



Centre for International
Economic Studies

Discussion Paper
No. 0308

**Speculative Behaviour, Debt Default and
Contagion: An Explanation of the Latin
American Crisis 2001-2002**

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March 2003

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ISSN 1444-4534 series, electronic publication

CIES DISCUSSION PAPER 0308

Speculative Behaviour, Debt Default and Contagion: An Explanation of the Latin American Crisis 2001-2002

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March 2003

This paper was written while on leave at the Reserve Bank of New Zealand. I gratefully acknowledge my colleagues within the Financial Stability Department for their constructive comments. In particular, I owe a debt of gratitude to Leslie Hull not only for her expertise with GAUSS programming but also for her wealth of useful suggestions and comments. All errors remain my own responsibility.

ABSTRACT

This paper provides a model incorporating strategic speculative behaviour into a framework of debt default and contagion. A basic model of contagion shows how economies which appear fundamentally sound, can fail to meet foreign obligations when there are inter-linkages with a defaulting country. Introducing speculators into the framework increases the incidence of debt default and contagion. However, when these speculators view the economy with a degree of uncertainty, the likelihood of default and contagion is even greater. Speculators' perceptions over the state of the economy are therefore paramount when estimating the impact of a crisis on a region.

Keywords: Currency Crises, Contagion, Common Knowledge.

JEL Classification: E44, F34, F41.

1. Introduction

World events of the last decade have generated a large and growing literature focused on contagion and the transmission of crises from one country to another. Indeed, contagion has been identified in many of the emerging markets over the last decade (Glick and Rose, 1999). The general story is that a crisis in one country will ultimately lead to crises in other financial centres since they are not only inextricably linked via trade and finance channels but also by speculator perceptions. It has been shown that a crisis in one country can generate a change in sentiment among speculators regarding the neighbouring region hence other countries are also subject to attacks on their financial systems.

However, the events of 2001-2002 in Latin America are not completely supportive of this theory. The debt-default in Argentina which hit during November 2001 did not pose an immediate threat to its neighbours. Indeed, the EMBI spreads indicate no great increase following the crisis and the commentators at the time were quick to question why the Latin American contagion had not happened. It was attributed to the fact that investors were more “savvy” about the state of each country’s fundamentals. This contradicts the Calvo and Mendoza (2000) argument where a crisis in one country acts as a “wake up” call to investors who view all other regional countries as homogenous. Conversely, during the latter half of 2002, as Argentinian fortunes worsened, EMBI spreads grew for many of the Latin countries and a regional crisis ensued.

A model is therefore needed that incorporates each scenario; the first in which a currency crisis is restricted to one country and the second in which it spreads throughout an entire region. To achieve this goal, the paper combines two influential models. It uses the inter-market bank framework of Elsinger et al. (2002) to

demonstrate how economies which initially appear solvent may be driven to default as a consequence of contagion. However, also built into this is the notion of common knowledge (from Morris and Shin, 1998) to illustrate the increased likelihood of contagion when speculators face uncertainty over the fundamental state of the economy.

The article is organised as follows. The next section outlines the situation facing Latin America in 2001-2002 i.e. an initial lack of contagion at the end of 2001 but increased contagion effects in the second half of 2002. Also presented is a summary of the literature that forms the basis of the model in this paper. The following section then sets up the framework describing the elements from each of the Morris and Shin and Elsinger approaches. Simulations are provided to contrast the frequency of contagion between two situations; the first in which each economy is viewed perfectly by all market participants; the second where the fundamentals are viewed with a degree of uncertainty. The paper then compares the level of the fundamentals required to trigger a crisis in each scenario. The final section contains concluding remarks incorporating policy implications.

2. Background

Summary of Events in Latin America

November 2001 saw Argentina enduring a debt default, a devaluation of the peso and a total of four presidents in ten days. In short, it plummeted into a financial crisis from which it is yet to recover. In April 2002, banking and foreign exchange activity was suspended and in November 2002 it again defaulted on its \$800m debt repayment to the World Bank having failed to re-secure IMF aid.

This generated concern not just for the state of the Argentinian economy but on the impacts on its neighbours. Fear of contagion from an Argentinian collapse provoked an IMF aid program for Brazil as early as September 2001 since it had much in common with Argentina in terms of a high proportion of external liabilities to exports and high public debt. However, Brazil was not subject to crisis until the middle of 2002. Opinion polls suggested an upcoming change of leadership which triggered adverse market expectations and hence a rise in the EMBI spread. This culminated in a sharp devaluation of the real in June 2002 and a deepening financial crisis.

A second country at risk from contagion in the region was Uruguay. While it did not immediately succumb to crisis in 2001 following the collapse of the Argentinian economy, there is still some empirical evidence of regional contagion. A large proportion of the deposit holders in Uruguay were Argentinians (Mussa, 2002) and having seen the peso collapse, they were keen to transfer their funds into dollars. As a consequence, by June 2002, reserves had fallen by 40% and the currency peg was abandoned.

Venezuela was also in difficulty at this time but not as a consequence of contagion. It experienced political and civil unrest throughout 2002 culminating in a nationwide strike which was not resolved until February 2003. The impact on the economy (particularly with regard to its oil exports) is yet to be fully realised. However, it too abandoned its peg following a run on its currency and depletion of foreign exchange reserves.

