Currency Crises and Bank Panics

by

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I. Introduction

Recent events in Mexico, Argentina, and the ERM suggest that there are important links between a country's exchange rate regime and its ability to maintain domestic financial sector liquidity. In particular, the 1994-1995 currency crisis in Mexico - abandonment of the exchange rate peg against the US dollar in December 1994 and subsequent run on peso denominated assets in international financial markets - has been accompanied throughout 1995 by domestic financial sector instability. Consequently, the Mexican monetary authorities are currently bailing out domestic banks facing both illiquidity and insolvency as private sector bad debt levels and default incidence rise.

In addition, it has been widely argued that by sterilizing reserve losses with debt monetization throughout 1994, the Mexican monetary authorities increased the likelihood of a currency crisis by preventing interest-rate increases that could induce renewed capital inflows. In addition, this provided liquidity to the domestic private sector that admitted continued current account deterioration and real domestic currency appreciation. Yet sterilization is commonly defended as necessary to promote stability in the domestic financial sector under a fixed exchange rate regime and, in this case, in face of large-scale peso asset sales worldwide. Sterilization, it is argued, was needed to prevent domestic bank runs on peso denominated assets - to maintain domestic financial stability.

More generally, there is now a substantial body of empirical evidence that currency crises are frequently accompanied by domestic banking crises. As Kaminsky and Reinhart (1995) document, the breakdown of a fixed exchange rate regime following reserve losses that prevent continued support of the target currency value (or band of values) has been preceded by or coincident with a severe and persistent banking crisis in about half of all recorded cases during the last two decades. While these authors find little evidence to support the hypothesis (see Stoker (1995) for example) that currency crises cause domestic bank panic, they argue that currency crises aggravate domestic banking sector liquidity or solvency problems that are evident prior to the collapse of the exchange rate regime.

Recent observations, then, suggest there may be bi-directional causality between external and internal liquidity crises, yet little can be inferred from the data concerning the nature of this relationship in the absence of a formal analytic framework.

In this paper I develop a preliminary version of a model that is designed to address these issues. Was sterilization of reserve losses in Mexico during 1994 an important policy error or essential to maintaining domestic liquidity? Could non-sterilized intervention have prevented the currency crisis and/or the domestic banking crisis? In the framework that I present here, only non-sterilized/unhindered intervention is consistent with a general equilibrium in which the domestic banking sector is always liquid. In addition, if there exists a general equilibrium for the economy in which the domestic authority limits the degree of exchange intervention, it will be one in which banks face illiquidity/panic conditions, and in which the likelihood of currency crisis is increased relative to a situation in which exchange intervention is unregulated. Finally, any attempt by the monetary autority to target the growth rate of its money supply is inconsistent with a general equilibrium in which foreign exchange intervention is freely conducted and the nominal exchange rate is fixed.

Below, I attempt to characterize and analyze systematically the relationship between domestic financial sector liquidity and the maintenence of a fixed exchange rate regime in a dynamic, two-country, two-currency, two-good general equilibrium model. In particular, I analyze conditions under which a (small) country can sustain a one-sided pegged exchange rate when that country is subject to random shocks to the demand for its assets in international markets - shocks which implicate private banks' asset portfolio allocation and liquidation policies. I also explore conditions under which the maintenance of a pegged exchange rate is inconsistent with domestic financial sector liquidity.

In each country there is a government that issues fiat curency and interes- bearing, long-term debt that are internationally traded. In addition, the domestic government determines a fixed value for the relative nominal price of its currency and maintains this by conducting foreign exchange intervention. The foreign country government sets its money growth rate independently of the peg, and conducts no foreign exchange intervention.

Private banks in both countries arise to intermediate savings within their home country, and hold asset portfolios comprising both currencies and the long-term bonds of each country's government in order to meet random (aggregate) demands for alternative currencies, and for liquid vs. illiquid assets.

These random portfolio demands derive ultimately from aggregate shocks to agents' preferences over domestic and foreign goods, and from individual shocks to preferences over the timing of this consumption. Since currency is always required in advance of goods market purchases, these preference shocks reflect in both individual uncertainty over liquid (currencies) and illiquid (bonds) assets, and in both individual and aggregate uncertainty over alternative currencies. This feature of the model is intended to capture the idea that in Mexico, while long-term, direct investment has been relatively stable, dramatic movements in short-term, portfolio investment appear to have produced the currency crisis and banking sector instability.

The results that I obtain in this environment are as follows. When the domestic monetary authority conducts a policy of completely accomodative non-sterilized foreign exchange intervention in order to maintain its exchange rate peg, banks' optimal portfolio allocation policies prevent the occurence of financial sector panic. Banks are always able to completely insure agents against aggregate uncertainty of liquid asset portfolio preferences, so that returns to deposits backed by alternative currencies are always equalized.

Domestic and foreign bank "panics" typically will arise, however, whenever the monetary authority limits the degree of exchange intervention. These panics are characterized by banks systematically setting returns to deposits backed by alternative currencies differentially in order to meet its obligations to depositors. The return differential is determined by the relative demands for the two curencies, and causes premia and discounts to the two currencies to arise relative to deposit returns backed by those currencies. In addition, it is also possible that deposits backed by a low-return currency pay a return at as high as deposits backed by high return bonds. In short, premia to liquid deposits can arise reflecting the constraints placed on banks' allocation of liquidity by government regulation of foreign exchange intervention.

I define a currency crisis as a situation in which the domestic government's foreign exchange reserve reaches a level that is inconsistent with meeting the maximum possible demand for foreign exchange in the following period. This reserve level I allow to be endogenously determined and is generally time-varying.

