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PUBLIC DEBT MATURITY AND CURRENCY CRISES

*** Accepted for publication in the
Scottish Journal of Political Economy
on 1 February 2007 ***

By
Paul Levine
(University of Surrey)
Alex Mandilaras
(University of Surrey)
&
Jun Wang
(University of Surrey)

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Department of Economics
University of Surrey
Guildford
Surrey GU2 7XH, UK
Telephone +44 (0)1483 689380
Facsimile +44 (0)1483 689548
Web www.econ.surrey.ac.uk
ISSN: 1749-5075

Public Debt Maturity and Currency Crises

Paul Levine
University of Surrey

Alex Mandilaras*
University of Surrey

Jun Wang
University of Surrey

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Abstract

The theory underlying the effect of debt structure on the probability of a currency crisis and the slope of the yield curve was developed in Benigno and Missale (2004). In this paper, we provide the empirical evidence to support their model's predictions. In a dynamic panel data framework we produce GMM estimates that give substantial support to the hypothesis that the role of short-term debt depends on how a devaluation affects the reputation of the policymaker and the real value of public debt. In addition to the empirical analysis, we generalize the theoretical framework to allow for the presence of non-deflatable debt and, for completeness, examine the case where the monetary authority can fully commit itself to an escape clause monetary rule.

JEL Classification: I163, F31

Keywords: Currency crisis, debt management.

*Corresponding author. Department of Economics, University of Surrey, Guildford, GU2 7XH. E-mail address: a.mandilaras@surrey.ac.uk. Tel. no.: +44 (0) 1483 682768. Fax no.: +44 (0) 1483 689548. We would like to thank two anonymous referees for very helpful comments. We acknowledge financial support for this research from the ESRC, project no. RES-000-23-1126.

Contents

List of Tables

List of Figures

1 Introduction

The mainstream literature on the monetary authority credibility (see Backus and Driffill, 1985 and Backus and Driffill, 1985b) argues that a defence of the fixed parity can signal the authority's 'toughness' towards inflation and thus improve the credibility of the exchange rate regime. A more recent literature has re-examined this issue in the context of a model economy in which there are persistence effects from failing to devalue following an adverse supply effect. For example, in Drazen and Masson (1994) there is persistence in unemployment and defending the fixed parity leads to higher future unemployment undermining the possibility that the currency peg will be maintained.[1] In Benigno and Missale (2004) –henceforth BM– persistence is driven not by unemployment, but by debt. In both models if the degree of uncertainty about the government's preferences is low, resisting a currency crisis may in fact reduce the credibility of the exchange rate regime. In this paper, we adopt BM's framework and produce new empirical work in order to see whether a result obtained for an EMS participant also generalises to emerging markets.

Following BM's approach, we employ a three-period stochastic version of the Barro and Gordon (1983) model, where the probability of devaluation in each period is derived from the monetary authority's optimization problem. Monetary policy is conducted in terms of an escape clause that specifies the threshold value of a negative supply-side shock above which devaluation will occur. We present a more general framework than BM for studying the policymaker's optimization problem that distinguishes between the commitment and discretionary optimal escape clauses. We also extend BM's model to allow for non-deflatable debt, i.e., in addition to nominal debt the government issues securities whose real returns cannot be eroded through an unexpected devaluation.

First, we examine the complete information game where the central bank can commit itself to a 2-period escape clause rule. Minimization of the bank's loss function delivers the optimum solution, which we regard as a benchmark. Then, still in a complete information

[1] Drazen and Masson (1994) explain the apparently paradoxical result that defending the parity may increase the likelihood of a future devaluation with an enlightening and entertaining example. We recommend referring to the original article, but for the convenience of the reader we summarise it here as well. In this example a colleague is assumed to announce that in an effort to lose weight he is planning to skip dinner. He then adds that as part of his dieting strategy he has not eaten for two days. Had he not avoided consuming food for two days the credibility of his announcement would be judged on its merits. But with several meals skipped one would expect the likelihood that he will eventually eat tonight to be greater.

game, we move to the case of discretionary policy where the monetary authority cannot commit. In both cases, with debt consisting of short-term (1-period) and long-term (2-period) components, it is shown that defending the fixed parity increases the debt burden and, thus the probability of having to resort to future devaluation. However, this increase in probability is less under commitment and disappears altogether as debt becomes entirely short-term. This is the *debt burden effect*. We also confirm the BM result for discretionary policy that, the probability of a first-period devaluation also increases with the level of public debt and, more interestingly, with the share of short-term debt. Comparison with the commitment case shows that the discretionary two-period escape clause rules are sub-optimal and involve an expected inflation bias. This can be lessened by the delegation of monetary policy to a 'tough' (inflation-averse) banker, but this relocates the problem to one of establishing the credibility of such toughness.