In short, the mood in mid 2002 in Latin America was summed up by events in Mexico. In a speech concerning public finances, the Mexican finance minister likened Mexico to Argentina prior to its crisis. This sparked a panic in the market and as a

consequence President Vicente Fox had to issue a statement confirming the Mexican economy was solid. In short, Argentina's collapse did not cause an immediate panic in the neighbouring financial markets. However, as the crisis deepened, market sentiment for the region started to change and by mid 2002 EMBI spreads rose throughout Latin America with other countries heading into difficulty.

Figure 1 provides the Emerging Market Bond Indices of Latin America for the years 2001-2003. The base year of January 2001 allows a comparison to be made across the countries in the region during Argentina's crisis period. An increase in this index implies that the bond spread is getting larger and hence that speculator-sentiment in the country is deteriorating. Therefore a rise in the index implies an adverse change in sentiment for the bonds of that particular country.

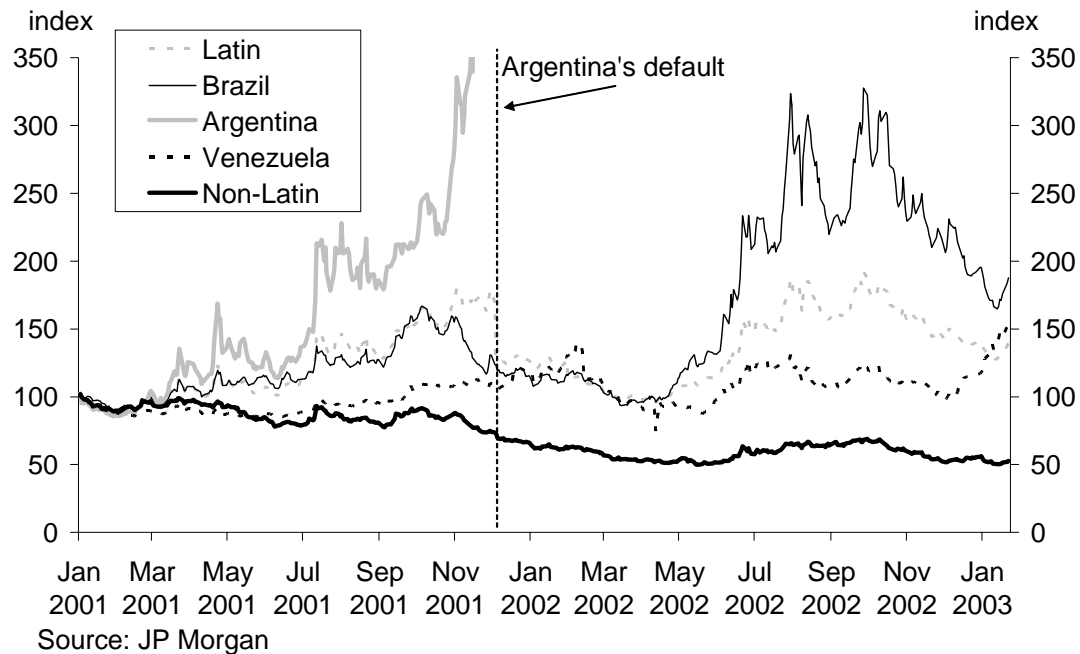
Clearly, at the time of the Argentinian debt default in 2001, the spreads for Venezuela and Brazil suggested no immediate danger from speculative attacks. However, by late 2002 indices for all of the Latin American countries were on the increase thus demonstrating a distinct fall in speculator sentiment. This supports the view that during the 2001 crisis period, speculators distinguished between economies in the region (Vogel, 2001). However, by late 2002 there had been a mood shift and sentiment for all countries had deteriorated.

The Literature on Contagion and Common Knowledge

It is well documented that the IMF intervened to support Brazil and Uruguay over widespread concerns of contagion from the collapse of the Argentinian economy. However, of equal importance was market reaction to the implementation of these IMF programs. Mussa (2002) notes that IMF reforms for Brazil could be highly successful if speculator sentiment were favourable but potentially disastrous otherwise. As a consequence, this paper brings together models that consider market

uncertainty and also contagion to explore the issue of Latin American countries in the 2001-2002 period.

Figure 1: Emerging Market Bond Indices for Latin America, 2001-2003



A concise summary of the literature into currency crises and contagion may be found in Pesenti and Tille (2000) which describes the differing schools of thought regarding the *causes* of crises and also the various channels for their spread to other countries. Since there is considerable debate surrounding what actually constitutes contagion,¹ this paper will use it in its broadest sense to capture any financial, real or political links within a region.

It is a matter of some debate as to which channel of contagion is the most relevant for each of the Latin countries in a time of crisis. Glick and Rose (1999) find empirical support for contagion through the trade channel for a number of different crises worldwide between 1971 and 1997 noting in particular how they tend to be regional. However, Allen and Gale (2000) attribute the spread of crises between banks to financial linkages. Hernandez and Valdes (2001), meanwhile find that the relevant

channel for contagion is region-dependent and also sensitive to how the crisis periods are measured. In short, the evidence is inconclusive and hence this calls for a model that captures each of the possible linkages; trade, financial or political.