Currency crises occur when the initial endowed world supply of liquidity (both currencies) and its cumulative growth - as determined by domestic foreign exchange intervention and the foreign country's exogenous money growth rate policy - fall below the cumulative world demand for liquidity. This is more likely to occur, for given stochastic realizations of demands for alternative currencies, the higher is the world demand for all liquid assets (which is deterministic), the lower is the foreign country's money growth rate, and the higher is the domestic country's chosen fixed value for its currency. It will clearly be more likely the less is the degree of accomodation of demands for liquidity by the domestic government through its foreign exchange intervention.

Finally, if the domestic monetary authority attempts to target the rate of growth of its money supply, there is no equilibrium in which the nominal exchange rate target can be sustained through foreign exchange intervention. While this does not correspond exactly to a policy rule of "sterilizing" reserve losses, it captures the general idea that when foreign exchange intervention is freely conducted to maintain a target exchange rate the policy authority must allow the growth of the other assets that it issues to be endogenously determined.

In the next section I describe a two-country, two-currency, two-good economy and in Section

III I show how the government issued currency and interest-bearing nominal debt of both countries are held in the asset portfolios of private sector, profit maximizing banks. Section IV presents conditions under which a general equilibrium obtains when the domestic country government executes a one-sided nominal exchange rate peg, and presents conditions under which the peg is no longer sustainable. Section V concludes.

II. The Environment

I consider a two-country, two currency overlapping generations economy in which a single, non-storable good is exogenously produced by each country. Infinitely lived national governments issue fiat currency and can hold reserves of the other country's money. In addition, the government of each country can issue interest bearing debt denominated in the currency of that country. [1]

I assume that the domestic country elects to fix the nominal exchange rate of its currency taking government policy in the foreign country as given. In general, as will be seen below, the domestic government must therefore be willing to buy and sell foreign exchange to private sector agents at the pre-determined exchange rate. While this is a two-country model, so that rates of return and prices are endogenously determined for both countries, the domestic country is "small" relative to the foreign country in the sense that the foreign country's monetary policy is conducted independently of the prevailing exchange rate regime.

The economy is inhabited by an infinite sequence of two-period lived overlapping generations, and at each date, t=1,2,..., a continuum of two-period lived young agents with unit mass is born in each country. In addition, at date t=1 a continuum of old agents resides in each country. Time, obviously, is discreet and is indexed by t=1,2,...

Within each country, all young agents are ex ante identical. However I allow for heterogeneity across countries, as I describe below. In addition, there are two sources of uncertainty in the economy; individual liquidity shocks which determine the aggregate desired allocation of savings in liquid vs. illiquid assets in each country, and also aggregate uncertainty regarding the desired portfolio allocation of savings in alternative liquid assets. These sources of uncertainty introduce ex post heterogeneity of agents within countries, induce a role for financial intermediaries that provide insurance against individual liquidity shocks, and motivate foreign exchange transactions between financial intermediaries and the government that can mitigate the effects of aggregate portfolio preference shocks.

[1] The general environment described here is similar in some respects to that developed in Betts and Smith (1995) and Champ, Smith and Williamson (1995).

A. Individual Agents

Let $i = d, f$ index domestic and foreign country variables respectively.

At the beginning of each date t=1,2,..., a continuum of young agents with unit mass is assigned to each country. Each young agent is endowed with y^i units of the good exogneously produced in their country of residence. The goods produced are differentiated across countries, non-storable, and can be traded costlessly by individual agents across national borders. Young agents have no other endowments of goods or assets at any date. A member of the initial old generation in each country is endowed with the inherited per capita stock of that country's money which is exogenously given by M_0^i.

For simplicity, I assume that agents care only about old age consumption and, ex ante, want to consume both home and foreign goods at that time. In particular, denoting by c^i per capita old-age consumption of the ith country's good in resident country good units, the utility function of a young resident of country i is

$$U^i(c) = \psi ln(c^d) + (1 - \psi) ln(c^f); \tag{1}$$

When young, agents therefore seek to sell their endowment of the home country's good and save the proceeds in the form of some stores of value, which are used in old age to purchase goods from the following generation in each country. These stores of value are as follows.

B. Assets

The first type of asset available to young agents is domestic and foreign currency, the per capita outstanding stocks at date t of which are denoted by M_t^i, and which are costlessly produced by the domestic and foreign government respectively. Denote by $m_t^i = M_t^i / p_t^i$ the real value of each country's currency in units of that country's good, where p_t^i is the price of the ith country's good in currency i units. Each unit of currency held between dates t and $t+1$ obviously earns the real gross rate of return of p_t^i / p_{t+1}^i. Currencies can be freely traded by young agents in the foreign exchange market.

In addition, agents can hold government-issued nominal interest-bearing debt of either country. The nominal, foreign currency value of outstanding foreign country bonds is denoted by B_t^f and the domestic currency value of outstanding domestic country government debt is given by B_t^d. Government debt can be freely traded by young agents in international bond markets, and government i pays a gross nominal interest rate on its debt of $I_t^i > 1$ units of the ith currency. The real gross rate of return on government debt for a resident of that government's country is then simply

$R^i_{i_t} = I^i_t(p^i_t/p^i_{t+1})$. Evidently, each currency is strictly dominated in rate of return by the bonds of that country (and, in equilibrium, by all bonds).

Finally, x_t is the real exchange rate of the domestic country. In other words, $x_t = \bar{e}p^f_t/p^d_t$, where $\bar{e}$ is the predetermined domestic currency price of a unit of foreign currency. Thus, the domestic goods value of a unit of foreign currency is $m^f_t x_t$ and of foreign bonds $b^f_t x_t$.

Young agents save the value of their endowment in the form of domestic and foreign real balances, and domestic and foreign government debt. The allocation of young agents' portfolios among these assets depends on their relative real rates of return, and their liquidity as is now described.