This leads us to an asymmetric information game where the authority's preferences are not known to the private sector. The decision to devalue might reveal a weak monetary authority, thus leading to inflationary expectations which in turn, *increase* the likelihood of a future devaluation. This is *the signalling effect* and this effect is important when there is substantial uncertainty about the authority's cost of devaluation and total debt is small. Whether the debt burden or the signalling effect prevails depends on the importance of debt fundamentals relative to the extent of the authority's credibility (signalling) problem.

We focus on three key predictions of the theory. The first is that if the debt burden effect dominates the signalling effect then defending the fixed parity increases the debt burden and, thus the probability of having to resort to future devaluation. Second, in debt burden countries the likelihood of a first-period devaluation increases with the share of short-term debt, as the incentive to devalue and exploit the lower rate (which follows the devaluation) also increases with the amount of debt to be rolled-over. On the other hand, when the uncertainty about the authority type is substantial, a lower interest rate results from the decision not to devalue. In that case, the probability of a first-period devaluation decreases with the proportion of short-term debt. The third prediction regards the slope of the yield curve over the two periods. The theory shows that the probability of a second-period devaluation seen at the beginning of period 1 does not depend on either debt maturity or credibility considerations. Therefore in debt burden (signalling) countries, a higher ratio of short-term debt implies a flatter (steeper) yield curve.

Since the extent of a country's credibility problem is not directly observed we cannot hope to test all three predictions. Instead, we assume that the first prediction is true and use the experience of countries following a successful defence of fixed exchange rate regime to separate countries where the debt burden or signalling effects are dominant. We use the Reinhart and Rogoff (2004) index to define the actual changes in the exchange rate regime for 10 emerging economies from 1993Q3 to 2001Q4 and construct a market pressure index in order to identify periods of high pressure in foreign exchange (FX) markets. We then proceed to identify observations where FX market pressure is accommodated (i.e. there is a shift in the regime) and where it is not. Countries where the debt burden effect dominates are subsequently distinguished from others where the signalling effect prevails, based on the behaviour of market expectations following successful defences or actual regime shifts. The theory's main predictions about the impact of debt maturity on the likelihood of crisis and the yield curve are then tested in a dynamic panel framework.

The paper is organized as follows. Section 2 sets out an open-economy stochastic Barro-Gordon model with short-term and long-term debt. Section 3 examines three cases: commitment and non-commitment with symmetric and asymmetric information. Section 4 presents the empirics and section 5 concludes.

2 The Model

We consider a three-period open economy of the Barro-Gordon model where the unexpected inflation that follows a devaluation increases output both through a standard price-output effect and through a tax-reduction effect. As in BM, Obstfeld (1994) and Velasco (1996), we assume that taxes are only levied in the last period and they involve an output cost. These tax distortions increase the incentive to devalue. Following the escape clauses approach of Obstfeld (1997), we assume that output is stochastic to take into account that even a tough policymaker, with a high aversion to inflation, will devalue if the economy is hit by unusually large shocks. We also take the size of a devaluation as given, i.e. independent of the magnitude of the shock, so the authority's choice is between maintaining a fixed parity or a devaluation of a fixed size.

Assuming Purchasing Power Parity and taking the foreign sector as given, it follows that the inflation rate π_t, in periods $t = 1, 2$ equals the rate of devaluation. Therefore, the output in period 1 is given by

$$y_1 = y^* + \alpha(\pi_1 - E_0\pi_1) - k - u_1 \tag{1}$$

where y^* is the target output, $\pi_1 - E_0\pi_1$ is inflation surprise, k is a goods or labour market distortion and u_1 is a supply shock. Under our assumptions, $\pi_t = 0$ when authority maintains fixed parity and $\pi_t = d$ when authority devalues. Thus, the equilibrium level of output under perfect foresight (no shocks) is $y^* - k$, which is considered to be too low by the authority. The output in period 2 is given by

$$y_2 = y^* + \alpha(\pi_2 - E_1\pi_2) - k - T - u_2 \tag{2}$$

where T is the output cost of distortionary taxation required to repay debt $B = B_{10} + B_{20}$, where B_{10} is the one-period (short-term) real debt and B_{20} is then two-period (long-term) real debt issued in period 0.