The model by Elsinger et. al. (2002) is used in this particular framework since it is easily adapted to consider contagion in its broadest definition. The original paper considers the spread of liquidity crises in an inter-bank market and hence is a model that explains bank runs. The roots of this type of approach lie in the story told by Diamond and Dybvig (1983) and more recently in Diamond and Rajan (2002). Banks fail for one of two reasons. First, they are fundamentally insolvent. Second, they are rendered insolvent by other banks that cannot clear their payments. This can generate a cascade of bank failures and, in the extreme, a complete collapse of a country's financial system. In this framework, the model is extended to consider *country* interdependence and hence a crisis in one country can induce crises elsewhere.

The currency crisis literature has also spawned a number of models which consider market uncertainty since speculators are not always perfectly informed. For instance, Calvo (1999) shows that a sale of emerging market securities by informed agents could be misinterpreted by uninformed agents as suggesting low returns from the market and thus cause a financial collapse. Berger and Wagner (2002) also consider contagion when there is uncertainty in private sector expectations. A mutual dependence of private sector expectations across countries implies that a crisis in one country will increase the probability of a crisis in the countries with which it is trading. This has implications for the maintenance of a pegged exchange rate regime since it is not only actual devaluations which spark crises elsewhere but also the likelihood of one.

¹ A useful summary of the definitions is provided by the World Bank Group (2000).

However, while the above models provide a useful insight into speculative behaviour during a crisis period, it is argued that models of multiple equilibria are more appropriate than single equilibrium models in explaining the process of contagion. In an examination of emerging market crises of 1994-5 and 1997, Masson (1999) finds that single equilibrium models conditional on macroeconomic fundamentals alone do not capture all forms of contagion. He argues that a more useful model would incorporate multiple equilibria and self-fulfilling expectations. Both of these features are incorporated in the common knowledge literature which explicitly models the nature of speculator uncertainty. It demonstrates how the collapse of a currency may result from imperfect knowledge over the state of the economy's fundamentals (Morris and Shin, 1998) or the central bank's willingness to defend a currency peg (Allsopp, 2002).

This framework has formed the basis for a number of other more recent investigations. Prati and Sbracia (2002) build on the work of Morris and Shin (1998) and also Metz (2002) to provide a model considering uncertainty about fundamentals. They find that speculative attacks in six Asian countries depend not only on fundamentals but on the market's expectations of them.

In the Morris and Shin (1998) framework, multiple equilibria exist if investors have complete information. However, when investors each receive private signals concerning the state of an economy's fundamentals with a degree of error, then a unique equilibrium emerges. The bottom line is that exchange rate pegs could collapse for values of the fundamentals that would otherwise be consistent with the peg if only a few or no speculators had attacked the currency. Arguably, this could explain the recent events in Latin America since the initial reaction to the Argentinian collapse was not a deterioration in speculator sentiment for all the nearby countries.

The marked deterioration in Brazilian and Venezuelan bond spreads occurred much later with a depletion of their foreign currency reserves and an abandonment of their currency pegs.

The Morris and Shin framework therefore explains the onset of a crisis when there is uncertainty over how to interpret the state of the economy or a central bank's willingness to defend a currency. The model of Elsinger et. al. then shows how the crisis will unfold. As will be demonstrated later in the paper, a crisis may be restricted to one country alone. Equally, there are instances where contagion will develop and hence an entire region will be affected. It follows that a combination of these frameworks achieves the goal of being able to model each of the two scenarios seen in the Latin American countries in 2001 and 2002.

3. Model

Modelling Contagion

A model to describe the Latin American experience needs to be sufficiently versatile to allow for the many different types of inter-linkages between countries. For instance, there are not only trade and financial linkages in the region but also political ties to consider². The different channels for spill-over can be incorporated in matrix form showing the extent of the commitments between each country. For simplicity these will be considered in financial terms.

There are N countries in the region. Each country, $i \in N$ has a particular level of foreign exchange reserves reflecting its fundamental state and its ability to defend a pegged exchange rate. This is denoted by θ_i . It also has liabilities to other countries

² These are not only evident between the Latin countries but also with economies outside the region e.g. between Mexico and US.

denoted by l_{ij} . When the fundamentals of countries are strong, central banks are more able to meet their debt obligations and hence θ_i takes on a large value. Conversely, when fundamentals are poor, central banks are less equipped to manage their foreign debt.

The inter-linkages between countries in the region can therefore be described by an $N \times N$ matrix, L whereas the fundamental state of each economy is reflected in the vector, $\theta \in R^N$. This system is denoted by (L, θ) which shows that a country's financial viability is dependent on (a) its net indebtedness with other countries and (b) its fundamental state reflected in its stock of foreign exchange reserves.

Each entry in the matrix, L , represents \$US billions. Rows indicate debt owed to other countries while columns indicate claims on other countries.

$$L = \begin{pmatrix} 0 & l_{12} & l_{13} \\ l_{21} & 0 & l_{23} \\ l_{31} & l_{32} & 0 \end{pmatrix} \quad (1)$$

For example Country 1 owes \$ l_{12} billion to Country 2 and \$ l_{13} billion to Country 3.

The zeros throughout the diagonals imply that the countries have no foreign debt with themselves. Conversely, Country 1 is owed \$ l_{21} billion dollars from Country 2 and \$ l_{31} billion from Country 3. It follows that total inter-country debt can be given by the vector $d = ((l_{12} + l_{13}), (l_{21} + l_{23}), (l_{31} + l_{32}))$. The vector, $\theta = (\theta_1, \theta_2, \theta_3)$ shows the level of foreign reserves held by each central bank and represents the fundamentals of the economy.

