can form a stationary linear combination of them. Therefore, the nonstationarity of p_{t-1} and $e_{t-6}^{\max}$ should not bias the regression estimates reported in Table 4.

Argentina's Model Prediction and Analysis

Between the late 1980s and early 1990s the Argentine economy experienced three episodes of sharp increases in peso-dollar exchange rates: 37% in Q3 1987, 50% in Q2 1988 and 280% in Q2 1989 (see Figure 6). These high depreciation events will be used to illustrate how the model predicts future dollarization levels. A plot of the estimated difference in the cost of holding and transacting in pesos versus dollars is provided in Appendix D (the x term in Equation 5). The plot trend shows a sustained switch in the advantage a currency from pesos to dollars in the Q2 1990, which matches the strong rise in dollarization depicted in Figure 6.

Predicted dollarization paths[31] are generated with the use of Equation (9) after substituting the parameters with their estimated values as Equation 11 shows.

$$\begin{aligned} p_t = {} & (1+\exp\{-(1/.724)[(.9*e_{t-1}+(1-.9)\,e_{t-n}^{\max})+(i_{t-1}^{*}-i_{t-1}) \\ & -(-4(.634-1)p_{t-1}^{2}+4(.634-1)p_{t-1}+2) \\ & +2\,(-4(.634-1)p_{t-1}^{2}+4(.634-1)p_{t-1}+2)\,p_{t-1}]\})^{-1} \end{aligned} \tag{11}$$

---

[31] See Appendix D for a graphical comparison between model prediction and actual dollarization levels.

Table 4

Phillips-Ouliaris Cointegration Test of the Demeaned and Detrended Case[32]

Lags	Rho	.99 Confidence Level	Tau	.99 Confidence Level
1	-79.6057	-58.1615	-8.6348	-5.5849

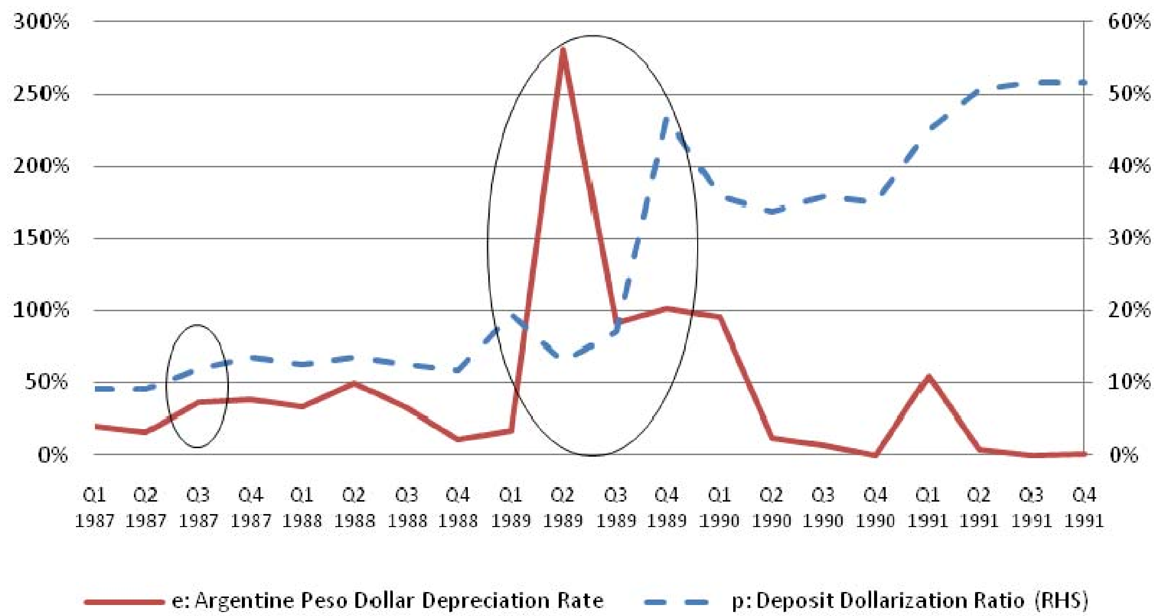

Figure 6: Argentina's Q2 1989 hyperdepreciation episode.

---

[32] The critical value for the .99 confidence level are from Ic and IIc tables in Phillips and Ouliaris (1990).

Equation 11 is plotted in Figures 7 and 8.[33] Figure 7 creates two estimated dollarization paths, using the quarterly data before and after the 37% depreciation episode in the Q3 1987, see Figure 7.

In Figure 7, the middle curve of Q2 1987 has three equilibrium points (like the ones in Figure 3 in the Introduction) with a stable equilibrium at the upper and lower points. The deposit dollarization ratio (p_t) was very low in Q2 1987, at about 9%, right about the lower equilibrium level. A near doubling of the depreciation rate in Q4 1987 shifted the curve upward, so that the dollarization path at Q1 1988 was higher due to the ratcheting effect of the sudden depreciation rate jump. However, the p_t level at the time of 14% was still below the middle unstable equilibrium point (at about 30%) signaling that asset substitution level should subside to the lower equilibrium. With some financial markets' stability, the four quarters following Q4 1987 did experience a drop in dollarization to about 11% (at the lower stable equilibrium point). The drop was helped by a strong premium increase in the interest rates paid on local currency deposits over dollar deposit, which increased from a 20% to 43% by Q2 1988. This strong interest rate differential in favor of peso deposits demonstrates the impact of a strong policy initiative that can have the ability to reverse dollarization. As the Q2 1988 dollarization path down shift shows, the upper equilibrium almost did not exist.

By Q4 1990, the depreciation rate dropped to 0% and the dollarization ratio to 36%. This stability did not continue for long as another big drop (50%) in the austral's

---

[33] For the exact values used with Equation 11 to produce Figures 7 and 8 see Appendix D.

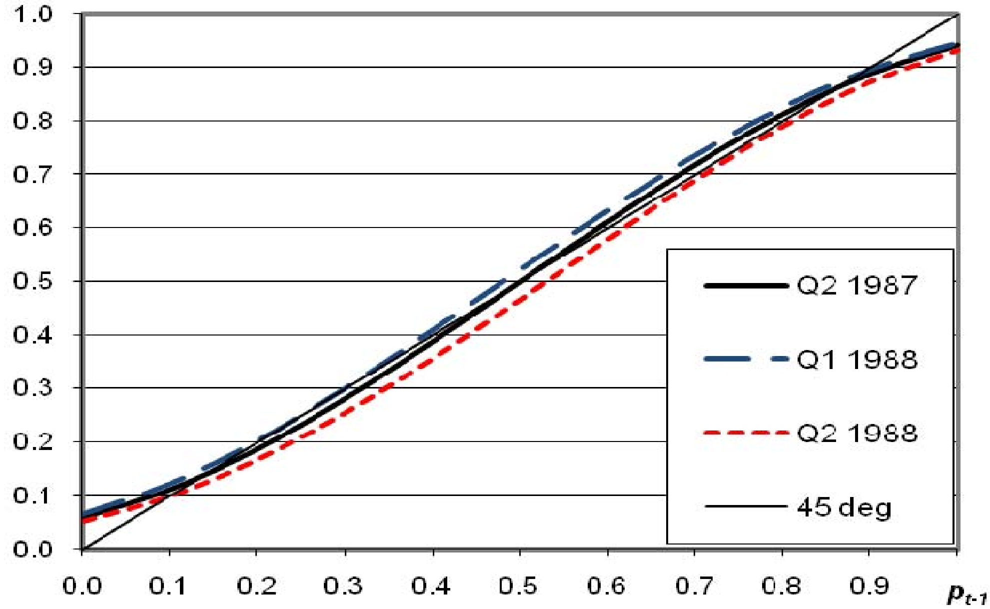

Figure 7:Argentina's Deposit dollarization prediction 1.

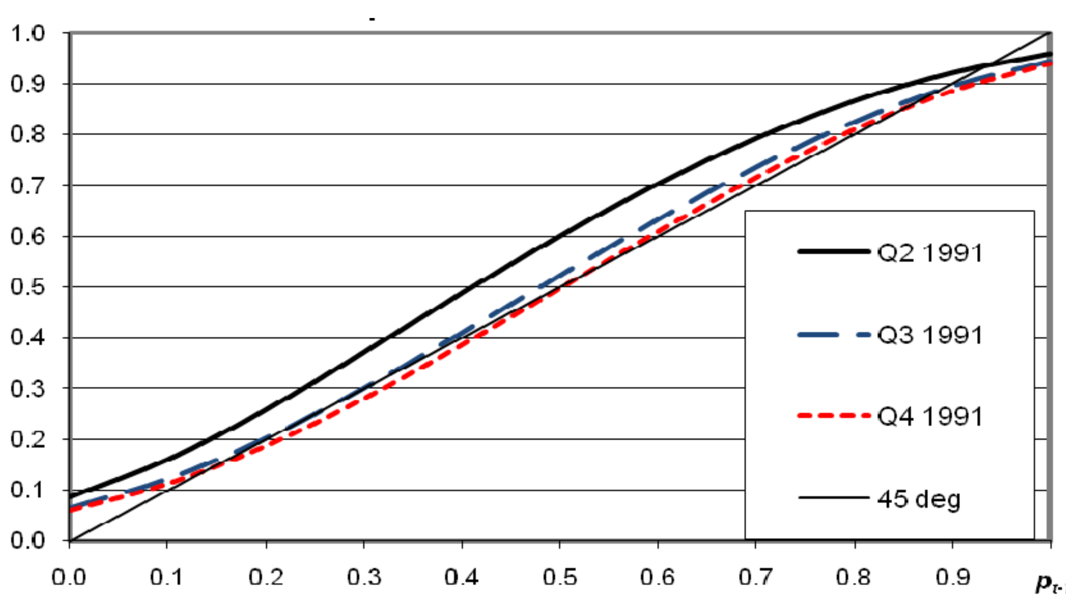

Figure 8: Argentina's Deposit dollarization prediction 2.

value took place in Q1 1991. Without an increase in the interest rate on local deposits, the dollarization path for Q2 1991 jumped to the upper curve in Figure 8. This instability pushed asset substitution to 45% by early Q2 1991.

In March 1991, the convertibility law was passed. It established a currency board that pegged the exchange rate of Argentina's new currency, the peso to parity with the dollar (or 1 peso:10,000 austral). This drastic move pulled down the dollarization path prediction associated with Q3 1991, thanks to the promise of low depreciation rates. However, a deposit dollarization ratio of 45% was higher than the middle equilibrium point. Crossing the middle unstable equilibrium point changes the dollarization dynamics to that which favors a continuous increase until the upper equilibrium point is reached. Simply stabilizing the exchange rate at that point was not adequate to reverse the dollarization process taking place in the country because the depository system was significantly dollarized already. The dollar network has gained enough momentum to pass the intermediate point, therefore, during the 1990s asset substitution marched steadily onward with the help of the growing transactional network of the dollar. Replacing the Austral with the new Argentine peso came too late to remedy the situation. Dollarization paths during the rest of the 1990s subsided a bit, but that was not enough since the dollarization levels have passed the higher middle equilibrium point of about 50% by few percentage points.

Figures 7 and 8 provide useful insights not only for academic or speculative purposes but also for suggesting possible policies to deal with high incidents of asset substitution, which is the subject of the next section.

Argentina's Policy Discussion

The positions of the curves of all dollarization paths are governed by regression coefficients and variables as of a certain point in time. Of these coefficients, policy makers may be able to manipulate two with monetary policy tools, the depreciation rate (*e*) and interest rate differential ($i^*_{t-1} - i_{t-1}$). The next two figures discuss what happens if *e* or $i^*_{t-1} - i_{t-1}$ are adjusted.

Figure 9 displays three dollarization paths. The upper one is the actual one and it is the same Q2 1991curve that was discussed in Figure 8. This curve can be shifted downward if depreciation rate is lowered from 54% to 25% as the middle curve demonstrates. The middle curve reestablishes a lower stable equilibrium point.
If the depreciation rate is really controlled and brought down to about 5%, then dollar depositors should be expected to attempt switch back to the peso and move along the lower curve in Figure 9, which only have a lower stable equilibrium. In this case, agents will switch because of the substantially decreased cost of holding pesos rather than its network advantage.

Alternatively, Figure 10 give policy makers the ability to reduce asset substitution by increasing the dividends on the peso brand. We can see if $i^*_{t-1} - i_{t-1}$ or the interest rate on peso deposits exceeded that of the dollar deposit by an extra 30% than what prevailed at Q1 1991 (from -29% to -60%) the dollarization curve will shift down enough to establish a lower equilibrium point.

It will take an interest rate difference of 60% to tip the balance of in favor of converting deposits into a peso denominated one. After the curve ratchets down enough,

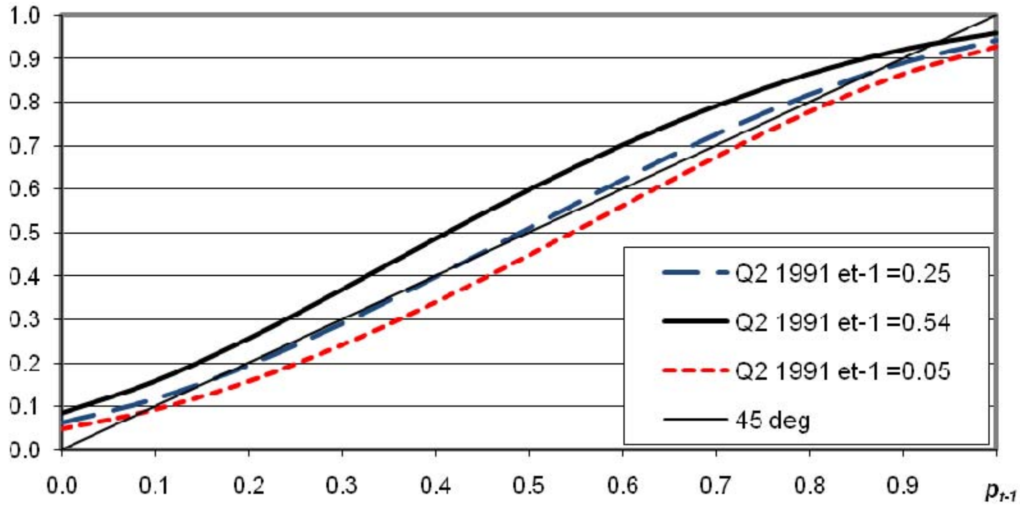

Figure 9: Policy simulation of lowering depreciation rates and the impact on dollarization paths.

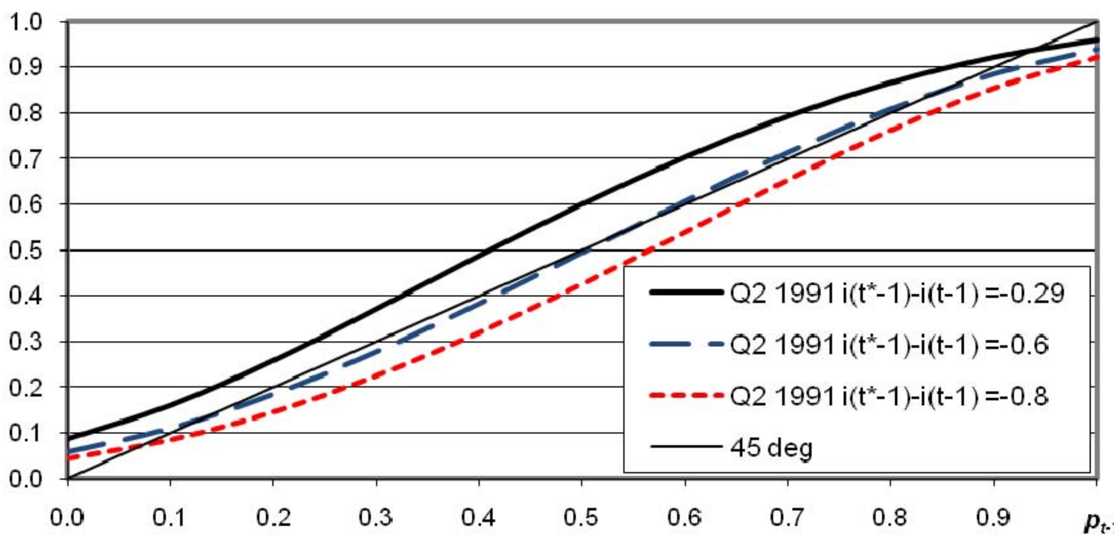

Figure 10: Policy simulation of increasing interest rates on peso deposits and the impact of dollarization paths.

the dynamics of the peso network gains momentum and can restore both the store of value and the medium of exchange functions to the Argentine peso.