Consider accumulated short-term and long-term debt, B_{1t} and B_{2t} respectively, at the end of periods $t = 1, 2$. Let r_t be the real interest rate in period t given by $r_t = \iota_t - \pi_t$ to a linear approximation. For nominal inflation-sensitive short-term debt, $\iota_t = E_{t-1}r_t + E_{t-1}\pi_t$, is the nominal interest rate at the beginning of period t demanded by the private sector to achieve an expected real interest rate of $E_{t-1}r_t$. Therefore, $r_t = E_{t-1}r_t - (\pi_t - E_{t-1}\pi_t) = r^* - (\pi_t - E_{t-1}\pi_t)$ where we assume $E_{t-1}r_t = r^*$, the fixed foreign real interest rate. Similarly for long-term debt $r_t = r^* - (\pi_t - E_0\pi_t)$. Let $\mu \in [0, 1]$ be the proportion of inflation-sensitive debt[2]. Assuming $r^* = 0$ for convenience, the levels of short-term and long-term debt at the end of period 2 are given, respectively, by

$$\begin{aligned} B_{12} &= [1 - \mu(\pi_1 - E_0\pi_1) - \mu(\pi_2 - E_1\pi_2)]B_{10} \\ B_{22} &= [1 - \mu(\pi_1 - E_0\pi_1) - \mu(\pi_2 - E_0\pi_2)]B_{20} \end{aligned} \tag{3}$$

At the end of period 2, taxes T must be levied to repay the accumulated debt, $B_{12} + B_{22}$.

[2]See Mandilaras and Levine (2001) for the role of inflation expectations in the determination of inflation-sensitive debt.

Assuming the effect on output to be proportional to debt we then have that $T = \tau(B_{12} + B_{22})$. Normalizing $\tau = 1$ (which implies that debt itself is measured in terms of output loss), using (3) and substituting into (2) yields

$$y_2 - y^* = (\pi_2 - E_0\pi_2)m + (\pi_1 - E_0\pi_1)\mu B - (E_1\pi_2 - E_0\pi_2)S - K - u_2 \tag{4}$$

where $B = B_{10} + B_{20}$ as before, is the real value of total debt at period 0, $m = \alpha + \mu B$, $S = \alpha + \mu B_{10}$ and $K = k + B$ is the expected deviation of output from target. Our basic model is then given by (1) and (4). The output effect of a revision in expectations depends on $S = \alpha + \mu B_{10}$, which increases with short-term inflation-sensitive debt, μB_{10}. If a devaluation leads to an upward revision in the interest rate, then the authority is worse off the shorter the maturity of its debt (the higher S), because short-term debt is refinanced at higher-than-expected interest rates.

At $t = 0$, the authority of type $i = W(\text{Weak}), T(\text{Tough})$ is assumed to minimize an intertemporal loss function:

$$\Omega_0^i = E_0^i[L_1^i + \beta L_2^i] \tag{5}$$

where E_0 denotes expectations conditional on the information in period 0, $0 < \beta < 1$ is the discount factor and L_t^i is a single-period loss function in which the authority weighs the cost of devaluation against the output deviation from the target y^*:

$$L_t^i = \theta^i \pi_t^2 + (y_t - y^*)^2\,;\ t = 1, 2 \tag{6}$$

where θ^i measures the cost of devaluation relative to output for type i and $\theta^W < \theta^T$. From our model, we have that L_1^i and L_2^i are functions:

$$L_1^i \;=\; L_1^i(\pi_1, E_0\pi_1, u_1)\,;\ \ L_2^i = L_2^i(\pi_1, E_0\pi_1, \pi_2, E_0\pi_2, E_1\pi_2, u_2)$$

(in addition to fixed parameters k, y^*, B_{10} and B_{20}) since in period 2 taxes T are repaid.

3 Solving the Model

3.1 Commitment under Complete Information

This section assumes complete information and presents a more general framework than BM that distinguishes between the cases where the monetary authority can commit itself to some predefined rules, and where it cannot commit and thus pursues a discretionary policy. In this sub-section, we first set out this general framework and then we consider the commitment case.

The two-period expected loss function in period 0 can be rewritten as

$$\Lambda_0 = E_0(L_1) + \beta[\rho_1 E_0 L_2(D) + (1 - \rho_1) E_0 L_2(F)] \tag{7}$$

where $\rho_1 =$ probability of a first-period devaluation and $L_2(h)$ is the welfare loss in period 2 following a history $h = D$(Devaluation)$, F$(maintaining the Fixed parity). In what follows we consider ρ_1 and the probability of a second-period devaluation at the end of period 1, $\rho_2(h)$, to be instruments chosen by the monetary authority to minimize its loss. As we will see, this is equivalent to choosing a threshold $\hat{u}_1$ in the first period for the magnitude of negative supply-side shock at which the monetary authority devalues, and a state-contingent shock $\hat{u}_2$, in the second period, which depends on the realization of $\hat{u}_1$ in period 1. Under complete information, the type of the monetary authority is known to the private sector so we suppress the type superscript in this and the next sub-section to ease the notation.