As in Elsinger et. al. a mechanism must be defined to settle payments in the event that countries cannot honour their debts. In their paper, default is resolved by the proportional sharing of the value of the debtor bank among its creditors. Clearly,

when we consider countries as a whole, this is not the typical outcome³. In the absence of a sovereign debt restructuring program, the nature of foreign law debt implies that it is a legal nightmare to resolve a country's debt defaults hence it is more often the case that none of the creditors receive their payments at least initially⁴. For these reasons, I report the results from each of the two approaches. Irrespective of the procedure adopted, the implication is that the resolution of insolvency determines actual payments between countries.

Using the proportional sharing of country value approach we get the following matrix $\Pi \in [0,1]^{N \times N}$ derived from L which normalises the cells by total obligations:

$$\Pi = \begin{pmatrix} 0 & l_{12}/(l_{12} + l_{13}) & l_{13}/(l_{12} + l_{13}) \\ l_{21}/(l_{21} + l_{23}) & 0 & l_{23}/(l_{21} + l_{23}) \\ l_{31}/(l_{31} + l_{32}) & l_{32}/(l_{31} + l_{32}) & 0 \end{pmatrix} \quad (2)$$

where:

$$\pi_{ij} = \begin{cases} \frac{l_{ij}}{d_i} & \text{if } d_i > 0 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

From this it is possible to describe a clearing payment vector which gives the total payments made by each country under the clearing mechanism. A clearing payment

vector for the system is a vector $p_i^* = \min \left[d_i, \max \left(\sum_{j=1}^N \pi_{ji} p_j^* + \theta_i, 0 \right) \right]$. This implies

that a country either honours its debts and hence $p_i^* = d_i$ or it defaults on its debts

and hence $p_i^* = \max \left(\sum_{j=1}^N \pi_{ji} p_j^* + \theta_i, 0 \right)$. Using an iterative process it is apparent that if

all countries meet their debts there is no default and hence no contagion. However, if one country cannot meet its obligations, the clearing mechanism then calculates the

³ More likely is the imposition of a sovereign debt restructuring mechanism through which the defaulting country reaches an agreement with its creditors to meet its obligations. In return the existing rights of creditors to sue in court are suppressed at least for a given period.

proportional payments made to the creditor countries. This in turn has an impact on the fundamentals of those countries. In a second iteration of this process, the creditor countries only receive a proportion of the debts due to them. This means that, in turn, they may not be able to meet their own debts. If that is the case then they are rendered insolvent and their own debts are subject to proportional sharing among their creditors. This procedure is derived from Eisenberg and Noe (2001) who refer to it as the “fictitious default algorithm”. They show that after N iterations at the most, it converges to the unique payment vector p^* .

In the extreme, countries which can readily meet their debt obligations for a given set of fundamentals still suffer a debt default when partner countries default on debts. In short, a country subject to default will render subsequent countries insolvent through contagion. Not only is it possible to identify those countries which will succumb to financial insolvency but also we can distinguish those countries which are prone to contagion. The usefulness of this is that it can act as an “early warning system” indicating countries which are financially vulnerable.

As in Elsinger et. al. this is illustrated using an example. L is a 4 x 4 matrix representing three regional economies, A, B and C with linkages to the rest of the world denoted by D all in \$US billions.

$$L = \begin{pmatrix} 0 & 0 & 0 & 250 \\ 150 & 0 & 50 & 0 \\ 100 & 100 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \quad (4)$$

There are two scenarios. The first one shows contagion when defaults are resolved through proportional sharing. By contrast, in Scenario 2 the defaulting country pays none of its creditors. For each scenario, the L matrix remains the same but three

⁴ It has been noted that Argentina’s debt is likely to take many years to resolve.

different vectors of fundamentals are considered. In the first case, fundamentals are such that all countries meet their debt obligations and hence no default arises. In the second case, one country is subject to default but contagion does not occur since the remaining countries have sufficiently strong fundamentals to offset the loss. In the final case, contagion prevails since the remaining countries do not have strong enough fundamentals to meet their debts if one of the other countries defaults. The outcome is seen in Table 1.

Table 1: A Table to Show the Frequency of Debt Default and Contagion for Different States of the Economy

Case	Scenario 1 (Proportional Sharing)	Scenario 2 (No Payments to Creditors)
No Defaults	$\theta = (100,100,150,1000)$ $p^* = (250,200,200,0)$ No Countries Default	$\theta = (100,100,150,1000)$ $p^* = (250,200,200,0)$ No Countries Default
1 Default – No Contagion	$\theta = (100,200,100,1000)$ $p^* = (250,200,150,0)$ Country C Defaults	$\theta = (100,200,100,1000)$ $p^* = (250,200,0,0)$ Country C Defaults
1 Default – Contagion	$\theta = (100,100,100,1000)$ $p^* = (250,171.43,142.86,0)$ Country C Defaults Country B Defaults Through Contagion	$\theta = (100,100,100,1000)$ $p^* = (0,0,0,0)$ Country C Defaults Countries B and A Default Through Contagion

Notably, the model shows the circumstances under which defaults are restricted to one country and equally when they are subject to contagion. The distinction between scenarios 1 and 2 becomes all apparent when looking at the degree of contagion generated by a defaulting country. When default is resolved through proportional sharing only Countries B and C default. However, when none of the creditors of defaulting countries get paid, Country A is also rendered insolvent. This has policy implications for international organisations such as the IMF or World Bank since an appropriate payments system could limit the damage of a debt crisis in a region and imply that a country could be spared the costs of default.