C. Trade

By convention, all goods market purchases must be conducted in the currency of the seller. In other words, there are currency-specific cash in advance constraints on all goods market transactions. In general, currency can either be held directly to satisfy these constraints, or nominal bond returns can be offered for goods. These constraints mean that domestic (foreign) young agents accept and receive only domestic (foreign) currency in exchange for their endowment, and then save the proceeds by adopting a portfolio allocation which is achieved by transacting in foreign exchange and world bond markets. How is this portfolio allocation determined?

First, I assume that currency has liquidity chracteristics that dominate those of bonds. In particular, bonds take time to mature and cannot be liquidated prior to maturity except at a (prohibitive) loss. The possibility of incurring this loss - which can be thought of as the outcome of real transactions costs incurred in asset market trading - is reflected simply in the timing of transactions (access to markets) in the economy. Asset - bond and currency - market transactions can be conducted only twice in an agent's lifetime; once when a young agent's entire endowment is allocated to alternative assets during initial portfolio trades, and again when bonds mature and bond income is received. Asset markets therefore open only once per period, during which time all agents have equal access to the market and trades are conducted without cost.

Thus, bond income can be used in goods market transactions following the maturation of these assets while currency held between periods can be used at any time to achieve consumption. Although governments offer positive net nominal returns on bonds, currency may still be valued for its liquidity. In the absence of some particular preference for "liquidity", however, only government bonds would be held as stores of value.

In fact, I assume that at the end of any date t, young agents face an exogenously given, known probability π^i of wanting to execute old age consumption prior to the maturation of bonds. This probability is constant over time and iid across agents within a country, and so while there is individual uncertainty no aggregate randomness results. This source of uncertainty is intended to reflect an aggregate distribution of world investors between those who are willing to accept long-term government projects, and those who demand that their portfolios be liquid.

If an agent turns out to be a π^i type, he would like to liquidate bonds and hold currency alone since bond income has no value in consumption. However, since bond liquidation is (prohibitively) costly, ex ante all young agents may wish to hold some fraction of their portfolio in the form of domestic and foreign currency to ensure that liquidity is available in accomplishing consumption. The convention that appropriate currency units be offered in advance of goods market purchases, and the fact that individual agents face prohibitive costs of continuous currency trades, mean that portfolio allocations designated to alternative currencies depend not on relative rates of return to those currencies (inflation rates) but on expected future consumption preferences.

In addition, young π^i agents who turn out to be "liquidity lovers" face a second source of risk. In each country, π^i agents face a probability δ_t^i, realized at the end of date t, that they want to consume only domestic country goods when old and a probability $(1 - \delta_t^i)$ that they consume only foreign goods at $t + 1$. [2] This probability is itself a random variable drawn from the time invariant probability distribution $F(.)$. This distribution function has associated continuously differentiable density function f. The probability and density functions are known by all young agents ex ante, and identical for agents within and across countries.

This shock represents a portfolio preference shock for investors who prefer to save through liquid rather than illiquid assets. In effect, short-term portfolio investments are subject to exogenous randomness that does not affect long-term investment decisions, randomness that is intended to reflect unpredictable changes in international investors' preferences over different countries' goods or currencies. In effect, this aggregate randomness represents shocks to ψ in the utility function (1).

In view of these sources of randomness, young agents allocate their portfolios among all assets in the economy consistently with expected future liquidity preferences and with expected future consumption preferences over domestic and foreign goods. Asset markets then close. Following the resolution of individual and aggregate uncertainty at the end of date t, old agents who prefer liquidity enter date $t + 1$ and use their accumulated real domestic and foreign money balances to purchase goods and consume, while $(1 - \pi^i)$ agents wait until they receive their bond income, trade

[2] It would complicate but not substantively alter the analysis - or results - to allow some of these agents to consume both types of goods at $t + 1$.

in nominal returns if necessary, and then purchase goods.

D. Financial Intermediaries

In general, the presence of individual uncertainty concerning future liquidity preferences induces a role for financial institutions that are large enough to diversify away individual risk in their asset portfolios and so can insure individual agents against liquidity preference shocks (see Greenwood and Smith (1993)). Such intermediaries achieve this insurance by accepting the deposits of young agents, paying state contingent deposit returns that are conditional on realizations of liquidity and consumption preferences, and holding asset portfolios comprising both types of currency as well as the bonds of both countries.

In the presence of free entry into banking, all such financial institutions choose state contingent deposit return schedules to maximize the expected utility of a young agent. In the presence of individual uncertainty about future liquidity needs, all savings will be intermediated. Consequently, I consider below only situations in which some banks arise in each country and all savings are intermediated through these banks.

Here, I allow "large" financial institutions to play an additional role; they can help reduce the impact of aggregate uncertainty over consumption preferences by transacting on behalf of young agents with the domestic government. In particular, I allow financial intermediaries to buy and sell foreign exchange at the price $\bar{e}$ units of domestic currency per unit of foreign currency at the end of date t following the revelation of π^i and δ^i by contacting the domestic government. By doing so, they are able to reallocate their portfolios to better satisfy the stochastic currency (consumption) preferences of young agents.

In effect, financial intermediaries arise in each country that specialize in mitigating both liquidity and portfolio preference shocks. Intermediation between individuals and the domestic government through the "foreign exchange desk" is not necessary to motivate banks arising, however.

E. Governments

Each government issues national fiat currency each period, M^i, can hold reserves of the other country's money, and can issue interest bearing net liabilities denominated in its own currency. At the beginning of date 1, the domestic government announces that the relative nominal price of the domestic currency is to be fixed at $\bar{e}$ units of domestic currency per unit of foreign currency.

The initial old generation in each country is endowed with the national stocks of currency $M_0^i > 0$ and initial foreign exchange reserves and debt levels are zero. Let these be denoted by F_0^i and B_0^i respectively in units of the ith country's currency. From this date onwards, currencies and interest-bearing government liabilities flow across national borders as young agents (or banks on behalf of young agents) select their asset portfolios.