Bolivia's Case Study

Bolivia, a country whose financial sector was also extensively dollarized will serve as another case study to test the predictive power of the model developed in this research. Bolivia's struggle with financial and fiscal crisis in the 1980s saw also a strong preference in formal and informal markets to holding dollars over Bolivianos, the official currency of the state. In response, the Bolivian government attempted to "dedollarize" the economy in 1982 by converting dollar-denominated financial instruments to pesos Boliviano at a below market exchange rate. To prevent flight to safety, a range of financial controls were sanctioned like capital flow restrictions, price freeze, and interest rate caps. Peso holders in Bolivia also experienced a real diminishing purchasing power as real interest rates were mostly negative during the high-inflation period of the early 1980s. Galindo and Leiderman (2005) note that "in response to this high inflation and the prohibition of holding dollar-denominated deposits on shore, offshore deposits grew significantly, and financial intermediation declined sharply" (p. 1).

Austere policy measures and market confidence restoration efforts in 1985 resulted in the adoption of a stabilization package. This package aimed at controlling and reducing the fiscal deficit, increasing monetary policy independence, and removing the ban on foreign currency deposits. Inflation and the fiscal spending gap were successfully reduced and financial intermediation resumed activities, however at higher levels of financial dollarization. Policy makers continued to be concerned about the long term viability of the local currency. They worked to bolster the boliviano by offering market based assurances of the future purchasing power of the local currency. Bolivia adopted an active policy to reduce public sector dollarization through the development of CPI-indexed debt instruments. Policymakers preferred CPI indexation to dollarization because indexation will allow the local currency to survive beyond the immediate worries of its users, with the hope of restoring confidence in its value in the long run. A dollarized system on the other hand that has adapted its pricing, contracts and practices will be harder to readapt again to using a local currency with all the associated cost and without clear reward (Galindo & Leiderman, 2005).

In the 1990s a quasi-crawling peg exchange rate regime was given the credit for stabilizing the real exchange rate of the Boliviano. Nevertheless, a 2003 IMF report listed Bolivia as the most dollarized economy after the officially dollarized South American states. After allowing dollar deposits again in 1985, the extent of deposit dollarization in the banking system rose from 15% to about 92% in 2003. Deposit dollarization was accompanied by a widespread use of the dollar as dollar-denominated deposits accounted for 77% of broad money and bank credit to the private sector in dollars was close to 97% (Schweickert, Thiele, & Wiebelt, 2005; see also Rennhack & Nozaki, 2006) a slight reversal in the intensity of Bolivia's dollarization was witnessed since early 2000.

In the following sections I will provide the statistical results of applying the model developed in this dissertation on Bolivia's dollarization history.

Bolivia's Data

All the data used in this dissertation came from the IFS database of the IMF. The data cover a 20-year period between Q4 1985 and Q4 2005. Appendix A lists the IFS data series and the formulas used in the regressions. Figure 2 in the Introduction plotted the deposit dollarization ratio and Bolivian-dollar depreciation time series. Figures 11 and 12 are the plots for the rest of variables used in the model. Table 5 contains descriptive statistics of the variables.

Bolivia's Model Estimation Results

The Gauss-Newton method of nonlinear regression was performed to estimate the parameters of Equation 10 using Bolivia's data. Table 6 reports the regression results. The regression fitting results suggest that about 97% of Bolivia's dollarization behavior can be explained by the model indicated by the *R*-square statistics. Also, the parameters or their restrictions have the correct signs and are highly significant at a 99% minimum level of confidence as their *t*-values indicates. The value of γ suggest that at its minimum, the transaction cost index will equal $\sigma = 1.53$ (the dollarization ratio at 50%). This σ value suggests that there is a strong influence for transaction cost on dollarization levels and agents' choices (but weaker than in the case of Argentina). The value of α (.95) suggest that agents predict the depreciation rate by looking both at this rate in the previous quarter (with a 95% weight) and the highest such rate in the previous six quarters (with a 5% weight). This indicates that ratcheting effects is playing a role in the model and in general; agents do care about the holding cost of their preferred currency.

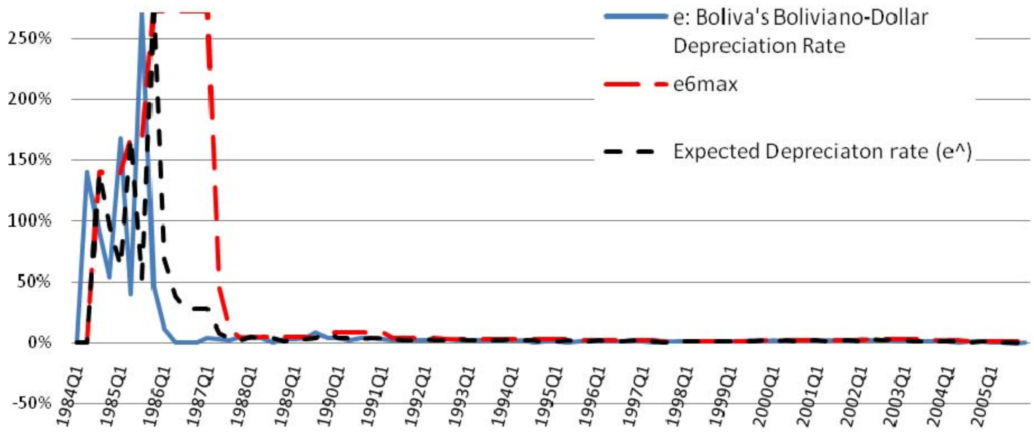

Figure 11: Bolivia's case study variables: The Boliviano's depreciation rate versus the dollar.

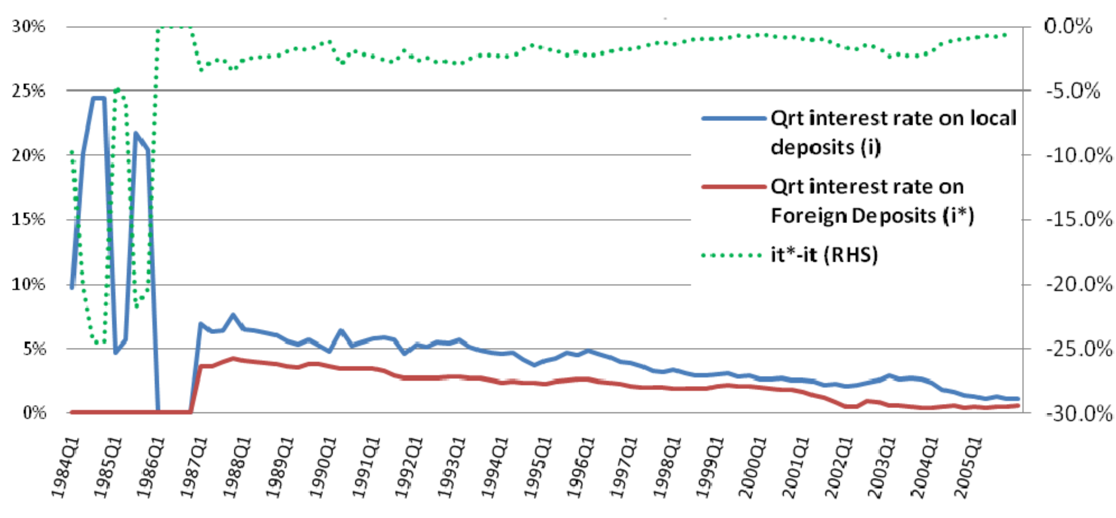

Figure 12: Bolivia's case study variables: Interest rates on local and foreign denominated bank deposits.

Table 5

Descriptive Statistics of Bolivia's Model Variables

Variable	*N*	Mean	Std Dev	Minimum	Maximum
Deposit Dollarization Ratio (p_t)	81	0.818	0.126	0.321	0.931
Boliviano- Dollar Depreciation Rate (e_t)	81	0.058	0.304	-0.005	2.722
Maximum depreciation rate in the previous six quarters ($e_{t-6}^{\max}$)	81	0.236	0.709	0.008	2.722
Qrt interest rate on local deposits (i_t)	81	0.04	0.026	0	0.204
Qrt interest rate on Foreign Deposits (i_t^*)	81	0.021	0.012	0	0.042
$i_t^* - i_t$	81	-0.019	0.022	-0.204	0

Table 6

Bolivia's Regression Fit and Estimated Parameters Results

R-Square	0.972	
Parameter	**Estimate**	***t*-Value**
φ	0.686	22.345
γ	0.530	3.033
α	0.955	25.521

The conclusions of the PP and the ADF tests of the time trend stationarity are similar to that of the Argentine case study (see Table 7). In Bolivia's case these tests suggest, as well, that the dollarization ratio (p_{t-1}) and its related variables

($\ln\left(\frac{1-p_t}{p_t}\right)$ and p_{t-1}^2) and $e_{t-6}^{\max}$ have unit roots (that the time series are nonstationary).

However, $(i_{t-1}^* - i_{t-1})$ and e_{t-1}, in the model have no time trends and are stationary at a 91% confidence level for $(i_{t-1}^* - i_{t-1})$ and 99% level for e_{t-1} (Tau test results in Table 7).

Also as in Argentina's case, the Phillips-Ouliaris co-integration test reported values in Table 8 are strong enough to reject the null hypothesis of no co-integration. Therefore, the nonstationarity of p_{t-1} and $e_{t-6}^{\max}$ should not bias the regression estimates reported in Table 6.

Table 7

Augmented Dickey-Fuller of Unit Root Tests With a Trend

Variable	**Lags**	**Tau**	**Pr < Tau**
Deposit Dollarization Ratio (p_t)	0	-1.88	0.6565
$i_t^* - i_t$	0	-3.16	0.0987
Bolivian Boliviano-Dollar Depreciation Rate (e_t)	0	-7.09	<.0001
Maximum depreciation rate in the previous six quarters ($e_{t-6}^{\max}$)	0	-2.58	0.2891

Table 8

Phillips-Ouliaris Cointegration Test of the Demeaned and Detrended Case

Lags	**Rho**	**.99 Confidence Level**	**Tau**	**.99 Confidence Level**
1	-66.7871	-58.1615	-7.2613	-5.5849

These statistical results indicate a stronger model fit and prediction ability in Bolivia's case over that of Argentina. Also, the transaction cost factor is slightly weaker than in Argentina, while the ratchet effect (previous maximum depreciations) is weaker.

Bolivia's Model Prediction and Analysis

Figure 13 shows a succession of hyperdepreciation episodes[34] that drove deposit dollarization ratio (p_t) to jump from about 4% in the Q2 1984 to 35% by the Q1 1986. Later on, as Figure 14 displays, the economy seems to be locked on a path towards an almost fully dollarized depository system by the early 1990s. By 2004, asset substitution subsided somewhat but remained at a very high level. In Figure 14 it is possible to distinguish several periods of stable dollarization ratios followed by jumps to new and higher levels (notice Q1 1987, Q1 1988, Q1 1990 and Q4 1996). These dollarization

[34] Depreciation (e) is measured by taking the log of the Boliviano / U.S. dollar quarterly market exchange rate, $e = \ln(Xt / Xt -1)$.

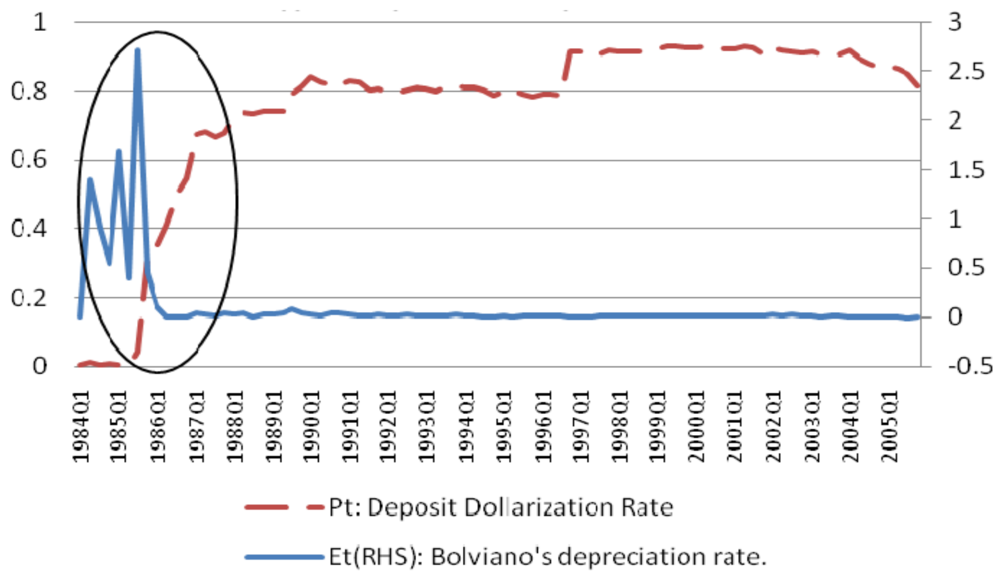

Figure 13: Bolivia's hyperdepreciation episodes in mid-1980s.

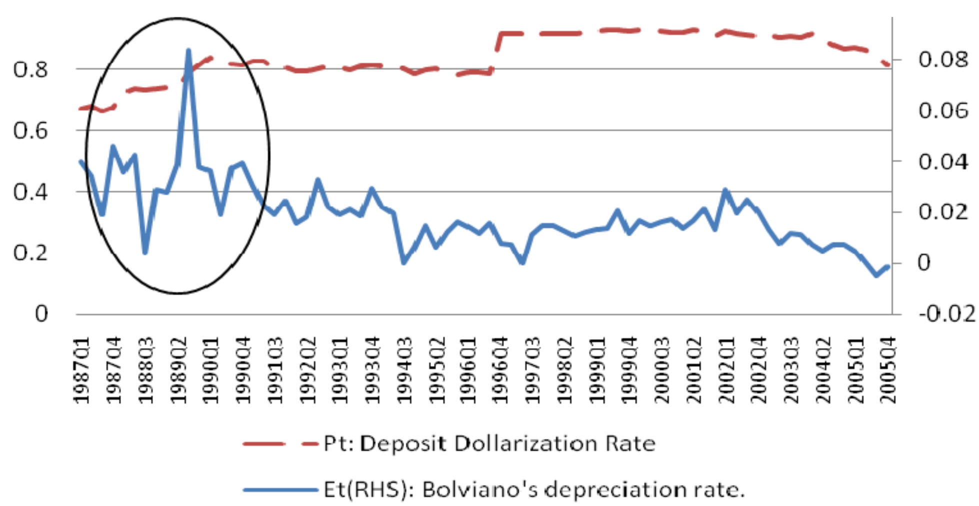

Figure 14: Bolivia's hyperdepreciation episodes in the later 1980s and early 1990s.

level jumps seem to persist even after the Boliviano's depreciation rate subsided to relatively low levels.