Clearly the preferable situation would be one of 'no default'. However, this could only be guaranteed if the countries in question were subject to constant scrutiny and restrictions issued by international organisations to prevent insolvency in the first place. However, this is not in the spirit of the IMF or World Bank. Given that defaults are inevitable, it therefore seems that the best response for the countries themselves is to ensure that they are not vulnerable to contagion. This suggests a need not only for strong fundamentals to offset losses from defaulting partner countries but also diversification of foreign investment.

Modelling the Onset of a Crisis

Morris and Shin illustrate the importance of common knowledge in a model of currency crisis by comparing two situations. In the first instance, investors view perfectly the fundamentals of the economy. In the second instance, they observe the fundamentals with a degree of error. It is shown that when common knowledge holds, the model is characterised by multiple equilibria. Conversely, when there is a lack of common knowledge regarding the state of the economy, a unique equilibrium prevails. When the state of the economy exceeds a particular level, an attack will not

occur. However, below this threshold, it becomes optimal for speculators to abandon the currency and as a consequence, the currency collapses.

Agents

The framework is as follows. The agents in the model consist of one central bank and Q speculators each with equal-sized holdings of the domestic currency. Each agent aims to maximise a payoff, the details of which will follow. The economy's exchange rate is assumed to be pegged at e^* and its fundamentals, θ , are uniformly distributed over the interval, $[0,1]$. In the absence of intervention, the exchange rate is a function of the fundamentals, $f(\theta)$ and lies at or below the pegged rate.

Payoffs

The central bank derives a value, $v > 0$, from defending a pegged regime but also faces a cost, $c(\alpha, \theta)$, which varies with the size of the fundamentals, θ and the proportion of speculators abandoning the currency, α . Defending the exchange rate peg yields a payoff of $v - c(\alpha, \theta)$ for the central bank while abandoning it gives a zero payoff. Each speculator observes a signal, x , drawn uniformly from the interval $[\theta - \varepsilon, \theta + \varepsilon]$ where ε represents a degree of error. When there is no uncertainty regarding the state of the fundamentals, ε takes on a value of zero. If the speculator attacks the currency, he/she incurs a transaction cost given by $t > 0$ which implies a payoff of $-t$ if the attack is subsequently defended. However, if the attack is successful and the peg is abandoned he/she earns $e^* - f(\theta) - t$.

Model Sequence

(1) At the outset, the fundamentals are determined by nature and are uniformly distributed over the interval, $[0,1]$.

(2) Each speculator receives a signal, x , concerning the state of the fundamentals. This is drawn uniformly from the interval, $[\theta - \varepsilon, \theta + \varepsilon]$ and is identically and independently distributed across individuals conditional on θ . If common knowledge prevails, they observe the fundamentals perfectly but when they face uncertainty, the signal contains a degree of error. He/She then decides whether to attack the currency or not.

(3) The central bank observes the proportion of speculators abandoning the currency, α and decides whether to defend the peg. In equilibrium, the strategy for the government and speculators is such that no agent has an incentive to deviate.

Tripartite Distinction of Fundamentals

Morris and Shin denote $\underline{\theta}$ as the value of the fundamentals which solves $c(0, \theta) = v$. This represents the value of θ at which the central bank is indifferent between defending or abandoning the peg. Conversely, they denote $\bar{\theta}$ as the value of θ solving $f(\theta) = e^* - t$. Using these two thresholds it is possible to describe a tripartite distinction for the fundamentals when common knowledge prevails. For values in the interval, $[0, \underline{\theta}]$ the currency is unstable since the peg will collapse irrespective of the actions of speculators. Conversely, when the fundamentals fall in the interval, $[\bar{\theta}, 1]$, the currency is deemed stable. Even if all speculators attack the currency, the end result is a depreciation that is so small as to make the payoff from abandoning the currency not worth the cost. The region, $[\underline{\theta}, \bar{\theta}]$ is termed “ripe for attack” since the central bank’s decision to abandon the peg will depend on the proportion of speculators leaving the currency.

Common Knowledge Versus Uncertainty

To understand the impact of common knowledge within the model, consider first the strategy of the central bank (known to all speculators) and hence the payoffs to speculators across all possible levels of the fundamentals.

The critical proportion of speculators needed to cause a currency to collapse is $a(\theta)$. In the unstable region this takes on a value of zero while elsewhere it is that value of α which solves $c(\alpha, \theta) = v$. It follows that the central bank will abandon the peg if α is greater than the critical mass, $a(\theta)$. Given the strategy of the central bank, it is possible to ascertain the payoffs between the speculators. In the model, $\pi(x)$ denotes the proportion of speculators to attack the currency when signal x is received. It follows that we can denote the proportion of speculators who attack the currency when the fundamentals are θ given the selling strategy, π , as $s(\theta, \pi)$. With signals uniformly distributed, this implies:

$$s(\theta, \pi) = \frac{1}{2\varepsilon} \int_{\theta-\varepsilon}^{\theta+\varepsilon} \pi(x) dx \quad (5)$$