The sequence of events under commitment is as follows. At period 0, the fiscal authority issues fixed-rate one-period (short-term) and two-period (long-term) bonds, including debts denominated in a foreign currency. Given this debt structure, the monetary authority commits itself to the two-period rule consisting of probability of devaluation in period 1, ρ_1 and in period 2, $\rho_2(h), h = D, F$ following a history $h = D, F$ in period 1. The interest rates of the debts are determined by (rational) expectation of inflation rates (rates of devaluation). Then in periods 1 and 2 shocks occur and the authority implements this *commitment rule* to devalue or maintain the parity. At the end of period 1 the one-period debt is rolled over and at the end of period 2 the total debt service is repaid by levying distortionary taxes.

Proposition 1. *Under commitment, the probability of a devaluation in period 2 following a fixed parity in period 1,* $\rho_2(F)$*, is the same as that following a devaluation,* $\rho_2(D)$ *if there is no long-term debt. As the proportion of long-term debt increases, then* $\rho_2(F)-\rho_2(D) > 0$ *and increases. If there is any long-term debt, then* $\rho_2(F) - \rho_2(D) > 0$ *also increases with total debt. (See the Appendix for proof.)*

The intuition behind this result is as follows. The central bank when committing to ρ_1, $\rho_2(D)$, $\rho_2(F)$ implies a commitment to the first-period nominal interest rate (equal to $\rho_1 d$) and the second-period nominal interest rate following first-period devaluation (D) or not (F), equal to $\rho_2(D)d$ and $\rho_2(F)d$ respectively. This is also confirmed by our prerequisites that the realization of the shocks, as well as the monetary authority's decision to devalue or not, are publicly observed under complete information. If there is only short-term debt, then any actions taken by the authority in period 1 (devalue or not) do not have any impact on how the short-term debt is rolled over at end of that period as everything has been defined in the commitment. Therefore, $\rho_2(D) = \rho_2(F)$. However, if there is any long-term debt, then a first period devaluation that follows a sufficiently large negative supply-side shock will erode some of this debt and thereby reduce the need to erode more in the second period. In an intertemporal optimization at time $t = 0$, the policymaker with commitment takes this fully into account with the result that, in the second-period, the history-contingent probabilities chosen at time $t = 0$ have the property that $\rho_2(D) < \rho_2(F)$.

3.2 Discretion under Complete Information

The sequence of events under discretion is now as follows. At period 0, the private sector forms expectations about inflation in periods 1 and 2, which determine the fixed interest rates of the one-period (short-term) and two-period (long-term) bond issues respectively. In period 1, after the realization of the output shock, the monetary authority decides whether to devalue or maintain the fixed parity. At the end of period 1, the one-period debt is rolled over at the interest rate that is determined by the revision of the private sector's expectation of second-period inflation. In period 2, after the realization of a second shock, the authority decides whether to devalue and finally repays the debt by levying distortional taxes. The game tree for this sequence of events is given in Figure 1.

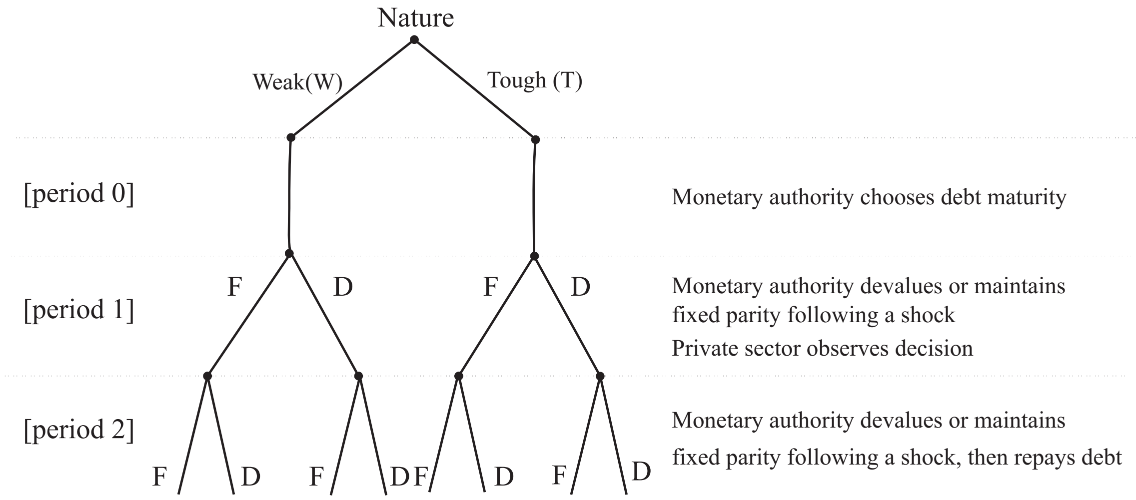

Figure 1: The Game Tree under Discretion.