Predicted dollarization paths[35] are generated with the use of Equation (9) after substituting the parameters with their estimated values as Equation 11 shows.

$$
\begin{aligned}
p_t = &(1+\exp\{-(1/.686)[(.95 * e_{t-1} + (1-.95)\, e_{t-6}^{\max}) + (i_{t-1}^{*} - i_{t-1}) - \\
&(-4(.527-1)p_{t-1}^2 + 4(.527-1)p_{t-1} + 2) \\
&+ 2(-4(.527-1)p_{t-1}^2 + 4(.527-1)p_{t-1} + 2)\, p_{t-1}]\})^{-1}
\end{aligned} \tag{12}
$$

Equation 12 is plotted in Figures 15 and 16. Figure 15 shows three estimated dollarization paths, using the quarterly data before and after the 272% depreciation episode in the Q4 1985. Deposit dollarization levels jumped in 1985 from near zero to 32%. Consistent with model predicted asset substitution paths in Figure 15, dollarization levels continued to rise gradually over the next year, despite the drop in Boliviano's depreciation rates. The paths in Figure 11 do drop down. However, a low equilibrium was not established even by end of 1986. This is explained by the lingering effect of the ratchet variable $e_{t-6}^{\max}$, which is affecting the expected depreciation rate, which was 13%. There was also barely any difference in interest rates paid on local versus foreign deposits to compensate customers for the extra risk of holding Bolivianos.[36]

---

[35] See Appendix A for a graphical comparison between model prediction and actual dollarization levels.

[36] For the exact values used with Equation 12 to produce Figures 15 and 16 see Appendix A.

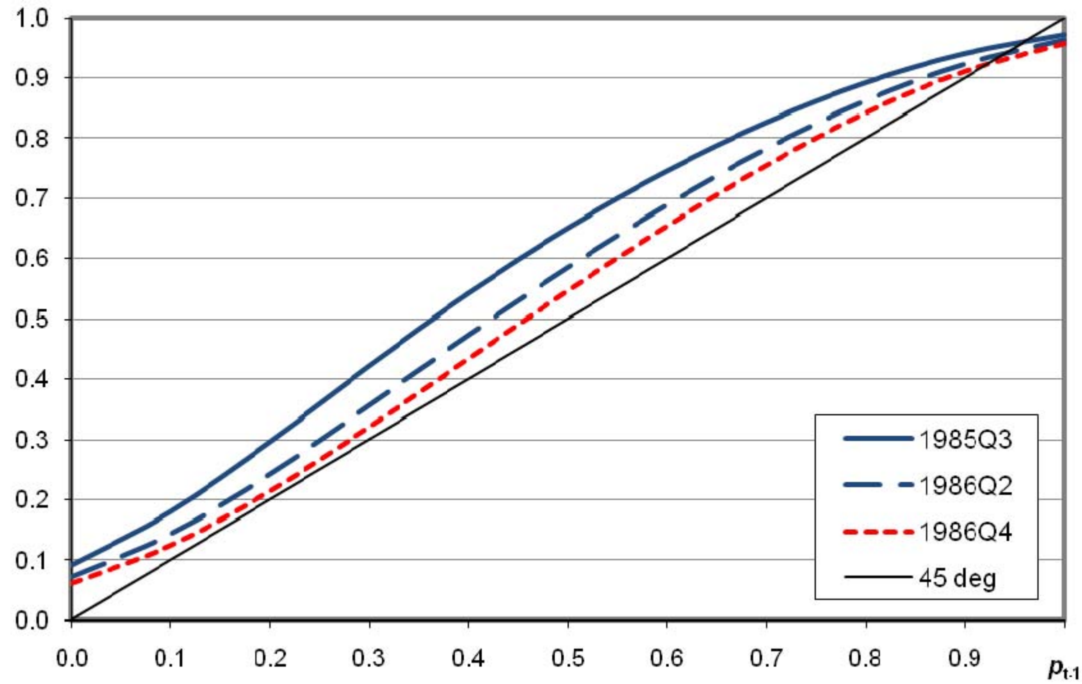

Figure 15: Estimated deposit dollarization prediction.

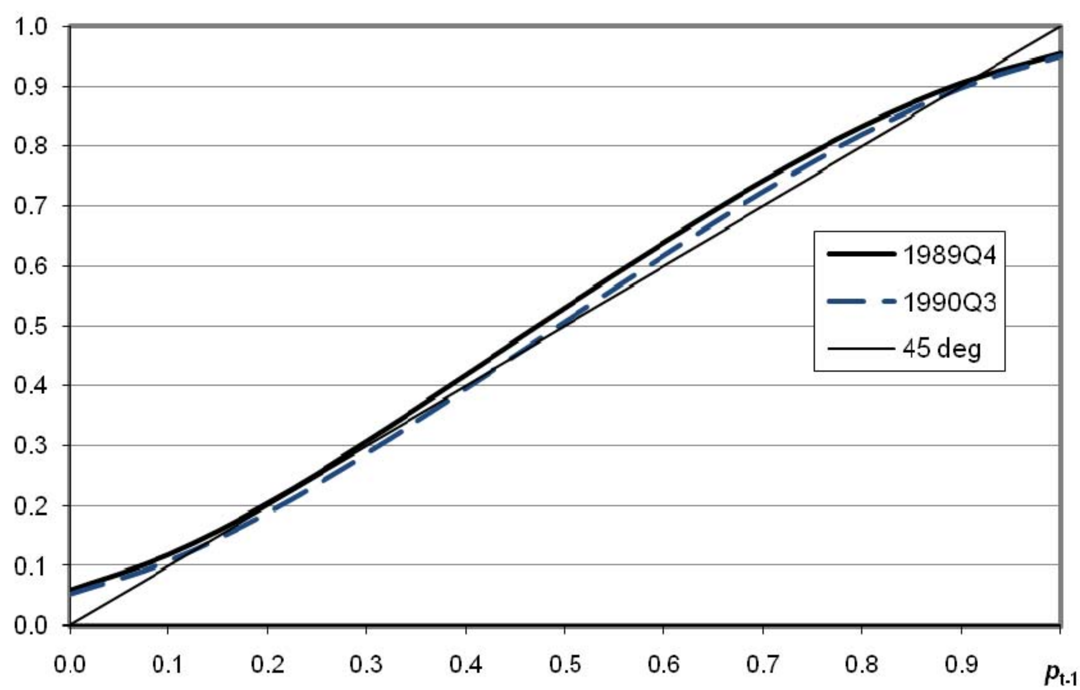

Figure 16: Deposit dollarization prediction for two paths.

In late 1989 another small episode of depreciation (8%) happened, prompting further increase in dollarization levels from its already high steady level of around 73% to about 82% by next year. Figure 16 demonstrate two dollarization paths. The Q4 1989 path also shows no possibility of a stable low equilibrium and predicts that dollarization will continue to rise to a resting point around the 90% level. However, the prediction path as of Q3 1990 shows the possibility of a lower equilibrium at about 15% if deposit dollarization was lower than 40%. The down shift in predicted dollarization path was made possible by increasing the opportunity cost of dollar deposits by offering higher rates on Boliviano deposits. The interest rate premium paid on Boliviano deposits increased from a 22% on average in 1989 to around 30% in the following 2 years.

Since dollarization levels were higher than 40% in 1989 and 1990, these levels continued to rise until reaching the upper steady level of around the mid 90% by 1996 and onward. The conclusion is that network and hysteresis effects will keep the economy at the upper equilibrium point unless drastic measures are taken. The goal of such measures will be to bring dollarization to a point below the intermediate equilibrium if possible. The following section will discuss the various policy options that can be exercised to control or reverse the dollarization of the Bolivian economy.

Bolivia's Policy Discussion

A forced conversion of dollarized deposits that bring dollarization ratio to less than 40% is expected to favor the peso network. The dynamics of the model (as in Figure 17) predict the economy to rest at the lower stable level of about 12%. However,

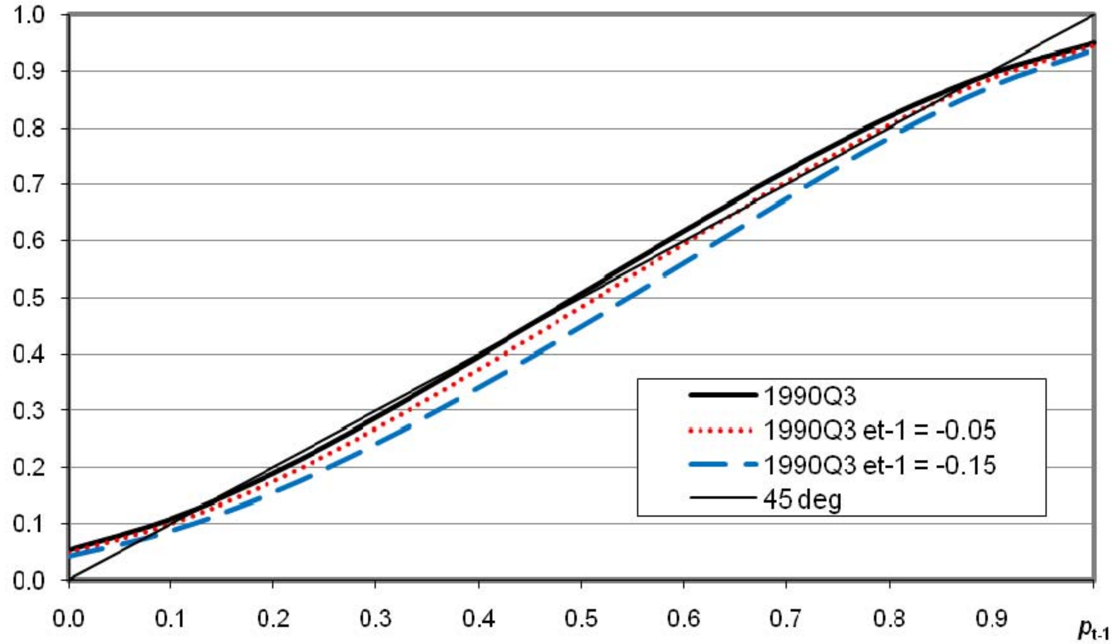

Figure 17: Policy simulation lowering depreciation rates and the impact on dollarization paths.

forced de-dollarization can have other adverse consequences that the current model is not designed to account for.

As mentioned in the policy discussion of Argentina's case study (policy makers may be able to manipulate two, the depreciation rate (e) and interest rate differential ($i^*_{t-1} - i_{t-1}$). Figures 17 and 18 show what happens if e or $i^*_{t-1} - i_{t-1}$ are adjusted. Figure 17, display three dollarization paths. The upper one is the actual one and it is the same Q3 1990 curve as was discussed in Figure 16. Since the depreciation rate by Q3 1990 was relatively low at 2%, this curve can be shifted downward if the depreciation rate is reversed to appreciate the Boliviano for example by 5% as the middle curve demonstrates. The middle curve may not do much from a policy point of view,

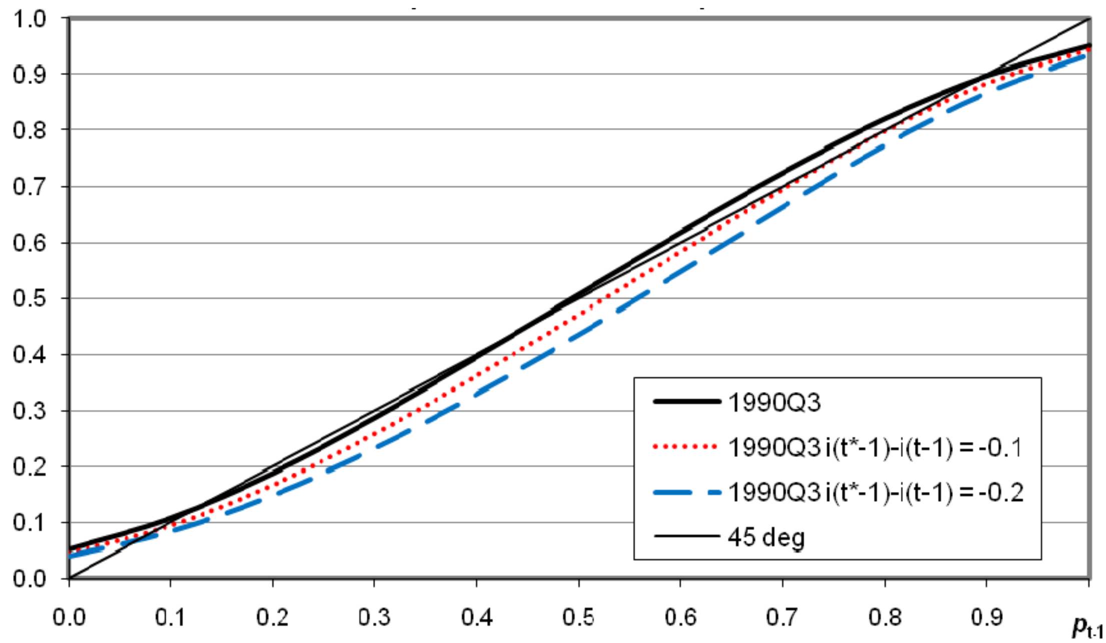

Figure 18: Policy simulation of increasing interest rates on peso deposits and the impact on dollarization paths.

especially when dollarization levels are higher than the middle unstable equilibrium point. To de-dollarize the depositary system, an even stronger measure to appreciate the Boliviano by, for example 15%, as the lowest curve shows.

The ratcheting down of expected depreciation, as the scenarios discussed above suggest, can de-dollarize the economy and put it on a path that will settle at a less than 10% dollarization level. This suggests that despite the present 92% deposit dollarization ratio, a 15% appreciation in peso's exchange will restore the store of value function to the peso.

The second policy option is to reduce asset substitution by increasing the dividends on the Boliviano brand as dollarization paths in Figure 18 show. We can see if

$i^{*}_{t-1} - i_{t-1}$ or the interest rate on peso deposits exceeded that of the dollar deposit by, for example 20% of what prevailed at Q1 1991 (from .23% to 20%), the dollarization curve will shift down enough to have only a lower equilibrium point.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The goal of this research is to contribute to the asset substitution body of knowledge by building on a model originally developed by Oomes (2003). The original model was modified in many ways to come up with an enhanced version. The enhancements include the introduction of a new predictive variable, interest-rate-differential, to measure the role of the opportunity cost of holding different currencies on dollarization levels. Some other variables and parameters were dropped, like institutional barriers and risk of confiscation. This addition and removal of predictors is beneficial primarily because empirical sources are hard to find for the dropped variables and easy to find for the added one. Also many other assumptions regarding the makeup of the economy, the nature of agents, theoretical support for model mechanism and sequence of events have been relaxed or their theoretical meaning improved, which helped make Oomes' model more flexible. The originally assumed functions for the key attributes of the model like the transaction cost and expected depreciation were replaced by new ones. The revised functions are thought to be more sound econometrically (do not have endogeniety problems) and theoretically (giving the transaction cost a more realistic shape). The regression methodology adopted in this research is also much different. Rather than imposing a linear based estimation process on a model that is assumed to have logistic shape, a nonlinear estimation approach was chosen. The two main advantages of fitting the model with a nonlinear method are: one, it directly estimates the parameters of the model and two, it is expected to produce better coefficient values when the variables exhibit nonlinear distribution.

The predictive ability of the model in this research is tested on two case studies. The Argentine and Bolivian experience with very high dollarization of their financial sector served as the two case studies. The model demonstrates good results both in terms of fit and significance statistics as well as predictive ability. Several policy suggestions were generated in each case study to stabilize dollarization levels or even reverse them to low long term equilibria. The policy suggestions tested the impact of appreciating the values of the local currencies or increasing the interest rate paid on deposits denominated in local currencies. Both of these measures directly impact the holding cost of local currencies. In reality, the adoption of one measure, like increasing local interest rates, will also appreciate the local currency. Hence, the severity of the simulated policy measures should not be as hard as presented in this research. The model simulation is also ignoring a host of other economic ripple effects that high interest rates can produce and the final impact on money demand in the economy.