I assume that the governments conduct policy in the following manner. At date 1, the foreign government issues currency and bonds, and assumes some initial (possibly zero) domestic currency reserve which it maintains forever without conducting further foreign exchange transactions. Thereafter, it sets a constant, once and for all growth rate for the world supply of foreign currency

$$\frac{M_{t+1}^f}{M_t^f} = \sigma^f \forall t \geq 1. \tag{2}$$

At date 1, the foreign country's government budget constraint is therefore

$$M_1^f + B_1^f = M_0^f + (1/\bar{e})F_1^f \tag{3}$$

where F_1^f is the net domestic currency position assumed by the foreign government at the end of date 1, and is endogenously determined as described below. As will become clear, this reflects the net world supply of domestic currency for redemption in foreign exchange units by banks in both countries.

After the initial period, this government faces the budget constraint

$$\begin{aligned} M_t^f + B_t^f &= M_{t-1}^f + I_{t-1}^f B_{t-1}^f + (1/\bar{e})(F_t^f - F_{t-1}^f) \\ &= M_{t-1}^f + I_{t-1}^f B_{t-1}^f \quad \forall t \geq 2 \end{aligned} \tag{4}$$

which, noting that $p_{t-1}^i/p_t^i = (m_t^i/m_{t-1}^i)(M_{t-1}^i/M_t^i) = (m_t^i/m_{t-1}^i)(1/\sigma^i)$, can be reexpressed as

$$m_t^f \left(\frac{\sigma^f - 1}{\sigma^f}\right) + b_t^f = b_{t-1}^f R_{f_{t-1}}^f. \tag{5}$$

Notably, the foreign government never conducts foreign exchange transactions with any other agent after date 1, and simply supplies $M_t^f = \sigma^{f^{t-1}} M_1^f$ in date t currency markets.

By contrast, the domestic government meets (excess) private sector demand for foreign currency at all dates t=1,2... subject to the foreign government's chosen money growth rate. Specifically, foreign exchange transactions are conducted between the domestic government and private sector banks in both countries at the end of each date to maintain the predetermined exchange rate. At date 1 the domestic government faces the following constraint;

$$M_1^d + B_1^d = M_0^d + \bar{e}F_1^d \tag{6}$$

and so assumes an endogenously determined net foreign exchange position at the end of date 1 of F_1^d. This position reflects (excess) private demand for domestic currency at date 1.

No generality is lost by assuming that only the domestic government actually conducts exchange transactions with the private sector banks of both countries at all dates t=1,2,..., and that at date 1 the foreign government simply agrees to accomodate the domestic government's net demand for foreign exchange. The determination of this demand is discussed in Section IV.

At all future dates t=2,...the following budget constraint must be met by the domestic country government;

$$M_t^d + B_t^d = M_{t-1}^d + I_{t-1}^d B_{t-1}^d + \bar{e}(F_t^d - F_{t-1}^d) \forall t \geq 2 \tag{7}$$

which, denoting the domestic country's money growth rate between t-1 and t as $\sigma_t^d = M_t^d / M_{t-1}^d$ for $t = 1, ...,$ can be reexpressed as

$$m_t^d \left(\frac{\sigma_t^d - 1}{\sigma_t^d} \right) + b_t^d = b_{t-1}^d R_{d_{t-1}}^d + (\bar{e}/p_t^d)(F_t^d - F_{t-1}^d) \tag{8}$$

As becomes clear below, σ_t^d must be endogenous if the domestic government is to maintain $\bar{e}$ and meet private demands for alternative currencies at this price. When the relative world demand for domestic goods - and so currency - is high, the domestic government's reserves rise through sales of new domestic currency at the price $1/\bar{e}$. In periods when this relative demand is low, reserves will fall as the government supplies foreign exchange to meet private banks' demand, and this tends to reduce the outstanding stock of domestic currency in the hands of the public. In each case, σ_t^d is adjusted to meet the government's budget constraint given the reserve movement.

Thus, the exchange rate peg is one-sided, with the domestic country required at each date t=1,2...to maintain $\bar{e}$ through domestic policy. At date t=1 only do the two governments co-operate to establish the necessary reserve positions for establishment of the fixed nominal exchange rate regime. The domestic government's foreign exchange reserve then evolves according to fluctuations in private sector relative demands for domestic and foreign goods and so currencies.

Finally, I assume that at a critical lower value of $F_{t-1}^d = \underline{F}_{t-1}^d > 0$, which need not be constant, the domestic government can no longer commit to meeting the maximum possible date t demand for foreign exchange. I allow this lower bound on reserves is determined endogenously at any date t. I call the realization of this critical value a "currency crisis", and assume that foreign exchange intervention by the domestic government is suspended at date t, with e_t being freely determined by market forces, or that at t $\bar{e}$ is raised.

III. The Behaviour of Financial Intermediaries

A. Unregulated Foreign Exchange Intervention

At each date, t, there are in each country some banks that behave competitively in the sense that they take asset returns - interest rates and inflation rates - as given. Each financial intermediary is large enough to face a positive measure of potential depositors. On the deposit side, banks act as Nash competitors announcing state contingent deposit returns as a function of realizations of π^i and δ^i. Since there is free entry into banking, these institutions maximize the expected utility of a young agent subject to a number of balance sheet and budget constraints.

In particular, a financial intermediary must satisfy the following balance sheet constraint when it accepts deposits and enters asset markets to establish a portfolio at t:

$$y^d \geq m^d_{d_t} + x_t m^f_{d_t} + b^d_{d_t} + x_t b^f_{d_t}. \tag{9}$$

Since all savings are intermediated, y^d is simply per capita deposits, $m^d_{d_t}$ denotes the bank's per capita portfolio holding of domestic real balances, $x_t m^f_{d_t}$ the domestic goods value of the bank's per capita foreign exchange portfolio holding, $b^d_{d_t}$ the value of per capita domestic bond holdings, and $x_t b^f_{d_t}$ the domestic goods value of per capita foreign bonds.