Proposition 2. *Under complete information and discretion, the probability of a devaluation in period 2 following a fixed parity in period 1, $\rho_2(F)$, is greater than that following a devaluation, $\rho_2(D)$ irrespective of the composition of debt. The difference $\rho_2(F) - \rho_2(D)$ is greater under discretion than under commitment. (See the Appendix for proof.)*

A first-period devaluation causes unexpected inflation, which reduces the real debt burden and thus the expected deviation of second-period output from target. Devaluation also affects the probability of a devaluation in period 2 through a downside revision in expectations and hence a lower-than-expected interest rate at which the short-term debt is rolled over. Thus, a devaluation in period 1 reduces the likelihood of a second-period crisis.

As shown in proposition 1, in the commitment case with complete information, short-term debt cannot act as a channel whereby the first-period devaluation decreases the likelihood of a second-period crisis. In other words, whether the authority devalues in period 1 or not does not affect the probability of a devaluation in period 2 if $B = B_{10}$. But in the case of discretion, current devaluation can ease the debt burden for the future; the short-term debt is crucial to this effect since the benefits of first-period devaluation are magnified by the amount of debt that is rolled over. On the one hand, $\Delta\rho_2^C$ does not depend on B_{10} while on the other hand, a rise in B_{10} increases the difference $\rho_2(F) - \rho_2(D)$ in the discretion case. Therefore, $\Delta\rho_2^D$ is greater than $\Delta\rho_2^C$ as long as there exists some short-term debt.

Proposition 3. *Under complete information and discretion, the probability of a first-period crisis increases with the share of short-term debt* B_{10} *and with the volume of inflation-sensitive debt,* μB*. (See the Appendix for proof.)*

The effect of a history of devaluation or maintaining the fixed rate in period 1 on the probability of a crisis in period 2 depends on the term $S = \alpha + \mu B_{10}$, which increases with short-term debt B_{10}. A higher proportion of short-term debt makes maintaining the fixed parity in the first period more costly leading to a greater chance that the monetary authority might choose to devalue in period 1. The intuition for that is that more short-term debt makes the inflation rate, which is expected after maintaining the parity, higher while making inflation expected after a devaluation lower. In other words, long-term debt can minimize the probability of an exchange-rate devaluation in the first period when the monetary authority's preferences are known to the market.

These results yield testable predictions regarding the yield curve $(E_0\pi_1, E_0\pi_2)$. As can be shown from (A-28), the expected second-period inflation rate increases with the total volume of debt, B, and with the proportion of inflation-sensitive debt μ, but is independent of its maturity structure. Combined with the previous proposition we then have:

Proposition 4. *The expected second-period inflation rate increases with the total volume of debt and the ratio of inflation-sensitive debt, but is independent of its maturity structure. Together with proposition 3 this implies that in the discretion case under complete information, the yield curve becomes flatter as the proportion of short-term debt increases.*

3.3 Discretion under Asymmetric Information

We now consider the case where monetary policy is conducted by a monetary authority with preferences unknown to the public. We assume there are two possible types of authorities: a 'tough' authority with a relatively high weight on inflation in (6) $\theta = \theta^T$, and a 'weak' authority with preference parameter $\theta^W < \theta^T$. As discussed above, one interpretation of this asymmetric information is that the authority with preference $\theta = \theta^T$ *delegate* to an independent 'conservative' banker in the Rogoff-sense with $\theta^T > \theta^W$, but the credibility of this central bank independence from the authority needs to be tested by the public in a process of Bayesian learning.

The solution to the discretion case under asymmetric information follows the complete information case, proceeding by backwards induction starting in period 2 but with the following changes: the probabilities of devaluation ρ_1^i, $\rho_2^i(D), \rho_2^i(F)$, $i = T, W$ are now type-dependent; in periods $t = 0, 1, 2$, the private sector attaches a probability q_t that the authority is tough (i.e., $\theta = \theta^T$) and a probability $1 - q_t$ that it is weak ($\theta = \theta^W$); in period 0 the private sector has a prior q_0 which is up-dated at the end of each of the following two periods observing devaluation D or a maintenance of the fixed exchange rate F and the realization of output shocks $u_t, t = 1, 2$ occurring during the period. It is also assumed that the debt maturity is the same for both types of authorities and so are their interest rates, $E_0\pi_1$ and $E_0\pi_2$. Then, following the first-period shock, each type of monetary authority will decide to devalue or not taking into account the impact of this decision on the beliefs of the private sector entering period 2.

Proposition 5. *Under discretion and asymmetric information, the credibility of the exchange regime is increased by a successful defense if and only if the difference between preferences, $\theta^T - \theta^W$, is large relative to the level of deflatable debt, μB. Moreover, the difference in probabilities $\rho_2(F \cap u_1) - \rho_2(D \cap u_1)$ is* less *than that under complete information owing to the* signalling effect *which depends on the degree of uncertainty $\theta^T - \theta^W$. (See the Appendix for proof.)*

This result follows because reputation considerations provide both type of authorities with an incentive to defend the exchange rate—for a tough authority to signal its type, and for a weak one in order to pretend to be tough. The greater the difference in the authority's preferences $\theta^T - \theta^W$ is, the stronger is the incentive.