The fact that dollarization is usually imposed in a de facto, market driven,[37] fashion on local economies imply that policy makers do not believe it to be in their best national interest. If they thought otherwise, dollarization would have been adopted in a

[37] Dollarization is described at times as demand driven. Agents in pursuit of their self-interest create and propagate dollarization. According to Dean (2000), the term “de facto dollarization” is defined generically to mean “unilateral, unofficial adoption of a foreign currency” (p. 1). The motive for de facto dollarization may be to adopt foreign currency as a medium of exchange--“currency substitution”--or to hold it as a store of wealth--“asset substitution.”

planned de jure fashion.[38] Hence, the practical side of this work is to further the understanding of how dollarization creeps into local economies, what domestic policies are the likely culprit behind it, and what can be done to stop or even reverse this process.

Dollarization can either be accepted as a bitter pill that may mitigate part of the compounded economic ailments of some emerging states, or not. To choose the latter path is to opt for what might be a more bitter process of building and sustaining credible domestic measures and financial instruments aimed at restoring trust in the value of relatively small money brands that circulate within specific national borders. Individual states obviously need to have a trust worth money and restrained economic policies. They can also develop locally based alternatives to dollar indexing, like indexing on the basis of local real asset values (see InterAmerican Development Bank [IADB], 2004; Singh et al., 2005).

However, the menu of possible measures to roll back dollarization should not include only possible policy measures by individual states. The menu should include regional currency agreements and even unions. Regional treaties, like the merging of small local monies, can create bigger regional brands with bigger networks that make it harder for the dollar to supersede. After all, small is not really beautiful in the arena of international currency competition.

---

[38] Panama in 1904 and East Timor in 2000 and the European Monetary Union with establishment of the Euro in 2002 may fall into this category. Other officially dollarized economies like the Ecuador in 2000 and El Salvador in 2001 did so in response to mounting economic difficulties and massive de facto dollarization.

APPENDIX A

BOLIVIA'S CASE STUDY

Data Sources

The IFS data series used in the regression are:

The rate of depreciation was calculated by taking the natural log of quarterly exchange rate (ln (Xt /Xt -1) * 100) as reported by the series "Bolivianos per U.S. Dollar: End of Period (ae) Market Rate."

Deposit Dollarization Ratio (DDR) used the series in the Table 9, in the following manner:

DDR = of which: Fgn. Currency Deposits / (Demand Deposits + Time, Savings, & Fgn. Currency Dep.

Interest rate differential (*R* = Deposit Rate (Fgn. Currency) - Deposit Rate)

Table 9

IFS: Bolivia's Deposit Data by Currency Denomination

Demand Deposits	**National Currency**	**Millions**
Time, Savings, & Fgn. Currency Dep.	National Currency	Millions
of which: Fgn. Currency Deposits	National Currency	Millions

Table 10

IFS: Bolivia's Deposit Interest Rate by Denomination

Deposit Rate	**Percent per annum**
Deposit Rate (Fgn. Currency)	Percent per annum

Data Mapping

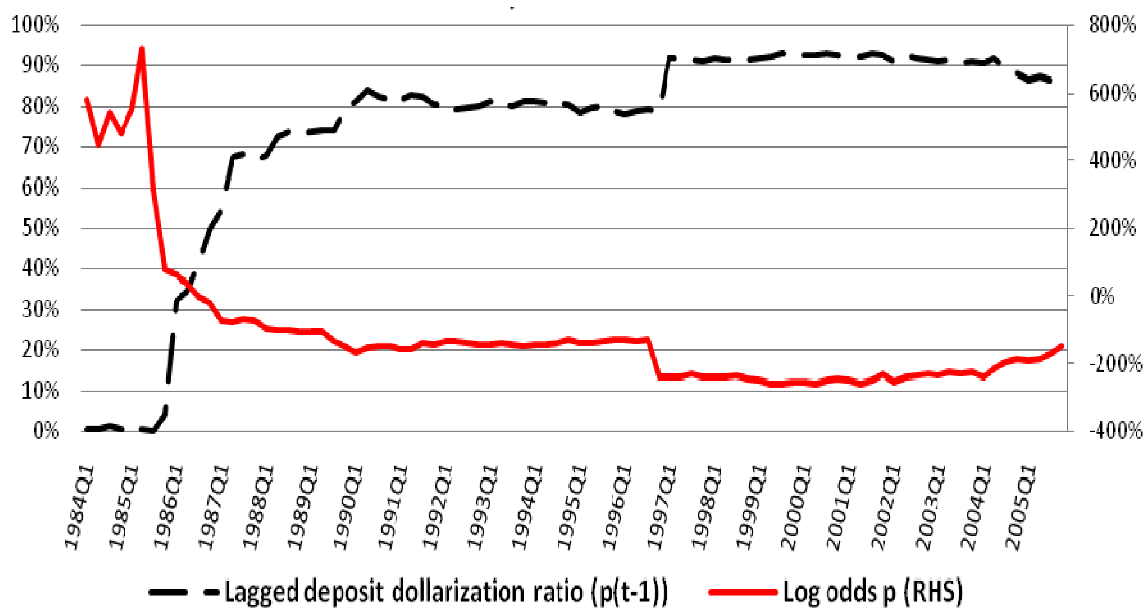

Figure 19: Time series trends.

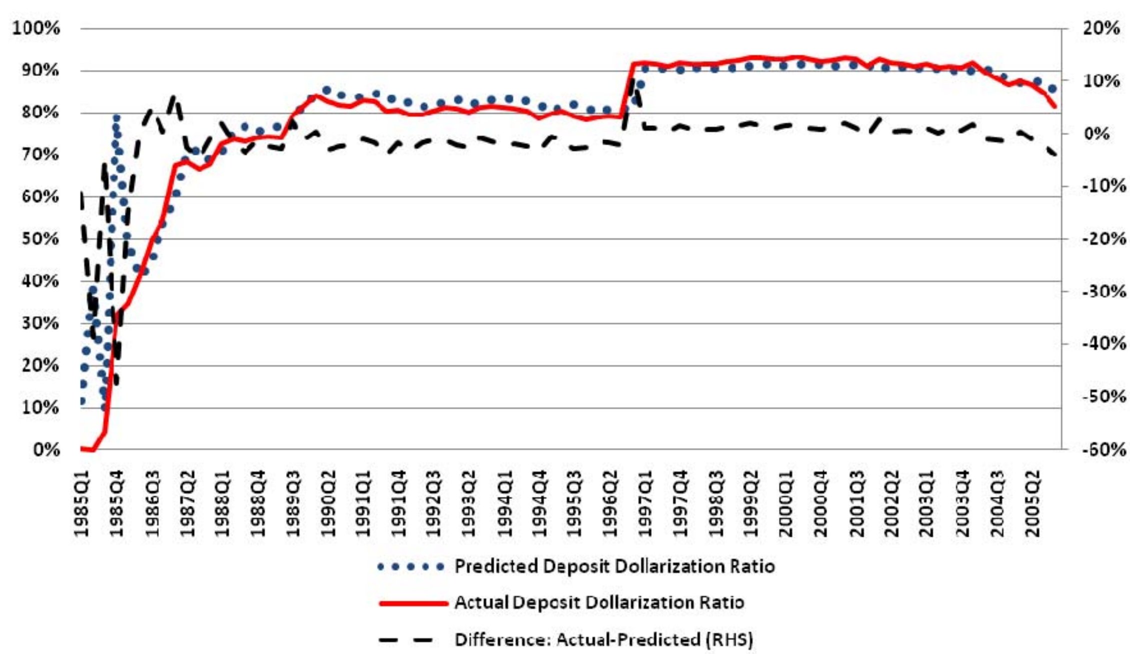

Figure 20: Actual versus modeled dollarization trends.

Model Simulation

Table 11

Model Simulation Data

Date	e_{t-1}	e_{t-6}^{max}	p_{t-1}	$i_{(t^*-1)}-i_{(t-1)}$	$\hat{e}_t$	σ
Q4 1989	8%	8%	79%	-0.18%	8%	1.69
Q1 1990	4%	8%	81%	-0.15%	4%	1.71
Q2 1990	4%	8%	84%	-0.35%	4%	1.75
Q3 1990	2%	8%	83%	-0.23%	2%	1.73
Q3 1985	40%	168%	0%	-3.31%	46%	2
Q4 1985	272%	272%	4%	-3.24%	272%	1.92
Q1 1986	45%	272%	32%	0.00%	56%	1.59
Q2 1986	12%	272%	35%	0.00%	23%	1.57
Q3 1986	0%	272%	41%	0.00%	13%	1.54
Q4 1986	1%	272%	50%	0.00%	13%	1.53

Statistical Tables

Table 12

Nonlinear Regression Results Estimation Summary

Method	**Gauss-Newton**
Iterations	3
R	2.05E-07
PPC(g)	3.03E-07
RPC(g)	0.001228
Object	6.90E-07
Objective	7.604016
Observations Read	81
Observations Used	81
Observations Missing	0

Note: An intercept was not specified for this model.

Source	**DF**	**Sum of Squares**	**Mean Square**	***F*-Value**	**Approx Pr > *F***
Model	3	263.3	87.7728	900.35	<.0001
Error	78	7.604	0.0975	R-Square	0.972
Uncorrected Total	81	270.9			

Parameter	**Estimate**	**Approx Std Error**	**Approximate 95% Confidence Limits**		***t*-Values**
phi	0.6860	0.0307	0.6249	0.7471	22.3453
g	0.5296	0.1746	0.1820	0.8773	3.0332
a	0.9545	0.0374	0.8801	1.0289	25.5214

Approximate Correlation Matrix

	phi	g	a
phi	1.000	0.903	-0.195
g	0.903	1.000	-0.207
a	-0.195	-0.207	1.000

*Note: Convergence criterion met.

Table 13

Unit Root Tests of Regression Variables

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	0.4216	0.7836	0.89	0.8983		
	1	0.3174	0.7569	0.5	0.8209		
	2	0.2201	0.7324	0.29	0.7675		
Single Mean	0	-4.9793	0.4278	-3.82	0.0038	10.13	0.001
	1	-5.9543	0.3404	-3.7	0.0056	8.42	0.001
	2	-6.7686	0.2793	-3.75	0.0049	8.1	0.001
Trend	0	-3.6852	0.9005	-1.88	0.6565	7.68	0.0205
	1	-5.0965	0.8063	-2.23	0.4696	6.89	0.0394
	2	-6.2329	0.7144	-2.51	0.3249	6.98	0.0372
Phillips-Perron Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**		
Zero Mean	0	0.4216	0.7836	0.89	0.8983		
	1	0.3917	0.7759	0.73	0.8709		
	2	0.3656	0.7692	0.63	0.8499		
Single Mean	0	-4.9793	0.4278	-3.82	0.0038		
	1	-5.0984	0.4162	-3.66	0.0063		
	2	-5.1786	0.4086	-3.57	0.0082		
Trend	0	-3.6852	0.9005	-1.88	0.6565		
	1	-3.9199	0.887	-1.89	0.6534		
	2	-4.0695	0.8779	-1.89	0.65		
Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	0.3464	0.7643	0.65	0.8548		
	1	0.2604	0.7425	0.4	0.7969		
	2	0.1881	0.7246	0.26	0.7581		
Single Mean	0	-3.8497	0.5485	-2.94	0.0446	6.27	0.01
	1	-4.4008	0.487	-2.9	0.0498	5.49	0.0274
	2	-4.8807	0.4372	-2.98	0.0409	5.45	0.0285
Trend	0	-1.8498	0.9722	-0.78	0.9631	4.85	0.2216
	1	-2.7631	0.944	-1.05	0.9316	4.42	0.3052
	2	-3.4334	0.9139	-1.24	0.8955	4.56	0.2779
Phillips-Perron Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**		
Zero Mean	0	0.3464	0.7643	0.65	0.8548		
	1	0.3211	0.7579	0.56	0.8341		
	2	0.3006	0.7527	0.49	0.819		
Single Mean	0	-3.8497	0.5485	-2.94	0.0446		
	1	-3.9351	0.5387	-2.87	0.0535		
	2	-3.9856	0.533	-2.83	0.0586		
Trend	0	-1.8498	0.9722	-0.78	0.9631		
	1	-2.058	0.967	-0.84	0.9576		
	2	-2.1579	0.9643	-0.87	0.9548		

Table 13 continued

The Dependent Variable:							
Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	-6.0226	0.0882	-2.51	0.0125		
	1	-5.1178	0.1169	-1.98	0.0464		
	2	-5.7608	0.0956	-2.51	0.0124		
Single Mean	0	-9.8352	0.1293	-3.75	0.0048	7.96	0.001
	1	-8.8188	0.1674	-3.09	0.0311	5.32	0.0323
	2	-10.5624	0.107	-4.41	0.0006	10.97	0.001
Trend	0	-11.1226	0.3397	-3.08	0.1173	7.1	0.0339
	1	-10.15	0.4023	-2.59	0.2881	4.84	0.2237
	2	-11.4562	0.3193	-3.48	0.0477	9.69	0.001
Phillips-Perron Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**		
Zero Mean	0	-6.0226	0.0882	-2.51	0.0125		
	1	-6.2143	0.0831	-2.51	0.0126		
	2	-5.9604	0.0899	-2.51	0.0125		
Single Mean	0	-9.8352	0.1293	-3.75	0.0048		
	1	-9.9205	0.1265	-3.73	0.005		
	2	-9.3832	0.1451	-3.84	0.0036		
Trend	0	-11.1226	0.3397	-3.08	0.1173		
	1	-11.3542	0.3258	-3.09	0.1151		
	2	-10.4162	0.3846	-3.06	0.1228		
Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	-11.5112	0.0164	-3.04	0.0028		
	1	-15.5887	0.0048	-3.83	0.0002		
	2	-12.3642	0.0127	-4.19	<.0001		
Single Mean	0	-14.8051	0.0348	-3.24	0.021	5.46	0.0281
	1	-20.7993	0.0065	-4.12	0.0015	8.86	0.001
	2	-16.0665	0.0245	-4.29	0.0009	10.02	0.001
Trend	0	-15.9862	0.1305	-3.16	0.0987	5.36	0.1212
	1	-22.2542	0.0316	-3.95	0.0139	8.56	0.0042
	2	-15.6966	0.1382	-3.83	0.0193	9.12	0.001
Phillips-Perron Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**		
Zero Mean	0	-11.5112	0.0164	-3.04	0.0028		
	1	-11.6749	0.0156	-3.04	0.0027		
	2	-9.9973	0.0258	-2.97	0.0034		
Single Mean	0	-14.8051	0.0348	-3.24	0.021		
	1	-15.181	0.0314	-3.26	0.0197		
	2	-12.9112	0.0579	-3.13	0.0283		
Trend	0	-15.9862	0.1305	-3.16	0.0987		
	1	-16.5668	0.1153	-3.21	0.0901		
	2	-13.9693	0.1977	-3.01	0.1342		

Table 13 continued

Augmented Dickey-Fuller Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau	*F*	Pr > *F*
Zero Mean	0	-51.0282	<.0001	-5.96	<.0001		
	1	-18.697	0.0018	-3.02	0.0029		
	2	-15.6864	0.0047	-2.98	0.0033		
Single Mean	0	-55.3057	0.0008	-6.28	<.0001	19.7	0.001
	1	-21.2939	0.0057	-3.21	0.023	5.14	0.0375
	2	-17.0099	0.0188	-2.98	0.0412	4.57	0.0583
Trend	0	-64.9275	0.0003	-7.09	<.0001	25.13	0.001
	1	-29.0151	0.0058	-3.79	0.0217	7.2	0.0313
	2	-20.9925	0.0424	-3.07	0.12	4.92	0.2083

Phillips-Perron Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau
Zero Mean	0	-51.0282	<.0001	-5.96	<.0001
	1	-44.0379	<.0001	-5.72	<.0001
	2	-51.1447	<.0001	-5.96	<.0001
Single Mean	0	-55.3057	0.0008	-6.28	<.0001
	1	-49.0891	0.0008	-6.08	<.0001
	2	-57.0134	0.0008	-6.33	<.0001
Trend	0	-64.9275	0.0003	-7.09	<.0001
	1	-60.4064	0.0003	-6.99	<.0001
	2	-69.5909	0.0003	-7.2	<.0001

Augmented Dickey-Fuller Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau	*F*	Pr > *F*
Zero Mean	0	-6.5554	0.0747	-1.83	0.0636		
	1	-8.5318	0.0404	-2.04	0.0401		
	2	-10.3809	0.0229	-2.51	0.0125		
Single Mean	0	-7.6594	0.2243	-1.98	0.2955	1.96	0.5771
	1	-10.141	0.1194	-2.21	0.203	2.45	0.4538
	2	-11.3614	0.0869	-2.48	0.1237	3.23	0.257
Trend	0	-11.6538	0.3085	-2.58	0.2891	3.4	0.5045
	1	-16.1108	0.1268	-2.91	0.1629	4.31	0.3277
	2	-14.9854	0.1603	-2.6	0.2818	3.57	0.4716

Phillips-Perron Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau
Zero Mean	0	-6.5554	0.0747	-1.83	0.0636
	1	-7.3534	0.0583	-1.94	0.0505
	2	-7.9794	0.048	-2.02	0.0422
Single Mean	0	-7.6594	0.2243	-1.98	0.2955
	1	-8.6217	0.1761	-2.1	0.2464
	2	-9.4016	0.1444	-2.19	0.212
Trend	0	-11.6538	0.3085	-2.58	0.2891
	1	-13.0312	0.2378	-2.71	0.2353
	2	-14.2631	0.1864	-2.82	0.1945

Experimenting with Different Model Specifications

Using Equation 10: $\sigma_t = -4(\gamma - 1)p_{t-1}^2 + 4(\gamma - 1)p_{t-1} + 2$ and different $e_{t-n}^{\max}$ lag values. See Table 14.