Now let $A(\pi)$ denote the event that the central bank abandons the peg when the speculators follow the strategy π . This is given by:

$$A(\pi) = \{\theta | s(\theta, \pi) \geq a(\theta)\} \quad (6)$$

Payoffs to speculators from attacking the currency when the fundamentals are θ and sales of the currency are π can be defined as follows:

$$h(\theta, \pi) = \begin{cases} e^* - f(\theta) - t & \text{if } \theta \in A(\pi) \\ -t & \text{if } \theta \notin A(\pi) \end{cases} \quad (7)$$

However, note that when speculators view the fundamentals with a degree of error, it is the *expected* payoff which is paramount in deciding whether to abandon the currency. The expected payoff conditional on signal x is the expectation of (7) and is described by:

$$u(x, \pi) = \frac{1}{2\varepsilon} \int_{x-\varepsilon}^{x+\varepsilon} h(\theta, \pi) d\theta = \frac{1}{2\varepsilon} \left[\int_{A(\pi) \cap [x-\varepsilon, x+\varepsilon]} (e^* - f(\theta)) d\theta \right] - t \quad (8)$$

The speculator's decision will therefore depend on whether $u(x, \pi)$ is positive or negative. For positive values, $\pi(x) = 1$ and all speculators sell their holdings of the currency. For negative values, $\pi(x) = 0$ and no speculators attack the currency.

Therefore the presence of a small amount of noise implies that the multiplicity of equilibria mentioned earlier disappears and there is a unique equilibrium. The main result of the Morris and Shin paper is to show that under imperfect information, a unique value of the fundamentals exists below which it is optimal for the central bank to abandon its currency peg. The reader is referred to Morris and Shin (1998) for a proof of this result.

Modelling the Crisis and the Resulting Contagion under Perfect and Imperfect Knowledge

Incorporating the Morris and Shin model into the Elsinger framework of contagion has significant implications for the frequency of initial speculative attacks and hence also on the likelihood of a regional crisis.

Agents

There are three types of agent in this model. As in the Morris and Shin framework there is a central bank which seeks to maximise its payoff. It attaches a value, $v > 0$, to maintaining a pegged exchange rate but incurs costs, $c(\alpha, \theta)$, from doing so. A speculative attack makes debt default more likely since it depletes reserves, reduces fundamentals and makes an economy less able to meet its commitments hence there is a positive value of maintaining the peg. The variable v is

therefore the value of avoiding the risk of possible debt default. For simplicity it is assumed constant across all economies in the region.

If the central bank defends the exchange rate peg its payoff is $v - c(\alpha, \theta)$ whereas abandoning the peg yields a zero payoff. The cost of defending a currency depends on the proportion of speculators abandoning the currency and the size of the fundamentals. This does not incorporate any additional costs associated with debt default.

There are Q speculators each of equal size in terms of their holdings of domestic currency. As before, each speculator observes a signal, x , drawn uniformly from the interval $[\theta - \varepsilon, \theta + \varepsilon]$ where ε represents a degree of error and takes on a value of zero when fundamentals are viewed perfectly⁵. Abandoning the currency incurs a transaction cost of $t > 0$ and if the attack is subsequently defended, the speculator's payoff is $-t$. However, if the attack is successful and the peg is abandoned he/she earns $e^* - f(\theta) - t$. Speculators do not observe the liabilities of their country or its claims on other economies. As such, they are ignorant of the entries in the L matrix and base their decision purely on the fundamentals of their own economy seen in the vector, θ_i .

The final group of agents are those foreign investors who have claims on the country's central bank. They have no strategic interaction within the model. Their purpose is purely to show a very basic inter-linkage between economies.

Fundamentals in the Model

In the Elsinger framework, a crisis is initially generated by fundamentals which are inconsistent with a country's foreign obligations. When fundamentals are

⁵ It is assumed that $2\varepsilon < \min\{\theta, 100 - \bar{\theta}\}$.

weak and claims cannot be met, a country will default. Their approach can thus model a debt default, but says nothing about the central bank's decision to abandon a pegged exchange rate regime. This is the role of the Morris and Shin component of the model in which the θ_i vector represents the fundamentals of each different country. The θ of each country is uniformly distributed over the interval, $[0,200]$.

Sequence of Events

The speculators base their decision of whether to abandon the currency on their observations of the fundamentals. These are viewed either with or without a degree of error depending on whether common knowledge prevails in the model. The central bank's decision regarding the defence of the peg depends on the percentage of speculators abandoning the currency, α . Notably, there is now an additional factor to consider; namely the link between the fundamentals and the liabilities to other economies. It is assumed that a speculative attack on the currency depletes the level of reserves and hence reduces the size of the fundamentals. In particular, the fundamentals will deplete by α . Clearly, this will influence the ability to manage foreign debt requirements, hence a debt default becomes more likely.⁶

The tripartite distinction for the fundamentals still exists when there is perfect information regarding the state of the fundamentals. When $\theta < \underline{\theta}$, then even if none of the speculators attack the currency, the central bank will still abandon the peg. However, as noted earlier, the rational strategy for the speculator is to attack when fundamentals fall below this level. Equally, when $\theta > \bar{\theta}$ and the fundamentals are sound, none of the speculators will attack the currency, since the fundamentals are strong enough to withstand a crisis even if all speculators chose to attack.

⁶ If debt defaults were allowed to precede speculative attacks in this model, the fundamentals would fall to zero making an attack on the currency and the subsequent abandonment of the peg inevitable.