In addition, each domestic bank must satisfy some budget constraints. At any date t, π^d of all depositors will want to hold only currency following the realization of consumption preferences. Of these, a fraction δ^d_t value only domestic currency while the remaining $1 - \delta^d_t$ value only foreign exchange. These depositors must be paid at the beginning of t+1 from the bank's holdings of domestic and foreign real balances respectively. By contrast, $(1 - \pi^d)$ of depositors can wait until nominal bond returns are realized before withdrawing their deposit returns. Since bond returns dominate those of currency, banks hold currency of either type in their intial portfolio only to satisfy the needs of agents that require liquidity in consumption.

Banks cannot perfectly predict δ^d_t, and any initial portfolio allocation assigned to domestic and foreign currency may be altered only through foreign exchange transactions conducted with the domestic government. In particular, they cannot liquidate long-term government loans in order to help pay depositors that require currency, nor can they conduct further international currency transactions at the end of date t.

When the domestic government commits to buying and selling foreign exchange freely in order to maintain $\bar{e}$, banks can use excess domestic (foreign) currency following the realization of portfolio preferences to purchase additional foreign (domestic) currency from the domestic government. In this case, the bank's budget constraints are as follows.

Let $\alpha^d_{d_t}(\delta^d)$ denote the (state contingent) fraction of domestic currency initially held by the bank - $m^d_{d_t}$ - actually paid out to depositors that require domestic currency at t+1, while $\alpha^d_{f_t}(\delta^d)$ denotes the fraction of $m^f_{d_t}x_t$ paid to depositors requiring foreign currency at t+1.

In addition, let $\beta^d_{d_t}(\delta^d)$ denote the fraction of excess foreign currency $((1-\alpha^d_{f_t})m^f_{d_t})$ held that is used to purchase additional domestic currency from the domestic government at the end of date t, while $1-\beta^d_{d_t}(\delta^d)$ of this excess foreign exchange is paid to the $1-\pi^d$ agents that require no liquidity, but who can use either currency to obtain consumption at $t+1$. Let $\beta^d_{f_t}(\delta^d)$ and $1-\beta^f_{d_t}(\delta^d)$ denote the analagous fractions of excess domestic currency held by the bank.

Finally, let $r^d_{d_t}(\delta^d)$, $r^d_{f_t}(\delta^d)$ and $r^d_t(\delta^d)$ denote the gross real rates of return between t and t+1 - expressed in domestic goods - guaranteed to agents that use only domestic currency, only foreign currency, and liquid or illiquid asset returns in second period consumption respectively.

Then, a domestic bank faces the following budget constraints at t:

$$\pi^d\delta^d_t y^d r^d_{d_t}(\delta^d) \leq \left[\alpha^d_{d_t}(\delta^d)m^d_{d_t} + \beta^d_{d_t}(\delta^d)(1-\alpha^d_{f_t}(\delta^d))m^f_{d_t}x_t\right]p^d_t/p^d_{t+1} \quad (10)$$

$$\pi^d(1-\delta^d_t)y^d r^d_{f_t}(\delta^d) \leq \left[\alpha^d_{f_t}(\delta^d)m^f_{d_t}x_t + \beta^d_{f_t}(\delta^d)(1-\alpha^d_{d_t}(\delta^d))m^d_{d_t}\right]p^d_t/p^d_{t+1} \quad (11)$$

and

$$(1-\pi^d)y^d r^d_t(\delta^d) \leq b^d_{d_t}R^d_{d_t} + b^f_{d_t}x_t R^d_{f_t} + \left[(1-\beta^d_{d_t})(1-\alpha^d_{f_t})m^f_{d_t}x_t + (1-\beta^d_{f_t})(1-\alpha^d_{d_t})m^d_{d_t}\right]\left(\frac{p^d_t}{p^d_{t+1}}\right) \quad (12)$$

where $R^f_{d_t}$ is the domestic value of the gross real rate of return to foreign bonds, or $R^f_{d_t} = R^f_{f_t}(x_{t+1}/x_t)$.

Noting that, for both domestic and foreign bonds to be held in equilibrium, $R^d_{f_t} = R^d_{d_t} \Rightarrow R^d_{d_t} = R^f_{f_t}(x_{t+1}/x_t) \Rightarrow I^d_t = I^f_t$, and letting $\gamma^d_{d_t} = m^d_{d_t}/y^d$ denote the portfolio weight assigned to domestic currency by the bank as a fraction of total per capita deposits and $\gamma^d_{f_t}m^f_{d_t}x_t/y^d$ denote the portfolio weight assigned to foreign exchange, then constraints (9) to (12) can be reexpressed as

$$\pi^d\delta^d_t r^d_{d_t}(\delta^d) \leq \left[\alpha^d_{d_t}(\delta^d)\gamma^d_{d_t} + \beta^d_{d_t}(\delta^d)(1-\alpha^d_{f_t}(\delta^d))\gamma^d_{f_t}\right]p^d_t/p^d_{t+1} \quad (13)$$

$$\pi^d(1-\delta^d_t)r^d_{f_t}(\delta^d) \leq \left[\alpha^d_{f_t}(\delta^d)\gamma^d_{f_t} + \beta^d_{f_t}(\delta^d)(1-\alpha^d_{d_t}(\delta^d))\gamma^d_{d_t}\right]p^d_t/p^d_{t+1} \quad (14)$$

and

$$(1-\pi^d)r^d_t(\delta^d) \leq (1-\gamma^d_{d_t}-\gamma^d_{f_t})R^d_{d_t} + \left[(1-\beta^d_{d_t})(1-\alpha^d_{f_t})\gamma^d_{f_t} + (1-\beta^d_{f_t})(1-\alpha^d_{d_t})\gamma^d_{d_t}\right]\left(\frac{p^d_t}{p^d_{t+1}}\right). \quad (15)$$