Table 14

Values Used in Testing Different Model Specifications

	$e_{t-2}^{\max}$		$e_{t-3}^{\max}$		$e_{t-4}^{\max}$		$e_{t-5}^{\max}$		$e_{t-6}^{\max}$		$e_{t-7}^{\max}$		$e_{t-8}^{\max}$	
***R*-Square**	**0.972**		**0.972**		**0.972**		**0.972**		**0.972**		**0.972**		**0.972**	
Parameter	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***
φ	0.68	22.69	0.68	22.69	0.68	21.96	0.68	22.08	0.69	22.35	0.68	22.47	0.68	22.57
γ	0.50	2.91	0.50	2.91	0.51	2.87	0.52	2.94	0.53	3.03	0.51	2.96	0.50	2.91
α	1.00		1.00		0.98	19.46	0.97	22.76	0.95	25.52	0.97	28.89	0.98	31.80
Bound α	1.47	1.44	0.75	0.49										

APPENDIX B

STATISTICAL DISCUSSION

Logistic Distribution

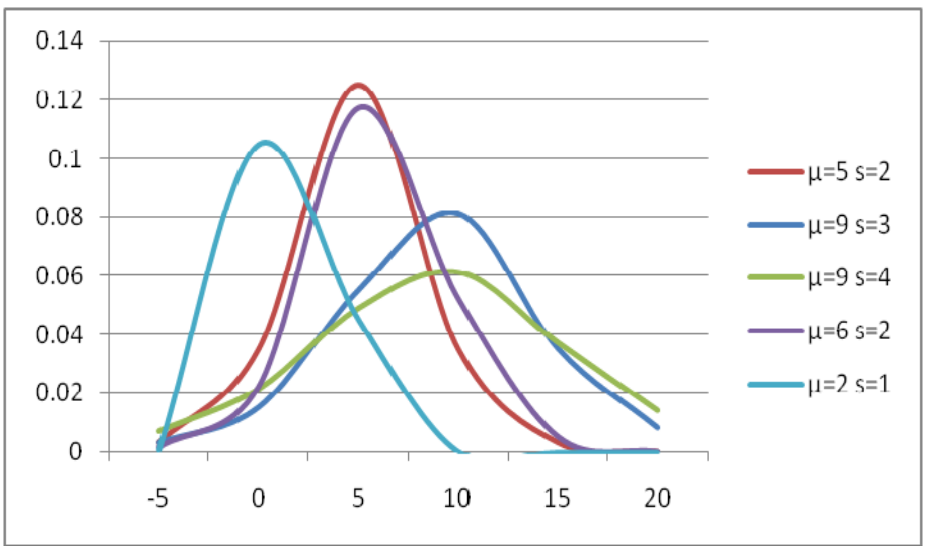

Figure 21: Logistic probability density function.

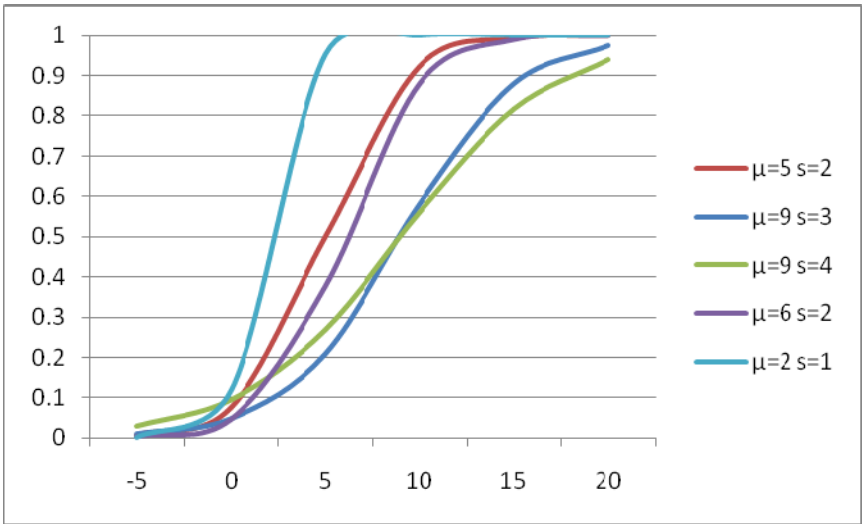

Figure 22: Logistic cumulative distribution function.

Parameters: μ location and s > 0 scale

Support: $x \in (-\infty; +\infty)$

Probability density function (pdf) $\frac{e^{-(x-\mu)/s}}{s\left(1+e^{-(x-\mu)/s}\right)^2}$

Cumulative distribution function (cdf) $\frac{1}{1+e^{-(x-\mu)/s}}$

Mean, Median, Mode: μ

Variance $\frac{\pi^2}{3}s^2$

Skewness: 0

Extreme Value Distribution

Definition

The probability density function for the extreme value distribution with location parameter μ and scale parameter σ is

$$y = f(x|\mu,\sigma) = \sigma^{-1}\exp\left(\frac{x-\mu}{\sigma}\right)\exp\left(-\exp\left(\frac{x-\mu}{\sigma}\right)\right)$$

If T has a Weibull distribution with parameters a and b, as described in Weibull Distribution, then log T has an extreme value distribution with parameters $\mu = \log a$ and sim $\sigma = 1/b$.

Theoretical Application

Extreme value distributions are often used to model the smallest or largest value among a large set of independent, identically distributed random values representing measurements or observations. The extreme value distribution used in the Statistics Toolbox is appropriate for modeling the smallest value from a distribution whose tails decay exponentially fast, for example, the normal distribution. It can also model the largest value from a distribution, such as the normal or exponential distributions, by using the negative of the original values.

Plot

The following code in Figure 23 generates a plot of the pdf for the extreme value distribution.

The extreme value distribution is skewed to the left, and its general shape remains the same for all parameter values. The location parameter, mu, shifts the distribution along the real line, and the scale parameter, sigma, expands or contracts the distribution. Figure 24 plots the probability function for different combinations of mu and sigma.

The Phillips-Perron Unit Root Test

An advantage of this procedure is that it is nonparametric as no generating model for the time series specification is needed beforehand. "This approach is nonparametric with respect to nuisance parameters and thereby allows for a very wide class of time series models in which there is a unit root" (Phillips & Perron, 1988, p. 336).

> In contrast to its chief competitor, the (augmented) Dickey-Fuller test, which is based on an autoregressive specification, at least as an approximation to the underlying model. To use the Phillips-Perron test [o]ne needs only to estimate a first-order autoregression with a constant and possibly a time trend and to calculate the appropriate transformed *Z* statistic. (Phillips & Perron, 1988, p. 345)

"However, simulation studies have suggested that the Phillips-Perron test can suffer quite severe size distortions even in moderately large samples" (Leybourne & Newbold, 1999, p. 51).

In the SAS software there are three types of the Phillips-Perron unit root test reported by the PHILLIPS option. They are as follows:

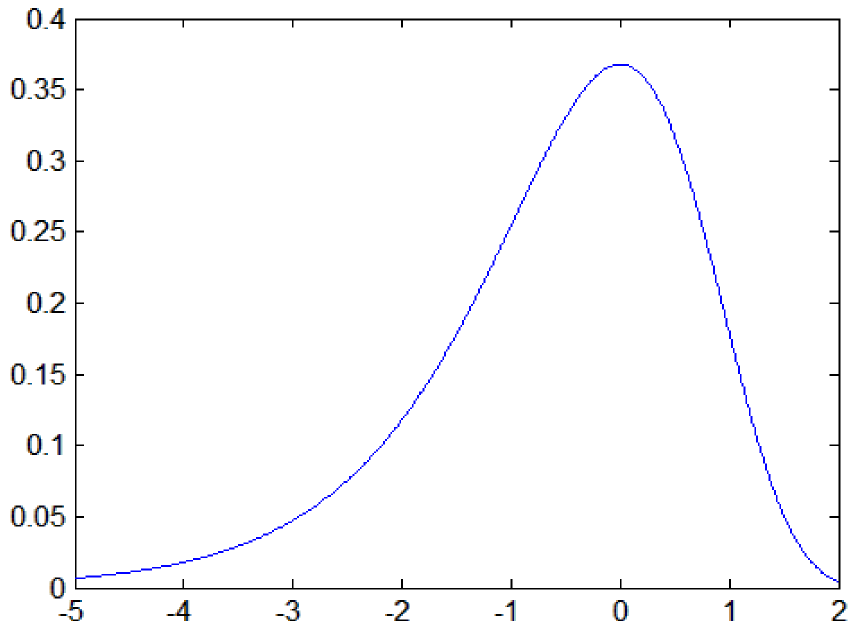

Figure 23: PDF plot for extreme value distribution.

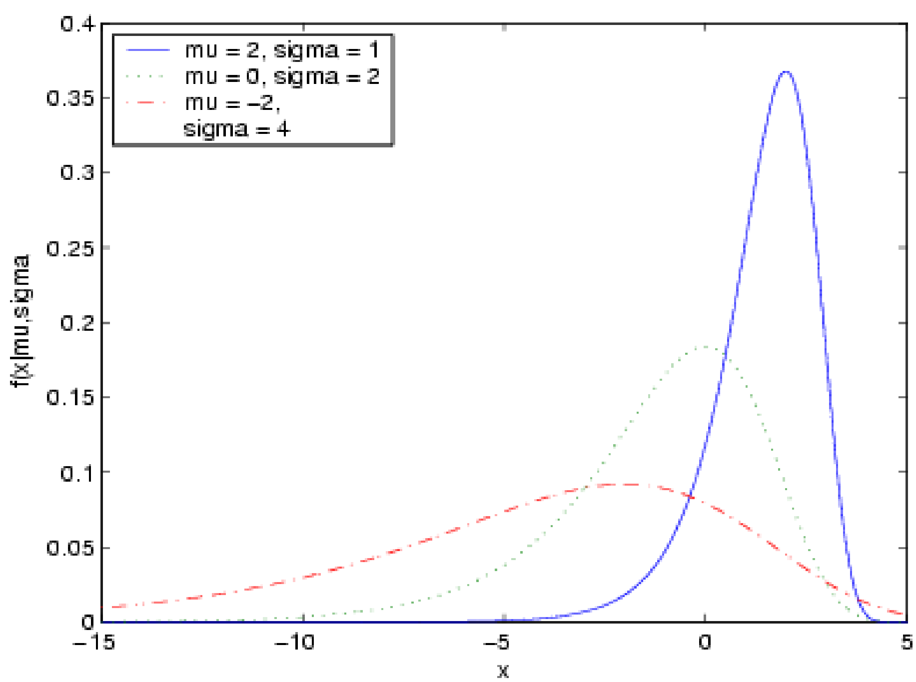

Figure 24: Plots of the probability function for different combinations of mu and sigma.

Zero Mean: computes the Phillips-Perron test statistic based on the zero mean autoregressive model.

Single Mean: computes the Phillips-Perron test statistic based on the autoregressive model with a constant term.

Trend: computes the Phillips-Perron test statistic based on the autoregressive model with constant and time trend terms.

APPENDIX C

MODEL PARAMETERS SIMULATION

This appendix shows, through a series of simulations, the effect of changes in the parameters e_t, σ_t and φ on the model's predictions in Equation 6 (reproduced below). These changes can be used in the model to produce multi steady dollarization states and to better understand the mechanics of the model.

$$p_t = (1 + \exp\{-\tfrac{1}{\varphi}[\hat{e}_t - \hat{e}_t^* + \hat{i}_t^* - \hat{i}_t - \hat{\sigma}_t + 2\hat{\sigma}_t \hat{p}_t]\})^{-1} \qquad (6)$$

Following is a discussion of the findings of the simulations.

The Peso Depreciation Term (e_t)

The starting values for this simulation are $\sigma_t = .25$ and $\varphi = .03$. See Figure 25.

Comments

- At very low depreciation levels $e_t = 2\%$ the curves are convex and under the 45 degree line (which represents equilibrium positions). Being below the equilibrium line, the dynamics of the model will bring down the dollarization level to nill.

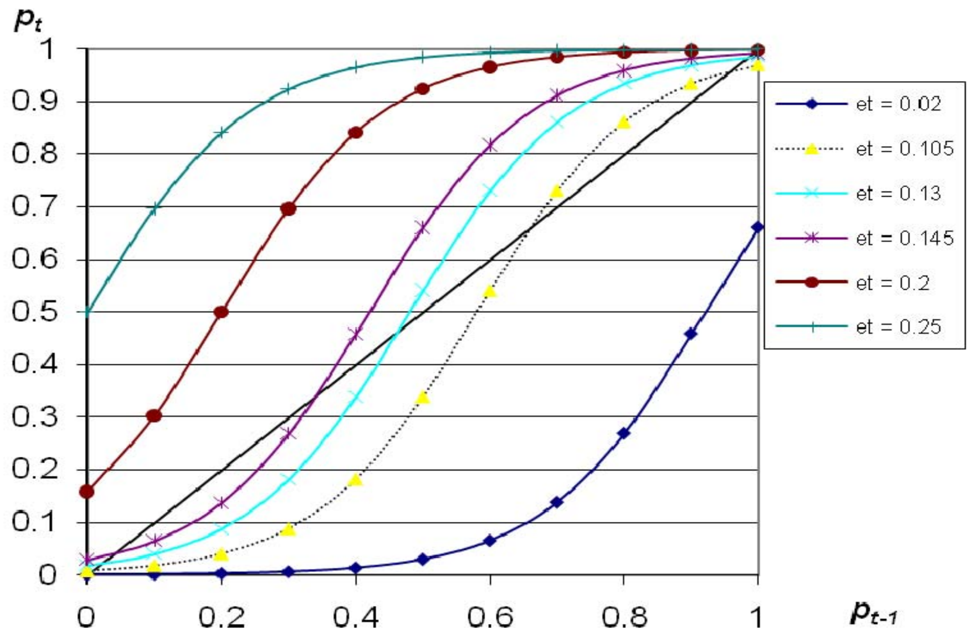

Figure 25: Simulating the effect of different depreciation rate values on dollarization paths.