Once more the interesting case is where the fundamentals fall between $\underline{\theta}$ and $\bar{\theta}$. With common knowledge, the outcome depends on the proportion of speculators who attack the currency. Thus for perfect information, multiple equilibria exist. However, a unique equilibrium prevails when speculators view the fundamentals with a degree of error and hence there is always an incentive to attack the currency when fundamentals fall in this ‘ripe for attack’ region.

Unlike the Morris and Shin framework, the story does not end there. There are countries’ liabilities with foreign investors to consider. Even when there is no speculative attack on a currency, there may still be a debt default. The only difference is that a debt default is more likely once a speculative attack has occurred since reserves will already be much reduced. We may therefore see one of four events occurring; a speculative attack and a debt default, a speculative attack and no debt default, no speculative attack and no default, no speculative and a debt default.

What is a Currency Crisis in this Framework?

This brings into question the definition of a currency crisis. In this paper, it is defined as a speculative attack on the currency which causes a central bank to abandon its exchange rate peg. As a consequence the country may or may not fall prey to debt default either as a consequence of reduced fundamentals or through contagion. This is termed a debt crisis. The speculative attack on the currency shows that a country which would otherwise have met its foreign obligations will be driven into default. The impact on the likelihood of debt crises and contagion may be seen by simulation. To form a comparison, the entries in the matrix L and vector θ_i will remain as before.

Simulation Using Figures From Elsinger Model

In order to provide a numerical simulation, functional forms need to be assigned to $c(\alpha, \theta)$ and $f(\theta)$. In the case of the cost function it is assumed that: $c = \alpha - \theta + \beta$. Thus the cost of defending a peg increases with the percentage of speculators attacking the currency and decreases with stronger fundamentals. The constant, β , ensures that in the worst state of fundamentals, the cost of defending the currency exceeds the value derived from it even when none of the speculators attack. It also implies that in the best state of fundamentals, the cost of defending the currency outstrips the value if all speculators attack the currency. This is not crucial to the model. When $\beta = 0$, this merely implies fewer instances in which speculative attacks are launched.

The exchange rate in the absence of central bank intervention, $f(\theta)$ is assumed to be less than the pegged rate, e^* but increasing in θ so that a higher floating rate is associated with stronger fundamentals. Again it takes on a simple form: $f(\theta) = y + \theta$ where the y parameter is included to show that even when fundamentals are at their lowest, the floating rate is non-zero.

The variables take on the following numerical values⁷:

$$v = 40, \quad \beta = 150, \quad \alpha = [0,100], \quad \varepsilon = 10, \quad \theta = [0,200],$$

$$y = 10, \quad t = 20.$$

Central Bank Strategy

The central bank will abandon the peg if $c(\alpha, \theta) > v$. Recall that $\underline{\theta}$ is the value of the fundamentals, θ , which solves $c(0, \theta) = v$ i.e. it is that value at which the central bank is just indifferent between defending the currency and maintaining it

when none of the speculators attack the currency. In terms of the figures shown above this is where $\underline{\theta} = 110$. Clearly the vectors of fundamentals given in Table 1 show a number of economies falling below this limit and hence these would be subject to speculative attacks. Conversely, $\bar{\theta}$ is the value of the fundamentals which solves $f(\theta) = e^* - t$. Beyond the level, $\bar{\theta} = 190$, the central bank's costs of defending an attack on the currency will always fall short of the value even if all speculators were to abandon the currency.

Speculators' Strategy

The speculators form their decisions based on the central bank strategy outlined above. If they view the fundamentals with perfect information, the payoff to attacking the currency will be:

$$h(\theta, \pi) = \begin{cases} e^* - f(\theta) - t & \text{if } \theta \in A(\pi) \\ -t & \text{if } \theta \notin A(\pi) \end{cases}$$

It follows that, when common knowledge prevails, any value of the fundamentals below 110 implies that it is optimal to attack while any value exceeding 190 implies that it is always preferable not to attack. In the ripe for attack region, the decision to abandon the currency rests on the proportion of speculators who attack and hence nothing more can be said of this case.

When there is imperfect information among speculators the payoff must be found from the posterior distribution across all states conditional on the signal received. The expected payoff is give by:

$$u(x, \pi) = \frac{1}{2\varepsilon} \int_{x-\varepsilon}^{x+\varepsilon} h(\theta, \pi) d\theta = \frac{1}{2\varepsilon} \left[\int_{A(\pi) \cap [x-\varepsilon, x+\varepsilon]} (e^* - f(\theta)) d\theta \right] - t$$

⁷ The qualitative results of the model are robust for other values of these variables. The only proviso is that the relationships already described in the paper are met.

Any value of θ exceeding 190 produces a negative expected payoff, $u(x, \pi)$, hence it is optimal for each speculator to refrain from attacking when the fundamentals fall in this region. However, when the fundamentals fall below 190 the expected payoff is positive, even in the ripe for attack region and thus it is rational to attack.

The model implies that it only takes a small degree of uncertainty in speculators' perceptions for a crisis to be triggered for values of the fundamentals which would otherwise be sound. The full impact of these speculative attacks, both with and without common knowledge of the fundamentals, can be seen in the model of contagion. The same vectors of fundamentals are used as in Table 1. The difference is that each value is compared with the critical values of $\underline{\theta}$ and $\bar{\theta}$ under perfect and imperfect information. If it falls in the crisis region, then the value of the fundamentals is reduced by the percentage of speculators attacking the currency. The country then needs to meet its debt obligations. At this point, debt default may arise.