3.3.1 Separating Equilibrium and Short-term Debt

The characterization of the possible equilibria when the private sector can make inferences observing the authority's actions, *and* the shock is rather complicated involving pooling or separating equilibria depending on the realization of u_1. Here, we follow the simplifying assumption of Drazen and Masson (1994) and assume that the realization of the shock u_1 cannot be inferred by the private sector at the beginning of period 2 (for example, as a result of the delayed publication of output data). Then the equilibrium is separating in strategies with the two types choosing different probabilities of devaluation in period 1 and history-dependent probabilities in period 2 given by (A-36) and (A-38) respectively.

Note that this assumption does not imply that the tough authority will never devalue or that a weak authority always devalues. In fact, both types of authorities will choose to devalue if the economy is hit by shocks that exceed their respective threshold levels and similarly neither will devalue if shocks are small. But since these shocks are not observed by the private sector, the equilibrium, although separating in shock-dependent strategies, does not reveal the type of policymaker with certainty.[3]

Proposition 6. *In the case of discretion under asymmetric information, the probability of a first-period devaluation increases with the proportion of short-term debt if the debt burden effect dominates. If the signalling effect dominates, the probability decreases with the proportion of short-term debt. Both effects are magnified by the volume of inflation-sensitive debt, μB. (See the Appendix for proof.)*

The reason why a short maturity of debt is crucial to the signalling effect is that it can bolster market confidence that the parity will be maintained. In this case, an increase in short-maturity debt –i.e. a larger μB_{10}– compels the monetary authority to resist a crisis in order to avoid rolling over the debt at a new higher interest rate. That is because a first-period devaluation increases market expectations of a second-period devaluation (and thus the interest rate) when the signaling effect dominates. However, when there is little uncertainty about the authority's preferences, the probability of a first-period devaluation increases with short-term debt, as it does under complete information.

Hence, together with (A-40) we have

Proposition 7. *If the uncertainty about the authority's type is substantial, a higher ratio of short-term debt implies a lower short-term interest rate and a steeper yield curve as the forward rate keeps constant. On the other hand, when there is little uncertainty about the authority's preferences, a short maturity leads to a higher current interest rate and thus a flatter yield curve, as in the case of complete information. (See the Appendix for proof.)*

[3] In the analysis of BM shocks are observed by the private sector. Then there are pooling equilibria where, for low realizations of shocks, both policymakers maintain the parity with probability 1 and, for large shocks, both devalue with probability 1. There also exists an intermediate range of shocks for which, in a separating equilibrium, a devaluation by the weak reveals its type and another higher range where maintaining the parity leads to the conclusion that the type must be tough.

4 The Empirics

4.1 Data and Methodology

In this section, we explore quantitatively the key predictions of the theory focusing on the role of short-term debt. We have seen that the effects of a successful defence of the peg on the credibility of the exchange rate regime will depend on whether asymmetric information or a high debt burden is the government's biggest problem (see proposition 5). Since we cannot observe asymmetric information directly, categorizing countries in one group or the other poses a challenge.

We overcome this difficulty in two steps: first, we identify periods of high pressure in the foreign exchange (FX) market and observe whether they have led to an actual change in the exchange rate regime. If the regime has remained unaltered following a period of increased FX pressure we classify the episode as 'successful defence'; if, on the other hand, increased FX activity has led to a more flexible regime, we classify the episode as 'accommodation'.

Second, we check the movement of the interest rate differential with the US following a successful defence or accommodation. Depending on whether the differential has increased or decreased we classify the economy as a debt burden or signalling economy. Using this rather *ad hoc* but sufficiently realistic classification procedure we are able to test the remaining two key predictions of the model. Namely, we examine the effect of short-term debt on the likelihood of a first-period devaluation and on the slope of the yield curve. The methodology employed is that of Arellano and Bond (1992).