- As the depreciation rate increases the initial convex curve changes into S shaped. At e_t = 9% the simulated curve is tangent to the 45 degree line at one equilibrium point near 80%. However, this is not a stable equilibrium point and dollarization will be expected to drop down to near zero.

- A 13% depreciation rate gives us a three equilibria curve. The upper and lower intersection points are stable while the intermediate one is not. The dynamics of the model suggest that low dollarization equilibrium in an economy can be maintained as long a threshold is not breached (in this case it is 45% dollarization level). If it is breached, the dollarization will keep on progressing to the nearly fully dollarized level of about 95%.

- A further slight increase in e_t to 14.5% produces a scenario where there are two steady state points. The lower one can be maintained only under conditions of low dollarization (below 35%). Once dollarization passes the 35% mark, it proceeds quickly to very high dollarization levels (over 95%).

- High and very high depreciation levels (20% and 25%) depict curves that are concave and do not intersect the 45 degree line, except at near full dollarization levels.

Conclusion

Depreciation rate plays a clear ratcheting role in the simulated dynamic model. Low *e* levels sustain the role of local currencies as a store of value, while high levels destroy it. Changing *e* will always produce positively sloped curves.

The Transaction Cost Factor (σ_t)

The starting values for this simulation are et = .15 and φ = .03. See Figure 26.

Comment

- At low transaction cost (σ_t = .15) the simulated curve tends to become flat, while at the other extreme, high cost (σ_t = .5) makes the curve very steep.
- Dollarization paths at σ_t = .23 and .42 reflect the position of the simulated curves that are tangent to the 45 degree line. At σ_t = .23 dollarization levels are expected to continue to rise until it reaches around 95%. At σ_t = .42 the stable equilibrium is the lower point of around zero dollarization.
- At σ_t = .7 the dollarization path becomes very steep and the resting point is at zero.

Conclusion

As expected high transaction cost are most effective in combination with moderate depreciation rates. On the other hand, lowering transaction cost (for example by legalizing dollar deposits for example) will flatten the dollarization path resulting in rapid asset substitution outcome.

The Rate Factor (φ)

The starting values for this simulation are e_t = .13 and σ_t = .15. See Figure 27.

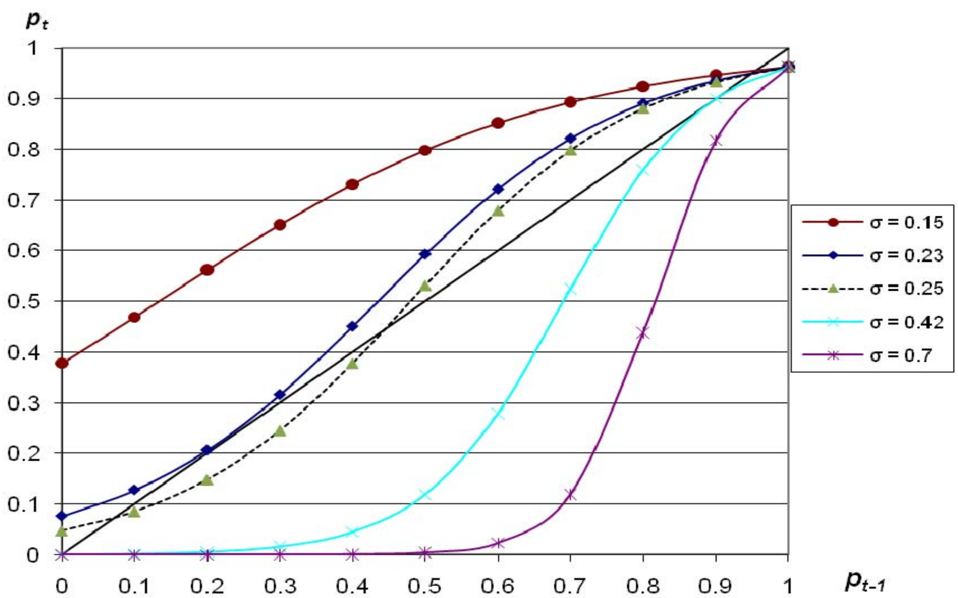

Figure 26: Simulating the effect of different transaction cost values on dollarization paths.

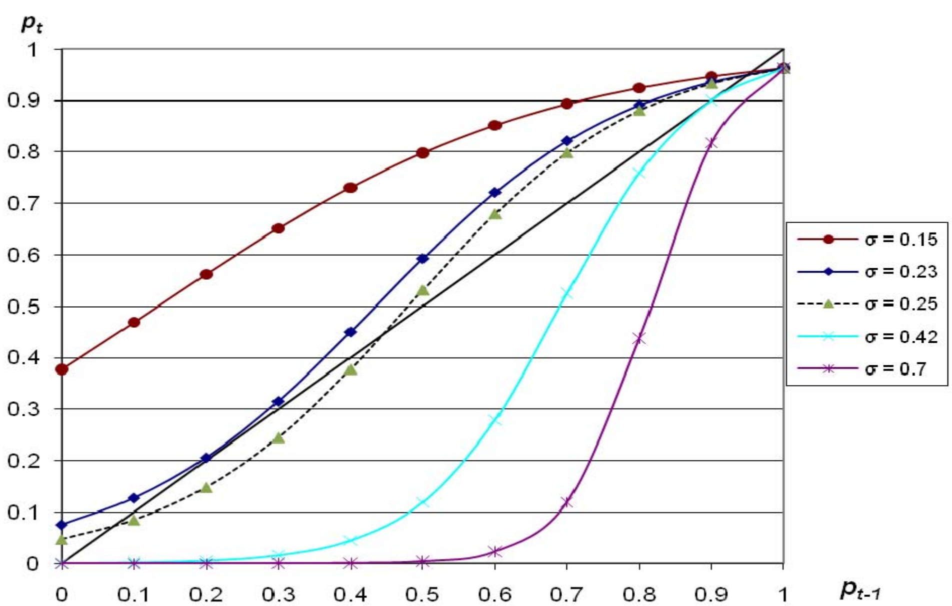

Figure 27: Simulating the effect of different change rate values on dollarization paths.

Comments and Conclusion

All the curves pass through one focal point. Given the values for e and σ used in this experiment the focal point is the center of the graph (.5, .5), but will change if e_t and σ_t values change. Increasing the value of φ changes the shape of the simulated lines from steep to flat.

APPENDIX D

ARGENTINA'S CASE STUDY

Data Sources

The data cover the time span between Q1 1981 and Q1 2001. The data were obtained mainly from Argentina's Central Bank (BCRA) covering the period from Dec. 1989 to Jan. 2006. For dollarization data from the early 1980s, I referred to monthly dollar deposit ratios as reported in graphs in Kamin and Ericsson's 2003 and 1993 papers. In an email, Ericsson stated that the data in his graph came from BCRA and Carta Economica (CE), a claim I could not verify independently.

The rate of depreciation was calculated by taking the natural log of quarterly exchange rate (ln (Xt / Xt -1) * 100) as reported by the series "Argentine per U.S. Dollar: End of Period (ae) Market Rate." See Table 15.

Interest rate differential (*R* = Deposit Rate (Fgn. Currency) - Deposit Rate)

Table 15

IFS: Argentina's Deposit Interest Rate by Denomination

Deposit Rate	**Percent per annum**
Deposit Rate (Fgn. Currency)	Percent per annum

Deposit dollarization ratio (DDR) was calculated as the ratio of Total Private Foreign Deposits over the Total Private Deposits. The DDR used the series in the Table 16, in the following manner:

DDR = (of which: Fgn. Currency Deposits) / Demand Deposits + Time, Savings, & Fgn. Currency Dep.

Table 16

IFS: Argentina's Deposit Data by Currency Denomination

Demand Deposits	**National Currency**	**Millions**
Time, Savings, & Fgn. Currency Dep.	National Currency	Millions
of which: Fgn. Currency Deposits	National Currency	Millions

Data Mapping

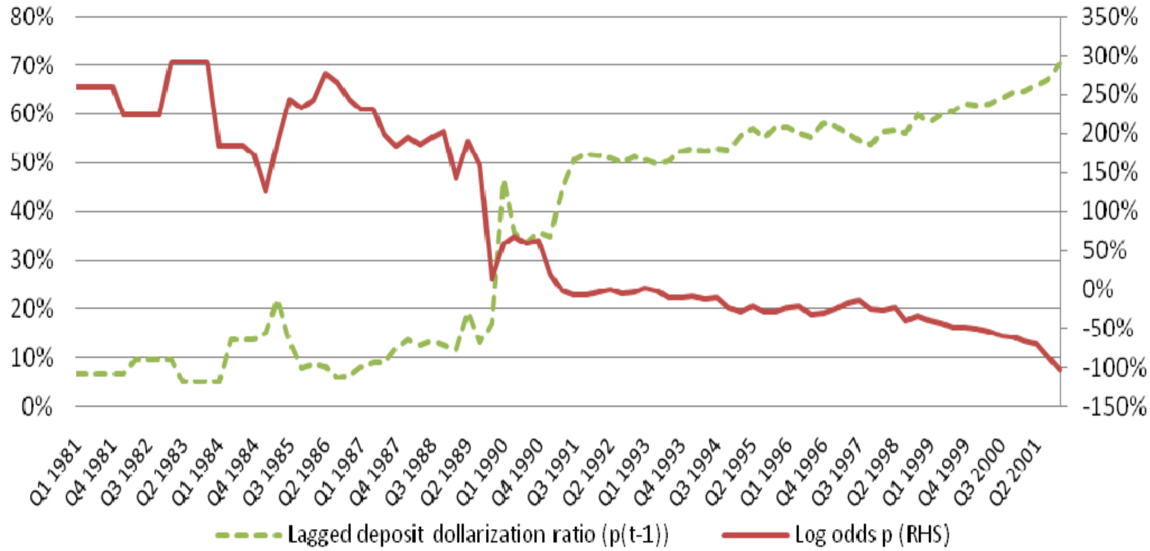

Figure 28: Argentina's time series plots.

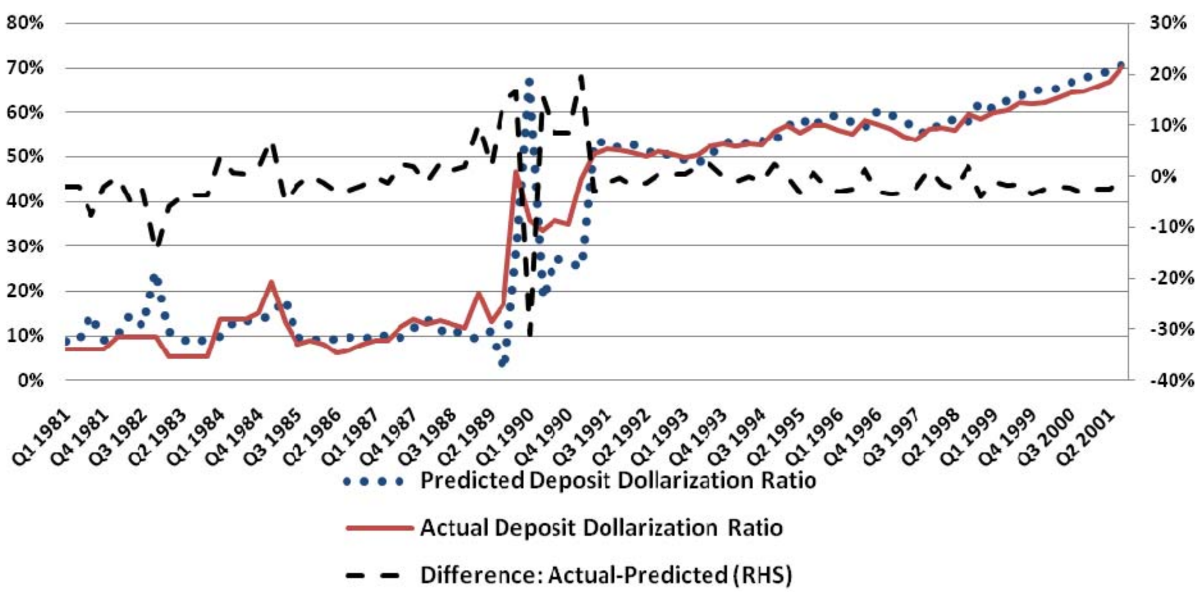

Figure 29: Argentina's actual versus modeled dollarization trends.

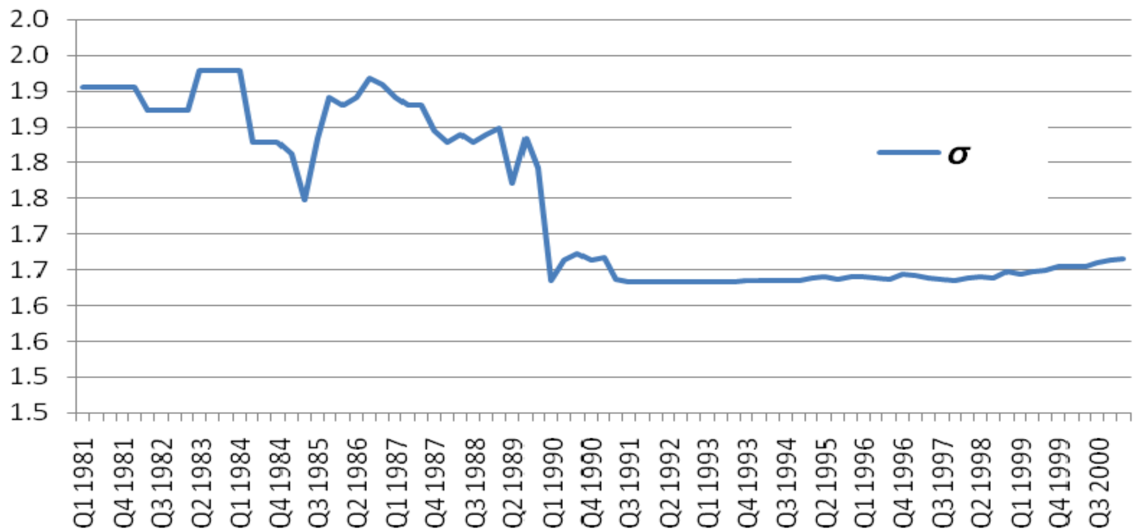

Figure 30: Argentina’s estimated transaction cost.