Banks choose $r^d_{d_t}(\delta^d), r^d_{f_t}(\delta^d), r^d_t(\delta^d), \gamma^d_{d_t}, \gamma^d_{f_t}, \alpha^d_{d_t}(\delta^d), \alpha^d_{f_t}(\delta^d), \beta^d_{d_t}(\delta^d)$ and $\beta^d_{f_t}(\delta^d)$ to maximize the expected utility of a young agent

$$E(U) = \pi^d \left[\int_0^1 \delta^d ln(r^d_{d_t}(\delta^d)y^d)f(\delta)d\delta + \int_0^1(1-\delta^d)ln(r^d_{f_t}(\delta^d)y^d)f(\delta)d\delta\right] + (1-\pi^d)ln(r^d_t(\delta^d)y^d)$$

subject to (13)-(15) and $0 \leq \gamma^d_{d_t} \leq 1, 0 \leq \gamma^d_{f_t} \leq 1, 0 \leq \alpha^d_d \leq 1, 0 \leq \alpha^d_{f_t}(\delta^d) \leq 1, 0 \leq \beta^d_{d_t}(\delta^d) \leq 1$ and $\beta^d_{f_t}(\delta^d) \leq 1$. Each saver then deposits at a bank which maximizes his expected utility through its announced return schedule.

The solution to this problem satisfies $\gamma^d_{d_t} + \gamma^d_{f_t} = \pi^d$, sets $\beta^d_{d_t}(\delta^d) = \beta^d_{f_t}(\delta^d) = 1, 0 < \alpha^d_{d_t}(\delta^d) < 1$, $0 < \alpha^d_{f_t}(\delta^d) < 1$, and $r^d_{d_t}(\delta^d) = r^d_{f_t}(\delta^d) = p^d_t/p^d_{t+1} < r^d_t(\delta^d) = R^d_{d_t}$. The composition of currencies in the initial portfolio is always indeterminate from the standpoint of any individual bank, as are the schedules $\alpha^d_{d_t}(\delta^d)$ and $\alpha^d_{f_t}(\delta^d)$. Exactly symmetric solutions apply to the (symmetric) problem of foreign banks.

Notably, while individual portfolio weight are indeterminate for each bank, the total amount of circulating media of either type of currency within each country and the world economy is always determined by the banks' budget constraints.

B. Remarks

I define a "bank panic" as an event in which banks are unable to meet payments to depositors while maintaining equal returns to domestic and foreign currency backed deposits which actually earn equal rates of return. Similarly to the panics studied by Champ, Smith and Williamson (1995), this event results in premia and discounts arising to alternative deposits relative to the return on the asset (currency) that backs them and, therefore, causes divergence in the return differentials between deposits backed by each currency and those backed by interest-bearing bonds.

It is clear that such events never occur as long as the domestic government freely trades in domestic and foreign currency to maintain $\bar{e}$. Equivalently, bank panics cannot occur when $\beta^d_{d_t}(\delta^d)$ and $\beta^d_{f_t}(\delta^d)$ are schedules of state contingent payments that are freely chosen by the bank. There is nothing *inherent* in a fixed exchange rate regime of the type studied here that produces a conflict between maintenance of domestic liquidity - either in total, or in a particular currency - and maintaining the exchange rate peg when foreign exchange intervention allows banks to freely trade in currencies such as to optimally allocate their asset portfolios.

Of course, this assumes that all private agents and the policy authority expect the regime to be maintained at all dates. In fact, there are clearly circumstances under which banks cannot freely choose the schedules $\beta^i_{i_t}(\delta^i)$ and $\beta^i_{j_t}(\delta^i), i, j = d, f$. In particular, the banks' decision problem

changes substantially in the event that the domestic government is no longer able to guarantee foreign exchange payments - when $F_{t-1}^d \leq \underline{F}_{t-1}^d$. In this event, suspension of all foreign exchange intervention and market determination of e_t is one alternative policy regime. Raising $\bar{e}$ at t is another.

In addition, banks need not in general anticipate continuation of the regime if the foreign exchange reserve of the domestic government is known to be low. Equilibria in which banks' expectations of the future course of e_t do not accord with $e_t = \bar{e}$ and of the degree to which they cannot determine their schedules $\beta_{i_t}^i(\delta^i)$ and $\beta_{j_t}^i(\delta^i), i, j = d, f$ are a topic for future study.

Finally, it is worth noting that any regime in which the government regulates foreign exchange intervention by setting (maximum) values for schedules $\beta_{i_t}^i(\delta^i)$ and $\beta_{j_t}^i(\delta^i), i, j = d, f$ can potentially produce bank panics as defined above. (Many of these will be inconsistent with general equilibrium, however.)

For example, suppose that domestic banks face $\beta_{d_t}^d \equiv \bar{\beta}_d^d < 1 \forall t$, and $\beta_{f_t}^d \equiv \bar{\beta}_f^d < 1 \forall t$. Then when the relative demand for one currency is sufficiently high, they set the return to the relevant deposit lower than that to the less favoured currency. All initial private reserves of the high demand currency are exhausted, and the bank conducts additional exchange transactions with the government to enhance these reserves.

Then, in the event that δ_t^d is low, the bank sets $\alpha_{f_t}^d(\delta^d) = 1, 0 < \alpha_{d_t}^d(\delta^d) < 1$, and $r_{d_t}^d(\delta^d) > r_{f_t}^d(\delta^d)$ holds. Whether the bank continues to set $r_t^d > max(r_{d_t}^d, r_{f_t}^d)$ depends on the value of the nominal interest rate on government bonds. In such a case, then, deposits backed by domestic currency earn a premium relative to the currency that backs them and to foreign currency backed deposits. In addition, when the nominal interest rate on government bonds is low enough, it is possible that the return to deposits backed domestic currency will equal that of deposits backed by bonds. Thus, liquidity premia and discounts can also emerge in this case.