The data on the level and structure of debt are from the *Bank for International Settlements* website. We obtain quarterly observations from the fourth quarter of 1993 to the third quarter of 2003 for all developing/emerging economies featured in the database: Argentina, Brazil, the Czech Republic, Hong Kong, Hungary, India, Malaysia, Mexico, Peru, Philippines, Poland, Russia, Singapore, South Africa, South Korea, Taiwan, Thailand and Turkey. Data on the rest of the control variables (these include monetary, fiscal and international liquidity indicators) are from the IMF's *International Financial Statistics*. The monthly exchange rate regime index is from Reinhart and Rogoff (2004); we convert this to a quarterly index to match the frequency of the dataset. Annual GDP

Table 1: Average Values

Countries	debtgdp	sstdebt	sintdebt	ir	resgdp	cabalgdp	qmongdp	class
Argentina	24.41	10.69	56.26	7.14	6.76	-0.37	18.98	S*
Brazil	38.06	47.48	6.72	24.39	7.01	-0.01	93.86	DB*
Czech Rep.	29.99	84.35	5.50	7.79	22.35	1.10	162.76	DB*
Hong Kong	NA	76.27	NA	5.47	NA	NA	NA	S
Hungary	NA	32.24	43.03	17.20	NA	NA	NA	NA
India	NA	10.21	NA	9.00	7.89	0.45	NA	S
Malaysia	37.20	6.03	8.24	4.06	33.85	0.92	270.34	S*
Mexico	15.86	44.89	28.07	19.66	6.49	0.13	NA	DB
Peru	NA	100.00	NA	16.14	16.50	0.15	72.20	DB
Philippines	37.53	28.27	15.74	11.12	13.99	0.38	174.38	S*
Poland	21.59	31.93	4.08	19.02	13.19	0.20	97.09	DB*
Russia	NA	52.26	26.71	15.37	NA	NA	NA	NA
Singapore	NA	43.59	0.98	2.56	NA	NA	NA	DB
South Africa	45.93	15.30	6.03	12.13	3.22	0.36	NA	DB
South Korea	13.23	20.12	4.17	8.68	13.34	0.68	190.20	S*
Taiwan	NA	9.99	NA	4.98	NA	NA	NA	NA
Thailand	10.34	9.73	30.17	3.47	23.96	0.08	321.06	DB*
Turkey	35.45	46.91	27.92	69.82	10.65	NA	NA	DB

Notes: All numbers are means (values for *ir* are medians). Fewer than 10 observations for a variable result in a NA entry. *debtgdp* is the sum of domestic debt issued by national governments (taken from BIS, table 16A) plus international bonds and notes (BIS, table 15B), expressed as a percentage of GDP. *sstdebt* is the value of domestic debt securities issued by national governments with remaining maturity up to one year (BIS, table 17), expressed as a share of domestic government debt. *sintdebt* is the sum of debt issued by non-residents plus debt issued by residents if it is in foreign currency or it is targeted at non-residents (BIS, table 15B). *ir* is the Treasury Bill rate (or another short-term interest rate if this is not available), *resgdp* is the value of total reserves minus gold as a fraction of GDP, *cabalgdp* is the current account balance as a fraction of GDP and *qmongdp* is the value of quasi-money, again as a fraction of GDP. Finally, the last column indicates whether a country is classified as 'signalling' or 'debt-burden' according to the procedure described later in the text. A (*) indicates that the country is used in the estimations.

data in US dollars, collected from the *World Development Indicators* of the World Bank, were interpolated with cubic splines to produce an approximation of the quarterly series. Descriptive statistics, along with variable definitions and more details on the debt data sources are presented in Table 1. Note that as a result of the lack of data on debt and/or GDP for some of the countries in the dataset the actual estimations were carried out with a subset of countries.

We employ the difference between the domestic money market interest rate and the USA fed funds rate to represent the probability of a current crisis as perceived by the market. This measure follows Drazen and Mason (1994) and BM.[4] An approximation of

[4]It has to be noted that the use of this measure, especially in relevance to emerging economies, is not

the yield curve is obtained by dividing the forward interest rate by the current market interest rate (we use the government long-term bond yield as a proxy for the former).

We gauge pressures in the FX market through the use of a market pressure index (MPI). The theoretical roots of the index can be found in an analysis of demand and supply of national currencies in Girton and Roper (1977), where the term "exchange market pressure" was first used. Here, we use a variation of the Eichengreen *et al.* (1996) index. It is calculated as

$$MPI_{it} = \alpha_i \times XR_{it} + \beta_i \times DIR_{it} - \gamma_i \times RES_{it}.$$

for country i, where XR is the change in the log of the nominal exchange rate with the US dollar, IRD is the change in the domestic interest rate, RES is the change in the logarithm of international reserves excluding gold (in US dollars), and the weights α, β and γ are determined by calculating

$$\left(\frac{1}{sd_j}\right) / \left(\frac{1}{sd_{XR}} + \frac{1}{sd_{DIR}} + \frac{1}{sd_{RES}}\right)$$

where $j = XR, IRD, RES$ and sd stands for the standard deviation. Higher values of the index indicate mounting FX pressures. The next stage of the empirical analysis is to distinguish between countries depending on whether the debt burden or signalling effects dominate.