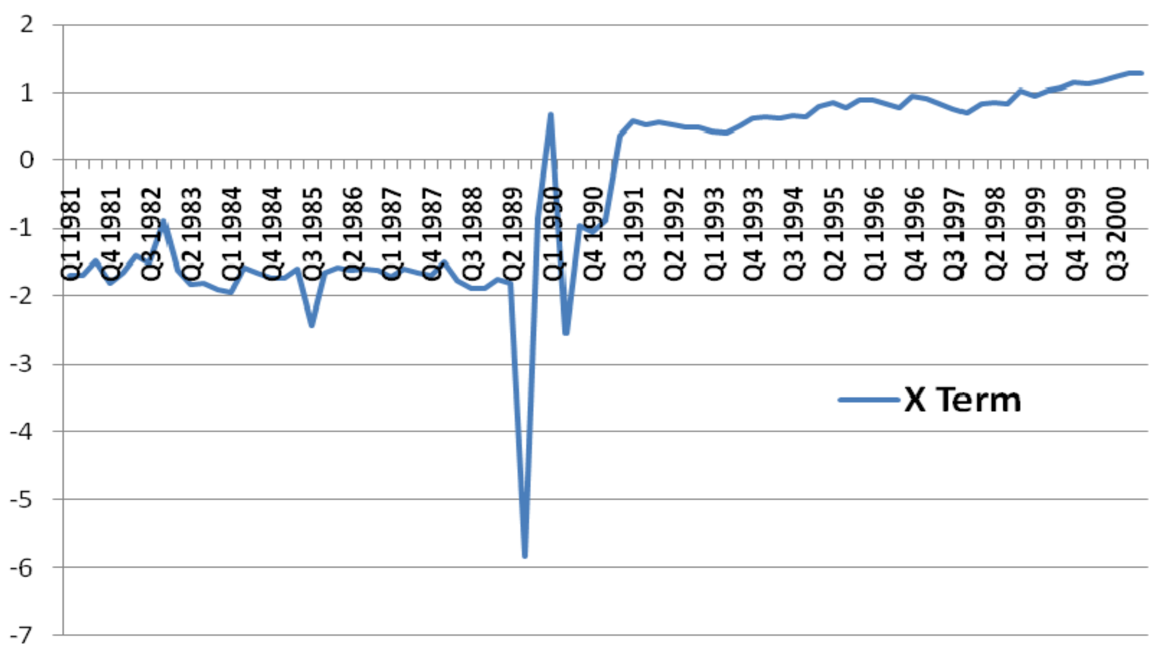

Figure 31: Argentina’s estimated difference in the cost of holding and transacting in pesos versus dollars (the x term in Equation 5).

Model Simulation Data

Table 17

Model Simulation Data

Date	e_{t-1}	$e_{t-6}^{\max}$	p_{t-1}	$i_{t-1}^{*} - i_{t-1}$	$\hat{e}_t$	σ
Q2 1987	20%	20%	9%	-20%	20%	1.880
Q1 1988	38%	38%	14%	-32%	38%	1.828
Q2 1988	33%	38%	13%	-43%	34%	1.840
Q2 1991	54%	101%	45%	-29%	59%	1.637
Q3 1991	4%	95%	51%	-6%	12%	1.634
Q4 1991	-1%	54%	52%	-6%	5%	1.634
Q1 1992	1%	54%	52%	-4%	6%	1.634
Q2 1992	-1%	54%	51%	-4%	5%	1.634

Statistical Tables

Table 18

*Nonlinear Regression Results Estimation Summary**

Method	Gauss-Newton
Iterations	3
R	3.66E-08
PPC(g)	3.72E-08
RPC(g)	0.000305
Object	9.01E-08
Objective	14.15115
Observations Read	84
Observations Used	83
Observations Missing	1

Note: An intercept was not specified for this model.

Source	***DF***	**Sum of Squares**	**Mean Square**	***F* Value**	**Approx Pr > *F***
Model	3	165.7	55.2436	312.31	<.0001
Error	80	14.1511	0.1769	*R*-Square	0.921
Uncorrected Total	83	179.9			

Parameter	**Estimate**	**Approx Std Error**	**Approximate 95% Confidence Limits**		***t*-Values**
φ	0.7239	0.0498	0.6247	0.8231	14.536
γ	0.6335	0.3208	-0.005	1.272	1.975
α	0.9037	0.0586	0.7872	1.0202	15.422

Approximate Correlation Matrix

	phi	*G*	*a*
φ	1	0.8571187	-0.0104636
γ	0.8571187	1	-0.2391611
α	-0.0104636	-0.2391611	1

*Note: Convergence criterion met.

Table 19

Unit Root Tests of Regression Variables

Augmented Dickey-Fuller Unit Root Tests

Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	0.9362	0.8985	0.97	0.9111		
	1	1.0373	0.9149	1.25	0.9449		
	2	1.1363	0.9289	1.75	0.9802		
Single Mean	0	-1.1623	0.8681	-0.66	0.8513	1.47	0.7002
	1	-0.7915	0.9022	-0.52	0.8812	1.81	0.6148
	2	-0.383	0.9332	-0.33	0.9152	2.76	0.375
Trend	0	-13.1465	0.231	-2.68	0.2478	3.63	0.4607
	1	-10.7342	0.362	-2.32	0.4187	2.72	0.637
	2	-6.7264	0.6718	-1.81	0.6936	1.67	0.8431

Phillips-Perron Unit Root Tests

Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
Zero Mean	0	0.9362	0.8985	0.97	0.9111
	1	1.0106	0.9108	1.15	0.934
	2	1.1042	0.9247	1.44	0.962
Single Mean	0	-1.1623	0.8681	-0.66	0.8513
	1	-0.9137	0.8916	-0.56	0.8726
	2	-0.6007	0.9176	-0.42	0.8999
Trend	0	-13.1465	0.231	-2.68	0.2478
	1	-12.1259	0.281	-2.58	0.2888
	2	-10.5878	0.3718	-2.43	0.36

p_{t-1}^2

Augmented Dickey-Fuller Unit Root Tests

Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	1.6242	0.9727	1.45	0.963		
	1	1.7489	0.9788	1.87	0.9847		
	2	1.8045	0.981	2.31	0.9948		
Single Mean	0	0.1001	0.9604	0.06	0.9607	1.78	0.6206
	1	0.4534	0.9743	0.32	0.9783	2.53	0.4334
	2	0.6663	0.9805	0.59	0.9886	3.61	0.1623
Trend	0	-13.8387	0.2013	-2.76	0.2161	4.31	0.3263
	1	-10.8182	0.3567	-2.37	0.3913	3.45	0.4944
	2	-7.9949	0.5651	-2.04	0.5703	2.92	0.5997

Table 19 continued

Phillips-Perron Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau
Zero Mean	0	1.6242	0.9727	1.45	0.963
	1	1.7459	0.9787	1.74	0.9798
	2	1.8494	0.9828	2.08	0.9907
Single Mean	0	0.1001	0.9604	0.06	0.9607
	1	0.3764	0.9717	0.25	0.9743
	2	0.6122	0.9791	0.46	0.9844
Trend	0	-13.8387	0.2013	-2.76	0.2161
	1	-12.3241	0.2707	-2.62	0.272
	2	-11.05	0.3426	-2.5	0.3274

Dependent variable (p_t log odds)

Augmented Dickey-Fuller Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau	*F*	Pr > *F*
Zero Mean	0	-2.7224	0.255	-1.62	0.0991		
	1	-2.6116	0.2649	-1.63	0.0969		
	2	-2.2635	0.2994	-1.7	0.0847		
Single Mean	0	-1.9916	0.7758	-0.98	0.7568	1.51	0.6889
	1	-1.7616	0.803	-0.93	0.7754	1.62	0.6623
	2	-1.2217	0.8621	-0.79	0.8154	2.08	0.5456
Trend	0	-14.2377	0.1858	-2.74	0.2227	3.76	0.4342
	1	-13.834	0.2012	-2.56	0.298	3.28	0.5274
	2	-9.5409	0.4441	-2.04	0.5688	2.09	0.7607

Phillips-Perron Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau
Zero Mean	0	-2.7224	0.255	-1.62	0.0991
	1	-2.6283	0.2634	-1.62	0.0992
	2	-2.4193	0.2834	-1.63	0.098
Single Mean	0	-1.9916	0.7758	-0.98	0.7568
	1	-1.8277	0.7953	-0.94	0.7712
	2	-1.4976	0.833	-0.85	0.8003
Trend	0	-14.2377	0.1858	-2.74	0.2227
	1	-14.1529	0.189	-2.73	0.2256
	2	-12.9864	0.2383	-2.63	0.2697

$$i^*_{t-1} - i_{t-1}$$

Table 19 continued

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	-47.0644	<.0001	-5.72	<.0001		
	1	-27.1942	<.0001	-3.66	0.0004		
	2	-10.059	0.0251	-2.16	0.0303		
Single Mean	0	-58.4972	0.0008	-6.65	<.0001	22.12	0.001
	1	-39.7444	0.0008	-4.36	0.0007	9.51	0.001
	2	-15.1494	0.031	-2.54	0.1098	3.24	0.2557
Trend	0	-65.7324	0.0003	-7.29	<.0001	26.57	0.001
	1	-50.8475	0.0002	-4.94	0.0007	12.22	0.001
	2	-20.9821	0.0414	-2.98	0.1439	4.46	0.2971

Phillips-Perron Unit Root Tests					
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
Zero Mean	0	-47.0644	<.0001	-5.72	<.0001
	1	-43.2411	<.0001	-5.58	<.0001
	2	-43.2784	<.0001	-5.58	<.0001
Single Mean	0	-58.4972	0.0008	-6.65	<.0001
	1	-56.5121	0.0008	-6.6	<.0001
	2	-57.492	0.0008	-6.62	<.0001
Trend	0	-65.7324	0.0003	-7.29	<.0001
	1	-64.6276	0.0003	-7.27	<.0001
	2	-65.5091	0.0003	-7.28	<.0001

e_{t-1}

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	-35.2956	<.0001	-4.72	<.0001		
	1	-19.8576	0.0012	-3.19	0.0017		
	2	-13.7805	0.0082	-2.53	0.0119		
Single Mean	0	-45.7167	0.0008	-5.55	<.0001	15.39	0.001
	1	-28.4346	0.0008	-3.71	0.0055	6.92	0.001
	2	-21.204	0.0056	-2.97	0.0422	4.43	0.0663
Trend	0	-57.1042	0.0003	-6.54	<.0001	21.37	0.001
	1	-41.097	0.0002	-4.42	0.0035	9.77	0.001
	2	-35.5589	0.0009	-3.71	0.0275	6.87	0.04

Table 19 continued

Phillips-Perron Unit Root Tests					
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
Zero Mean	0	-35.2956	<.0001	-4.72	<.0001
	1	-30.6716	<.0001	-4.49	<.0001
	2	-31.5755	<.0001	-4.54	<.0001
Single Mean	0	-45.7167	0.0008	-5.55	<.0001
	1	-42.4899	0.0008	-5.42	<.0001
	2	-44.5083	0.0008	-5.5	<.0001
Trend	0	-57.1042	0.0003	-6.54	<.0001
	1	-55.7006	0.0003	-6.5	<.0001
	2	-58.0277	0.0003	-6.56	<.0001

$e_{t-6}^{\max}$

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	***F***	**Pr > *F***
Zero Mean	0	-6.2299	0.0825	-1.79	0.0698		
	1	-6.6927	0.0713	-1.81	0.0671		
	2	-7.5269	0.055	-1.9	0.0549		
Single Mean	0	-9.2156	0.1508	-2.16	0.2205	2.34	0.4801
	1	-10.3727	0.1118	-2.22	0.202	2.46	0.4518
	2	-11.6936	0.079	-2.24	0.1928	2.54	0.4316
Trend	0	-12.1489	0.2798	-2.62	0.2734	3.55	0.4765
	1	-14.1325	0.1894	-2.72	0.2322	3.81	0.4241
	2	-15.7634	0.1347	-2.64	0.2627	3.52	0.4819

Phillips-Perron Unit Root Tests					
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
Zero Mean	0	-6.2299	0.0825	-1.79	0.0698
	1	-6.4606	0.0767	-1.82	0.0653
	2	-6.7139	0.0709	-1.86	0.0606
Single Mean	0	-9.2156	0.1508	-2.16	0.2205
	1	-9.7058	0.1329	-2.22	0.2005
	2	-10.2202	0.1164	-2.28	0.1814
Trend	0	-12.1489	0.2798	-2.62	0.2734
	1	-12.7735	0.2484	-2.68	0.2491
	2	-13.426	0.2186	-2.74	0.2255

Experimenting With Different Model Specifications

Using Equation 10: $\sigma_t = -4(\gamma - 1)p_{t-1}^2 + 4(\gamma - 1)p_{t-1} + 2$ and different $e_{t-n}^{\max}$ lag values. See Table 20.

$$\ln\left(\frac{1-p_t}{p_t}\right) = -\frac{1}{\varphi}[(\alpha e_{t-1} + (1-\alpha)\, e_{t-n}^{\max}) + (i_{t-1}^{*} - i_{t-1}) - (-4(\gamma-1)p_{t-1}^2 + 4(\gamma-1)p_{t-1} + 2)$$
$$+ 2\,(-4\,(\gamma-1)p_{t-1}^2 + 4(\gamma-1)p_{t-1} + 1)\, p_{t-1}]$$

Modified Transaction Cost

A modified transaction cost equation: $\sigma_t = -4(\gamma - 1)p_{t-1}^2 + 4(\gamma - 1)p_{t-1} + 1$ and different $e_{t-n}^{\max}$ lag values. See Table 21.

$$\ln\left(\frac{1-p_t}{p_t}\right) = -\frac{1}{\varphi}[(\alpha e_{t-1} + (1-\alpha)\, e_{t-n}^{\max}) + (i_{t-1}^{*} - i_{t-1}) - (-4(\gamma-1)p_{t-1}^2 + 4(\gamma-1)p_{t-1} + 1)$$
$$+ 2\,(-4\,(\gamma-1)p_{t-1}^2 + 4(\gamma-1)p_{t-1} + 1)\, p_{t-1}]$$

Discussion of Experiment Results

The main problem with σ's second specification in the above regressions is that its value is stuck at the upper restriction value of 1, which leads to the conclusion that there is no transaction cost effect in the model. In σ's first specification (with +2 at the end), the estimated values are comfortably within the specified value bounds. The *R*-square values are also lower under the second specification by about .1. This indicates that the first specification of σ has a strong impact on improving model fit.

Table 20

Values Used in Different Model Specifications 1

	$e_{t-2}^{\max}$		$e_{t-3}^{\max}$		$e_{t-4}^{\max}$		$e_{t-5}^{\max}$		$e_{t-6}^{\max}$		$e_{t-7}^{\max}$		$e_{t-8}^{\max}$	
***R*-Square**	**0.922**		**0.919**		**0.920**		**0.920**		**0.921**		**0.923**		**0.922**	
Parameter	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***
φ	0.73	14.41	0.73	14.19	0.73	14.36	0.73	14.39	0.72	14.54	0.72	14.72	0.73	14.59
γ	0.67	2.03	0.56	1.71	0.62	1.90	0.62	1.91	0.63	1.97	0.67	2.08	0.66	2.05
α	0.76	5.65	0.99	10.08	0.91	11.12	0.92	13.48	0.90	15.42	0.89	17.13	0.91	18.62

Table 21

Values Used in Different Model Specifications 2

***R*-Square**	**0.824**		**0.823**		**0.824**		**0.824**	
Parameter	**Est**	***t***	**Est**	***t***	**Est**	***t***	**Est**	***t***
φ	0.453	18.805	0.456	19.549	0.452	17.787	0.450	17.659
γ	1.000		1.000		1.000		1.000	
α	0.959	8.030	1.000		0.975	13.283	0.971	15.871
Bound γ	3.589	2.618	3.456	2.476	3.563	2.552	3.595	2.563
Bound α			4.079	0.912				
***R*-Square**	**0.825**		**0.827**		**0.826**			
φ	0.445	17.808	0.440	18.045	0.445	18.004		
γ	1.000		1.000		1.000			
α	0.952	18.208	0.938	20.570	0.957	22.206		
Bound γ	3.693	2.602	3.819	2.679	3.765	2.667		
Bound α								

Testing different $e_{t-n}^{\max}$ lag values results mainly in different α parameter values, which affects how the expected depreciation function $(\alpha e_{t-1} + (1-\alpha)\, e_{t-n}^{\max})$ weighs its two variables. Lower α values gives a bigger role for the ratchet variable $e_{t-n}^{\max}$. The final specification of $e_{t-6}^{\max}$ was chosen because the coefficient was in the best possible range in both case studies.