This example corresponds to what one might think of as a bank panic. It is driven by the fact that banks cannot meet demands for alternative currencies at equal returns when governments regulate official reserve transactions by restricting private access to additional domestic and foreign currency. Thus, domestic financial sector "illiquidity" and panic obtain under a fixed exchange rate regime only when official reserve transactions do not fully accomodate private sector demands.

IV. General Equilibrium

For the economy to attain general equilibrium, the following conditions must obtain when $F^d_{t-1} > \underline{F}^d_{t-1}$.

First, the two money markets must clear. The foreign government conducts all policy through date t asset markets, at which time banks select their initial portfolio allocations in domestic and foreign currency. Thus, at date t, the real supply of foreign currency by the foreign government must satisfy

$$m^f_t = \gamma^d_{f_t} y^d / x_t + \gamma^f_{f_t} y^f \tag{16}$$

The domestic government injects domestic currency both in date t asset markets and during subsequent foreign exchange intervention if necessary. Thus, the domestic money market clearing condition is

$$m^d_t = \delta^d_t \pi^d y^d + \delta^f_t \pi^f y^f x_t \tag{17}$$

- the domestic government always meets demand for its currency at the foreign currency price $1/\bar{e}$, as long as $1/e_t = 1/\bar{e}$.

In addition, the domestic government supplies foreign currency to private banks that demand it at the price $\bar{e}$ until $F^d_{t-1} = \underline{F}^d_{t-1}$. As long as F^d satisfies this condition, the evolution of the domestic government's foreign exchange reserve is given by

$$\frac{F^d_t - F^d_{t-1}}{p^f_t} = m^f_t - (1 - \delta^d_t)\pi^d y^d / x_t - (1 - \delta^f_t)\pi^f y^f, \tag{18}$$

and is zero otherwise.

In addition, a world bond market clearing condition must hold. Since banks are indifferent between the bonds of the two governments in equilibrium, the world demand and supply of bonds must be equated, or

$$b^d_t + x_t b^f_t = (1 - \pi^d) y^d + (1 - \pi^f) y^f x_t \tag{19}$$

Two goods market clearing conditions also obtain at each date t in general equilibrium. The supply of domestic goods is simply y^d, per capita, while the per capita demand for these goods at t derives from old bond-income recipients in the two countries - $\psi\left((1-\pi^d)y^d + (1-\pi^f)y^f xt\right) R^d_{d_{t-1}}$ - and the real income of holders of domestic currency at the beginning of date t, which is simply $\delta^d_{t-1}\pi^d y^d (p^d_{t-1}/p^d_t) + \delta^f_{t-1}\pi^f y^f x_{t-1}(p^d_{t-1}/p^d_t)$. Hence the domestic goods market clears when

$$y^d = \left[\delta^d_{t-1}\pi^d y^d + \delta^f_{t-1}\pi^f y^f x_{t-1}\right]\left(\frac{p^d_{t-1}}{p^d_t}\right) + \psi\left[(1-\pi^d)y^d + (1-\pi^f)y^f x_t\right] R^d_{d_{t-1}}; \quad \forall t \geq 2. \tag{20}$$

The foreign goods market clearing condition $\forall t \geq 2$ takes the analagous form

$$y^f = \left[(1-\delta^d_{t-1})\pi^d y^d + (1-\delta^f_{t-1})\pi^f y^f x_{t-1}\right]\left(\frac{p^f_{t-1}}{p^f_t}\right) + (1-\psi)\left[\frac{(1-\pi^d)y^d}{x_t} + (1-\pi^f)y^f x_t\right] R^d_{d_{t-1}}\left(\frac{x_{t-1}}{x_t}\right).$$

In addition, the two government budget constraints (5) and (8) must hold.

Of these eight equations, seven are linearly independent by Walras's Law, and determine $x_t, R^d_{d_{t-1}}, m^d_t, m^f_t, b^d + x_t b^f_t, \sigma^d_t$ and $F^d_t - F^d_{t-1}$. $p^f_t, R^f_{f_{t-1}}$ and p^f_t follow immediately, while b^d_t and b^f_t are selected to satisfy the government budget constraints.

A. The Initial Period

At date t=1, the two goods market clearing conditions and the government budget constraints take a different form as I now describe.

At date 1, there is a unit measure of old agents in each country who are endowed with initial per capita money stocks of the country in which they reside. They do not, however, earn any bond income since inherited bond stocks $B^i_0 = 0$ by assumption. I assume that all members of this generation are $(1-\pi^i)$ agents and so can transact in foreign exchange markets during $t = 1$ in order to attain their desired consumption allocation. Then, the domestic and foreign goods market clearing conditions are simply given by

$$y^d = \psi\left[\frac{M^d_0}{p^d_1} + \frac{\bar{e}M^f_0}{p^f_1}\right] \tag{22}$$

$$y^f = (1-\psi)\left[\frac{M^d_0}{\bar{e}p^d_1} + \frac{M^f_0}{p^f_1}\right]. \tag{23}$$

First period prices and so the real exchange rate x_1 are immediately determined.

Since $F^d_0 = F^f_0 = 0$, to establish the fixed exchange rate the foreign government supplies currency to the domestic government at the end of date t at a price of $\bar{e}$ per unit if necessary. Then, assuming that all foreign exchange intervention is conducted by the domestic government at t, $F^f_1 + \bar{e}F^d_1 = 0$ - the foreign government simply accomodates the net demand for foreign exchange by the domestic government.