Common Knowledge

When speculators observe fundamentals with no degree of error, it is optimal to attack the currency if the fundamentals fall below 110. Referring back to Table 1, Country A is always subject to attack, Country D (representing the rest of the world) is never attacked, Country B is attacked in Cases 1 and 3 when its fundamentals are just 100 and Country C is attacked in Cases 2 and 3 when its fundamentals are 100. However in Case 1, its fundamentals fall in the 'ripe for attack' region hence whether it is initially attacked or not depends on the proportion of speculators to attack the currency. However, this becomes immaterial when contagion is examined since Country C falls prey to debt default as a consequence of contagion. Indeed, compared with Table 1 it is apparent that allowing for speculative behaviour in the foreign

exchange markets implies a higher incidence of debt default than when speculative behaviour is not incorporated.

Table 2: A Table to Show the Frequency of Debt Default and Contagion for Different States of the Economy when Speculators have Perfect Knowledge of Fundamentals

Case	Scenario 1 (Proportional Sharing)	Scenario 2 (No Payments to Creditors)
1 Default – 2 Cases of Contagion	$\theta = (0,0,150,1000)$ $p^* = (150,85.71,171.43,0)$ Country B Defaults Countries A and C Default Through Contagion	$\theta = (0,0,150,1000)$ $p^* = (0,0,0,0)$ Country B Defaults Countries A and C Default Through Contagion
1 Default – 1 Case of Contagion	$\theta = (0,200,0,1000)$ $p^* = (175,200,50,0)$ Country C Defaults Country A Defaults Through Contagion	$\theta = (0,200,0,1000)$ $p^* = (0,200,0,0)$ Country C Defaults Country A Defaults Through Contagion
3 Defaults – No Cases of Contagion	$\theta = (0,0,0,1000)$ $p^* = (0,0,0,0)$ Countries A, B and C Default	$\theta = (0,0,0,1000)$ $p^* = (0,0,0,0)$ Countries A, B and C Default

Imperfect Knowledge

Under imperfect information, the same scenario prevails as shown in Table 2 with one main exception. In Case 1, it becomes optimal for speculators in Country C to attack their currency since fundamentals fall in the ‘ripe for attack’ region. It follows that reserves are depleted and hence the fundamentals fall from 150 to 50. The vector of fundamentals is given by $\theta = (0,0,50,1000)$ and the clearing payment in each scenario becomes $p^* = (0,0,0,0)$. In this particular instance, all countries default immediately with none subject to contagion.

It has been shown that incorporating speculative behaviour into the basic contagion framework increases the frequency of debt defaults among economies. This also makes contagion more likely since countries’ fundamentals are weakened through speculative attacks. When we then distinguish between the nature of information received by speculators, it is shown that imperfectly viewed fundamentals cause an even greater incidence of initial defaults of countries since speculative attacks becomes more frequent. Therefore, the overall impact of combining strategic speculative behaviour with a model of country indebtedness is to cause considerably more instances of debt default than if the basic foreign debt inter-linkages were viewed in isolation.

4. Conclusion and Policy Implications

The aim of this paper was to produce a model to explain the events of 2001-2 in Latin America. At the time, these countries were characterised by large foreign debt obligations and inter-linkages with both neighbouring countries and the rest of the world. The initial collapse of the Argentinian economy was not immediately followed by contagion in the region. However, as the crisis deepened in 2002, more countries were subject to speculative attacks.

A model of contagion alone is shown to be useful in examining the spread of debt default across countries in the region (for instance between Argentina and Uruguay). However, it fails to explain a crucial aspect of the crises; namely strategic speculative behaviour. Hence the framework adopted in this paper incorporates the role of speculators.

Using the model one may argue that during 2001, many of the Latin countries had strong enough fundamentals to deter an attack and withstand the collapse of a close financial or trading partner. However, during the following year, fundamentals deteriorated and hence economies were vulnerable to attack from speculators and an inability to meet debt obligations.

What are the implications for policy? In terms of the contagion model alone, one would suggest that countries diversify their trade and financial links rather than rely on one close partner. It is apparent that a debt default by the partner economy increases the likelihood of default for the home economy. Furthermore, a strengthening of the fundamentals would also be recommended as a long term prescription. However, when the strategic behaviour of speculators is included, it is not just the soundness of the fundamentals which counts but the speculators' perceptions of them. As noted earlier, the lack of contagion during 2001 was attributed to positive speculator sentiment (Vogel, 2001), hence its role in a model of currency crisis should not be underestimated.

In the unlikely event that the state of the economy is viewed perfectly, a 'ripe for attack' region implies that if enough speculators attack a currency, the peg will be abandoned. However, if speculator sentiment is high, an economy can maintain its currency peg yet still have fundamentals of this magnitude. If the economy is viewed with uncertainty as is more often the case, there is an even greater incentive to ensure

that fundamentals are sound and do not fall in this region. If they do, a speculative attack is optimal and as a consequence, debt default can follow. The policy advice is then apparent; the state of the economy is crucial not just to avoid the obvious default on foreign obligations but also to deter the possibility of speculative attacks on a currency. The Latin American central banks will be well aware of these issues. The task now is to re-build sound fundamentals and a solid reputation from crisis-ridden economies.

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