REFERENCES

Baliño, T., Adam, B., & Eduardo, B. (1999). *Monetary policy in dollarized economies. Occasional Paper, 171*. Washington, DC: International Monetary Fund.

Barro, R. J., & Fischer, S. (1976). Recent developments in monetary theory. *Journal of Monetary Economics, 2*, 133-167.

Baumol, W. J. (1952). The transactions demand for cash: An inventory theoretic approach. *The Quarterly Journal of Economics, 66*, 545-556.

Bergsten, C. (2002). The Euro versus the dollar: Will there be a struggle for dominance? *Journal of Policy Modeling, 2*, 307.

Brock, W. A., & Durlauf, S. N. (2001). Discrete choice with social interactions. *Review of Economic Studies, 68*, 235-260.

Broda, C., & Levy-Yeyati, E. (2003a). Dollarization and the lender of last resort. In E. Levy-Yeyati & F. Sturzenegger (Eds.), *Dollarization* (pp. 101-132). Cambridge, MA: MIT Press.

Broda, C., & Levy-Yeyati, E. (2003b). *Endogenous deposit dollarization, staff report, 160*. New York, NY: Federal Reserve Bank of New York.

Burnside, C., Eichenbaum, M., & Rebelo, S. (1999). *Hedging and financial fragility in fixed exchange rate regimes* (NBER Working Paper, 7143). Cambridge, MA: National Bureau of Economic Research.

Calvo, G. A. (2002). On dollarization. *Economics of Transition, 10*, 393-403.

Calvo, G. A., & Rodriguez, C. A. (1977). A model of exchange rate determination under currency substitution and rational expectations. *Journal of Political Economy, 85*, 617-625.

Camera, G., Craig, B., & Waller, C. J. (2004). Currency competition in a fundamental model of money. *Journal of International Economics, 64*, 521-544.

Catão, L., & Terrones, M. (2000). *Determinants of dollarization: The banking side* (IMF Working Paper WP/00/146) Washington, DC: International Monetary Fund.

Cesarano, F. (1999). Competitive money supply: The international monetary system in perspective. *Journal of Economic Studies, 26*, 188-200.

Claasson, E.-M., & Martinez, J. (1994). Dollarization and its impact on the economy: Argentina, Bolivia and Uruguay (Working Paper Series 168). Washington, DC: InterAmerican Development Department.

Cohen, B. J. (2004). *The future of money*. Princeton, NJ: Princeton University Press.

Collyns, C., & Kincaid, G. R. (2003). *Managing financial crises: Recent experience and lessons for Latin America*. Washington, DC: International Monetary Fund.

Daniel, L. I. (2001). *Dollarization in Argentina.* Duke University: Duke Journal of Economics.

David, P., Greenstein, S. (1990). The economics of compatibility of standards: A survey. *Economics of Innovation and New Technology, 1*, 3-41.

de Freitas, M. L., & Veiga, F. (2006). Currency substitution, portfolio diversification, and money demand. *Canadian Journal of Economics, 39*, 719-743.

de la Torre, A., E. Levy-Yeyati, & S. Schmuckler (2002). *Argentina's financial crisis: Floating money, sinking banking* (Working Paper). Washington, DC: The World Bank.

de la Torre, A., Levy-Yeyati, E., & Schmukler, S. L., 2003. *Living and dying with hard pegs: The rise and fall of Argentina's currency board* (Policy Research Working Paper Series 2980). Washington, DC: The World Bank.

Dean, J. (2000). Informal dollarization in the Americas: To dollarize or not to dollarize? Currency Alternatives for the Western Hemisphere Conference, Ottawa, Canada, 2000.

Dominguez, K. M. E., & Tesar, L. L. (2004). International borrowing and macroeconomic performance in Argentina. NBER Conference on International Capital Flows, Santa Barbara, California, 2004.

Dornbusch, R., & Reynoso, A. (1989). Financial factors in economic development. *American Economic Association, 79*, 204-209.

Dornbusch, R., & Wolf, H. C. (1990). *Monetary overhang and reforms in the 1940s* (CEPR Discussion Papers 464). Washington, DC: Center for Economic and Policy Research.

Dowd, K., & Greenaway, D. (1993). Currency competition, network externalities and switching costs: Towards an alternative view of optimum currency areas. *Economic Journal, 103*, 1180-1189.

Edmunds, J. C., & Marthinsen, J. E. (2003). Wealth by association: Global prosperity through market unification. Westport, CT: Greenwood Publishing Group.

Eichengreen, B. (2005). *Sterling's past, dollar's future: Historical perspectives on reserve currency competition* (NBER Working Paper, 11336). Cambridge, MA: National Bureau of Economic Research.

Engineer, M. (2000). Currency transaction costs and competing currencies. *Journal of International Economics, 52*, 113-136.

Ezrati, M. (2004). The new U.S.-Asian dollar bloc. *International Economy, 18*, 48-50.

Farrell, J., & Saloner, G. (1985). Standardization, compatibility, and innovation. *Rand Journal of Economics, 16*, 70-83.

Farrell, J., & Saloner, G. (1986). Installed base and compatibility: Innovation, product preannouncement, and predation. *American Economic Review, 76*, 940-955.

Feige, E. L., Faulend, M., Sonje, V., & Sosic, V. (2003). Unofficial dollarization in Latin America: Currency substitution, network externalities, and irreversibility. In D. Salvatore, J. W. Dean, & T. D. Willett (Eds.), *The dollarization debate* (pp. 46-74). Oxford, UK: Oxford University Press.

Friedman, M. (1968). The role of monetary policy. *American Economic Review, 58*, 1.

Friedman, M. (2005). The optimum quantity of money. *The Economics of Deflation, 1*, 3-52. International Library of Critical Writings in Economics series, 189. An Elgar Reference Collection. Published originally in 1969.

Galindo, A., & Leiderman, L. (2005). *Living with dollarization and the route to dedollarization* (RES Working Papers 4397). Washington, DC: InterAmerican Development Bank, Research Department.

Girton, L., & Roper, D. E.. (1981). Theory and implications of currency substitution. *Journal of Money, Credit, and Banking, 13*, 12-30.

Girton, L., & Roper, D. (1976). *Theory and implications of currency substitution* (International Financial Discussion Papers). Washington, DC: Federal Reserve Board.

Girton, L., & Roper, D. (1986). Theory and implications of currency substitution. In B. H. Putnam, & D. S. Bluford (Eds.), *The monetary approach to international adjustment* (pp. 212-235). Westport, CT: Greenwood Publishing Group. Original 1981.

Greene, W. H. (2003). *Econometric analysis*. Upper Saddle River, NJ: Prentice Hall, 2003.

Greenspan, A. (2001). *The Euro as an international currency* (Remarks by Chairman Before the Euro 50 Group Roundtable). Washington, D.C.

Guidotti, P. E., & Rodriguez, C. A. (1991). *Dollarization in Latin America - Gresham's law in reverse?* (IMF Working Papers 91/117). Washington, DC: IMF.

Havrylyshyn, O., & Beddies, C. H. (2003). Dollarisation in the former Soviet Union: From hysteria to hysteresis. *Comparative Economic Studies, 45*, 329-57.

Hayek, F. A. (1978). *Denationalisation of money*, 2nd edition. London: The Institute of Economic Affairs.

Hellwig, C. (2000). *Money, intermediaries, and cash-in-advance constraints* (FMG Discussion Paper 349). London: London School of Economics.

Holmes, P. (1977). Denationalisation of money. *Economic Journal, 87*(346), 391.

InterAmerican Development Bank, (IADB). (2004). *Housing finance in Latin America:* Time *to build a better market ideas for development in the Americas.* InterAmerican Development Bank, Research Department.

Ize, A., & Levy-Yeyati, E. (1998). *Dollarization of financial intermediation: Causes and policy implications* (IMF Working Papers: 98/28). Washington, DC: IMF.

Ize, A., & Powell, A. (2004). *Prudential responses to de facto dollarization* (IMF Working Paper, WP/04/66). Washington, DC: IMF.

Jameson, K. P. (2001). Latin America and the dollar bloc in the twenty-first century: To dollarize or not? *Latin American Politics and Society, 43*, 1-36.

Jameson, K. P. (2003). Dollarization in Latin America: Wave of the future or flight to the past? *Journal of Economic Issues, 37*, 643-665.

Kamin, S. B., & Ericsson, N. R. (1993). *Dollarization in Argentina* (International Finance Discussion Paper No. 460). Washington, DC: Board of Governors of the Federal Reserve System.

Kamin, S. B., & Ericsson, N. R. (2003). Dollarization in post-hyperinflationary Argentina. *Journal of International Money and Finance*, *22*, 185-211.

Kareken, J., & Wallace, N. (1981). On the indeterminacy of equilibrium exchange rates. *The Quarterly Journal of Economics, 96*, 207-222.

Kenen, P. B. (2002). The Euro versus the dollar: Will there be a struggle for dominance? *Journal of Policy Modeling, 24*, 347-355.

Kiyotaki, N., & Wright, R. (1993). A search-theoretic approach to monetary economics. *American Economic Review, 83*, 63.

Krugman, P. (1993). *What do we know about the international monetary system?* Princeton University: Essays in International Finance.

Latin America Research Group, (LARG). (2005). LARG brief: Dollarization in Latin America. Atlanta, GA: FRB.

Levy-Yeyati, E. (2004). *Financial dollarization: Evaluating the consequences*. Latin American Meetings 184, Econometric Society.

Levy-Yeyati, E. (2005). Financial dollarisation: Evaluating the consequences, preliminary. *Economic Policy, 21*(45), 61-118.

Leybourne, S., & Newbold, P. (1999). On the size properties of Phillips-Perron tests. *Journal of* Time *Series Analysis, 20*, 51.

Lucas, R. E. Jr. (1980). Equilibrium in a pure currency economy. *Economic Inquiry, 18*, 203-220.

Lucas, R. E. Jr., & Stokey, N. L. (1987). Money and interest in a cash-in-advance economy. *Econometrica, 55*, 491-515.

Lyons, R. K., & Moore, M. J. (2005). *An information approach to international currencies* (NBER Working Papers 11220). Cambridge, MA: National Bureau of Economic Research.

Matsuyama, K., Kiyotaki, N., & Matsui, A. (1993). Toward a theory of international currency. *The Review of Economic Studies, 60*, 283-307.

McCallum, B. T., & Goodfriend, M. S. (1986). *Theoretical analysis of the demand for money* (Working Paper 86-3). Richmond, VA: Federal Reserve Bank of Richmond.

McKinnon, R. (2000). On the periphery of the international dollar standard: Canada, Latin America, and East Asia. *North American Journal of Economics & Finance, 11*, 105-122.

McKinnon, R. (2002). The Euro versus the dollar: Resolving a historical puzzle. *Journal of Policy Modeling, 24*, 355-360.

McKinnon, R. I. (2001). The problem of dollar encroachment in emerging markets. *Journal of Policy Modeling, 23*, 301-320.

Melvin, M. (1988). The dollarization of Latin America as a market enforced monetary reform: Evidence and implications. *Economic Development and Cultural Change, 36*, 393-397.

Miles, M. (1978). Currency substitution, flexible exchange rates, and monetary independence. *The American Economic Review, 68*, 428-436,

Mundell, R. (2000). Currency areas, volatility and intervention. *Journal of Policy Modeling, 22*, 281-300.

Mundell, R. (2003). Currency areas, exchange rate systems, and international monetary reform. In D. Salvatore, J. W. Dean, & T. D. Willett (Eds.), *The dollarization debate* (pp. 266-282). Oxford, UK: Oxford University Press.

Neanidis, K. C., & Savva, C. S. (2006). *The effects of uncertainty on currency substitution and inflation: Evidence from emerging economies* (Working Paper). University of Manchester, Economic Studies, School of Social Sciences.

Oomes, N. (2003). *Network externalities and dollarization hysteresis: The case of Russia* (IMF Working Papers: 03/96). Washington, DC: International Monetary Fund.

Padoa-Schioppa, T. (2003). The Euro goes east. *Comparative Economic Studies, 45*, 215-231.

Peiers, B., & Wrase, J. M. (1997). *Dollarization hysteresis and network externalities: Theory and evidence from an informal Bolivian credit market* (Working Papers: 97-21). Philadelphia, PA: Federal Reserve Bank of Philadelphia.

Phillips, P. C. B., & Ouliaris, S. (1990). Asymptotic properties of residual based tests for cointegration. *Econometrica, 58,* 165-193.

Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrica, 75*, 2, 335-346.

Portes, R., Ray, H., De Grauwe, P., & Honkapohja, S. (1998). The emergence of the Euro as an international currency. *Economic Policy, 13*, 305-343.

Rennhack, R., & Nozaki, M.. (2006). *Financial dollarization in Latin America* (IMF Working Paper: 06/7). Washington, DC: IMF.

Ritter, A. R. M., & Rowe, N. (2000). *Cuba: From dollarization to Euro-ization?* (Working Paper). Dallas, TX: Federal Reserve Bank of Dallas.

Rogoff, K. (2004). U.S. imbalances and the Euro's outlook. *CATO Journal, 24,* 41-44.

Salvatore, D., Dean, J. W., & Willett, T. (Eds). (2003). *The dollarization debate*. Oxford, UK: Oxford University Press.

Savastano, M. (1996). *Dollarization in Latin America: Recent evidence and some policy issues* (Working Paper). Washington, DC: International Monetary Fund, Research Department.

Schweickert, R., Thiele, R., & Wiebelt, M. (2005). *Macroeconomic and distributional effects of devaluation in a dollarized economy: A CGE analysis for Bolivia, Ibero America Institute for Econ* (Research [IAI] Discussion Papers 120). Ibero-America Institute for Economic Research.

Singh, A., Belaisch, A., Collyns, C., De Masi, P., Krieger, R., Meredith, G., & Rennhack, R. (2005). *Stabilization and reform in Latin America: A macroeconomic perspective on the experience since the early 1990s - Chapter 6: Financial Dollarization in Latin America* (Occasional Paper 238). Washington, DC: IMF.

Snowdon, B., & Vane, H. R. (2005). *Modern macroeconomics: Its origins, development, and current state*. Cheltenham, UK: Edward Elgar.

Sturzenegger, F. (1992). *Inflation and social welfare in a model with endogenous financial adaptation* (NBER Working Paper, 4103). Cambridge, MA: National Bureau of Economic Research.

Sturzenegger, F. (1997). Understanding the welfare implications of currency substitution. *Journal of Economic Dynamics and Control, 21*, 391-416.

Svensson, L. O. (1985). Money and asset prices in a cash-in-advance economy. *Journal of Political Economy, 93*, 919.

Tobin, J. (1952). Asset holdings and spending decisions. *The American Economic Review, 42,* 109-123.

Tobin, J. (1956). The interest-elasticity of transactions demand for cash. *Economics and Statistics, 38*, 241-247.

Tobin, J. (1958). Liquidity preference as behavior towards risk. *Economic Studies, 25,* 65-86.

Tobin, J. (1963). *Commercial banks as creators of 'money'* (Cowles Foundation Discussion Papers: 159). New Haven, CT: Cowles Foundation, Yale University.

Uribe, M. (1997). Hysteresis in a simple model of currency substitution. *Journal of Monetary Economics, 40,* 185-202.

Velde, F. R., & Veracierto, M. (2000). *Dollarization in Argentina: Economic perspectives* (Working Paper). Chicago, IL: Federal Reserve Bank of Chicago.

von Furstenberg, G. (2000). A case against U.S. dollarization. *Challenge, 43*, 108-120.

von Furstenberg, G. (2001). Pressures for currency consolidation in insurance and finance. *Journal of Policy Modeling, 23*, 321-332.