Then initial domestic money market clearing requires simply that

$$m^d_1 = \pi^d \delta^d_1 y^d + \pi^f \delta^f_1 y^f x_1 \tag{24}$$

while the foreign money market clearing condition for date 1 only takes the form

$$m^f_1 = \pi^d(1-\delta_1)y^d/x_1 + \pi^f(1-\delta_1)y^f. \tag{25}$$

Finally, the government budget constraints are given by (3) and (6), or

$$m_1^d + b_1^d = M_0^d/p_1^d + F_1^d\bar{e}/p_1^d \quad (26)$$

$$m_1^f + b_1^f = M_0^f/p_1^f - F_1^d/p_1^f \quad (27)$$

Evidently, since x_1, p_1^d and p_1^f are determined from goods market clearing, m_1^d and m_1^f are generated by the satisfaction of money market clearing, and M_1^i follow immediatly. The bond market clearing condition, and two government budget constraints then determine b_1^d, b_1^f, and F_1^d. These seven equations therefore determine the unknown variables $x_1, p_1^d(p_1^f), m_1^d, m_1^f, b_1^d + x_1 b_1^f$, and F_1^d. In particular, young agents' stochastic demands for domestic and foreign consumption goods determine date 1 money stocks and the initial foreign exchange transaction between the domestic and foreign central banks.

B. Remarks

It is clear that the general equilibrium attained in this economy with the foreign exchange reserve of the domestic government being endogenously determined is inconsistent with manipulation of the growth rate of the domestic money supply, or the exogenous setting of σ_t^d. In particular, the nominal exchange rate cannot be maintained at a constant value in such a situation. While this does not correspond exactly to a policy rule of "sterilizing" reserve losses, it captures the general idea that when foreign exchange intervention is freely conducted to maintain a target exchange rate, the policy authority must allow the growth of other assets that it issues to be endogenously determined.

In addition, if F_{t-1}^d ever reaches its lower bound, $\underline{\mathrm{F}}_{t-1}^d$, so that $F_t^d - F_{t-1}^d = 0$, then banks can no longer obtain additional foreign currency from the domestic government at $\bar{e}$. From (18), this situation occurs when

$$F_{t-1}^d = \sum_{i=0}^{t-2} \left[{\sigma^f}^{t-2-i} M_1^f + (\delta_{t-1-i}^d - 1)\pi^d y^d p_{t-1-i}^d/\bar{e} + (\delta_{t-1-i}^f - 1)\pi^f y^f p_{t-1-i}^f \right] \quad (28)$$

$$= \sum_{i=0}^{t-2} \left[{\sigma^f}^{t-2-i} M_1^f + M_{t-2-i}^d/\bar{e} - (\pi^d y^d p_{t-1-i}^d/\bar{e} + \pi^f y^f p_{t-1-i}^f) \right] \quad (29)$$

$\leq \underline{\mathrm{F}}_{t-1}^d$.

If $\underline{\mathrm{F}}_{t-1}^d$ is selected to be that value of F_{t-1}^d at which the domestic government could not meet the maximum possible demand for foreign exchange at date t at the price $\bar{e}$, then $\underline{\mathrm{F}}_{t-1}^d$ is such that

$\underline{F}^d_{t-1} + M^f_t < (1-\delta^d_t)\pi^d y^d p^d_t/\bar{e} + (1-\delta^f_t)\pi^f y^f p^f_t$ for some δ^d_t, δ^f_t and therefore satisfies

$$\begin{aligned}
&\textstyle\sum_{i=0}^{t-1}\left[\sigma^{f^{t-1-i}} M^f_1 + M^d_{t-i}/\bar{e} - (\pi^d y^d p^d_{t-i}/\bar{e} + \pi^f y^f p^f_{t-i})\right] \\
&= \textstyle\sum_{i=0}^{t-1}\left[\sigma^{f^{t-1-i}}[M^f_0 - F^d_1 - B^d_1] + M^d_{t-i}/\bar{e} - (\pi^d y^d p^d_{t-i}/\bar{e} + \pi^f y^f p^f_{t-i})\right] \\
&< 0 \qquad (30)
\end{aligned}$$

Thus, I allow the critical value of the foreign exchange reserve of the domestic government at which a currency crisis occurs to be endogenous.

From (28) and (29), a currency crisis occurs when, for a given foreign money growth rate, the cumulative accomodated demands for domestic currency are low relative to the total cumulative demand for liquidity in the world economy, or when there are many small realizations of demands for domestic relative to foreign goods, δ^i_t. (30) makes clear that this corresponds to a situation in which the policies of the two governments over time produce insufficient currency to satisfy the world demand for liquidity. Ultimately, then, the constraint that prevents sustainability of a one-sided peg regime is the monetary policy of the "large" government, the nominal exchange rate peg itself, and initial world stocks of currency.

In particular, from (28)-(30), the lower is $\bar{e}$ set, the lower is the foreign government's money growth rate, and the higher is the total demand for liquidity in the economy, the π^i, the more likely is it that a currency crisis will occur for given realizations of preferences over alternative currencies. Notably, an increase in π^i will tend to raise the likelihood of crisis, ceteris parabus.

Finally, if *limited* exchange intervention is ever consistent with general equilibrium, it is evident that the likelihood of observing a currency crisis is increased, ceteris parabus, since the degree accomodation of the domestic money supply to private sector demands is less than 100%.

V. Conclusion

The results presented here are very preliminary. However, they suggest that when liquid assets are subject to unpredictable (transactions) demand fluctuations, then the maintenance of domestic financial sector "stability" and the sustainability of a one-sided peg exchange rate regime are contingent on the degree to the monetary authority accomodates private sector demands for liquidity.

In particular, only completely unhindered foreign exchange intervention is consistent with a general equilibrium in which the domestic banking sector is always liquid. In addition, if there exists a general equilibrium for the economy in which the domestic authority limits the degree of exchange intervention, it will be one in which banks face illiquidity/panic conditions, and in which the likelihood of currency crisis is increased relative to a situation in which exchange intervention is unregulated. Finally, any attempt by the monetary autority to target the growth rate of its money supply is inconsistent with a general equilibrium in which foreign exchange intervention is freely conducted and the nominal exchange rate is fixed.

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