4.2 Measuring the Debt Burden and Signalling Effects

We know from the theory that when there is substantial uncertainty about the government's type, a strenuous defense of the exchange rate can signal the government's commitment and, as a result, enhance the credibility of the exchange rate regime; but with the debt burden effect prevailing, this policy worsens fundamentals by increasing the real value of debt, making the economy more vulnerable to adverse shocks in the future.[5]

entirely innocuous. It is used, however, in the absence of a better alternative.

[5]Other candidate explanations of why a debt-burden country's decision to defend the currency in the face of FX market pressure increases the likelihood of a future devaluation include the possibility that successfully defending countries may fail to implement institutional reforms in contrast to countries that have 'learnt their lesson' (by unwillingly devaluing). However, in the empirical implementation we confine ourselves to using the specific predictions of our extension of BM's theory.

The first step in determining the relative importance of the two effects for each country is to identify instances of successful defence or accommodation of FX pressure in the data. We use the MPI to represent FX market pressure. If an observation exceeds the mean value plus 1.5 times the standard deviation of a series of a country, then it is classified as a crisis observation. More succinctly:

$$Crisis = \begin{cases} 1 & \text{if } MPI \geq mean(MPI) + 1.5 \times sd(MPI) \\ 0 & \text{if } MPI < mean(MPI) + 1.5 \times sd(MPI) \end{cases}$$

In this way, we construct a binary crisis index for each country in the sample.[6] We now need to observe the reaction of the policymaker to the excess FX pressure. Has there been a policy change with regard to the exchange rate arrangements (i.e. a 'softening' of the exchange rate regime) or has there been no change at all?

We obtain the required information from Reinhart and Rogoff (2004) who offer a comprehensive *de facto* classification of exchange rate regimes.[7] We employ their 'coarse' index, which registers substantial shifts in the regime –see Table 2. If there is a move towards a softer regime within the crisis quarter or the next, then we consider the reaction of the policymaker as accommodating. If the exchange rate regime remains unchanged then we consider it as successful defence.[8]

Next, we examine the interest rate differential with the US following a successful defence or accommodation of the pressure. We classify the countries in two groups depending on the direction of movement of the differential. As indicated in Proposition 5, countries where the debt burden is more important than signalling will find that a current devaluation increases the probability that a future defense of the new parity will succeed. In other words, we should observe a drop in the market interest rate differential following accommodation (and a rise following a successful defence).

On the other hand, in countries facing substantial uncertainty over the authority's

[6]This is not the only way to classify observations as crisis or non-crisis. A Markov-switching estimation with two regimes can also determine whether an observation belongs to a 'crisis' or 'non-crisis' distribution. The resulting classification is similar to the one we obtain using the above formula.

[7]Note that the use of this index restricts the time dimension of the data to the fourth quarter of 2001.

[8]There is only one instance where a crisis is followed by a tightening of the regime. This takes place in the beginning of the sample for Brazil and we ignore it as it is also accompanied by excessive interest rate movements.

Table 2: Classification of Exchange Rate Regimes

Regime	**Index**
No separate legal tender	1
Pre announced peg or currency board arrangement	1
Pre announced horizontal band that is narrower than or equal to +/-2%	1
De facto peg	1
Pre announced crawling peg	2
Pre announced crawling band that is narrower than or equal to +/-2%	2
De facto crawling peg	2
De facto crawling band that is narrower than or equal to +/-2%	2
Pre announced crawling band that is wider than or equal to +/-2%	3
De facto crawling band that is wider than or equal to +/-5%	3
Moving band that is wider than or equal to +/-2%	3
Managed floating	3
Freely floating	4
Freely falling	5
Dual market in which parallel market data is missing	6

Source: Reinhart and Rogoff, 2004.

resolve not to devalue, accommodation of FX pressure would reveal a weak authority possibly heading towards further devaluations. This generates inflationary expectations and a higher interest rate differential. In contrast, resisting a crisis enhances the credibility of the authority and the expectation that the parity will be maintained. Therefore, the interest rate spread in signalling countries rises after a crisis and drops after a successful defence.

We implement the classification procedure as follows. Subsequent to a defence or accommodation incident we define three time windows of two, four and six observations, respectively. We then compare the average interest rate differentials during these time windows to the average of the differentials during the corresponding number of quarters *prior* to the incident. If the average differential after a successful defence (accommodation) is higher (lower) compared to its average value before the incident then the country is classified as debt burden. Otherwise, it is classified as signalling.[9] For example, Argentina experienced high FX pressure in the first quarter of 1995, which was followed by lower differentials than before the crisis –see Figure 2. As the exchange rate regime did not

[9]Occasionally, the decision to classify a country as signalling or debt burden is sensitive to the time window. As an example, the two-quarter horizon may give a conflicting outcome to the six-quarter horizon. In such cases, we classify the country according to the outcome of the remaining horizon (e.g. the four-quarter one).

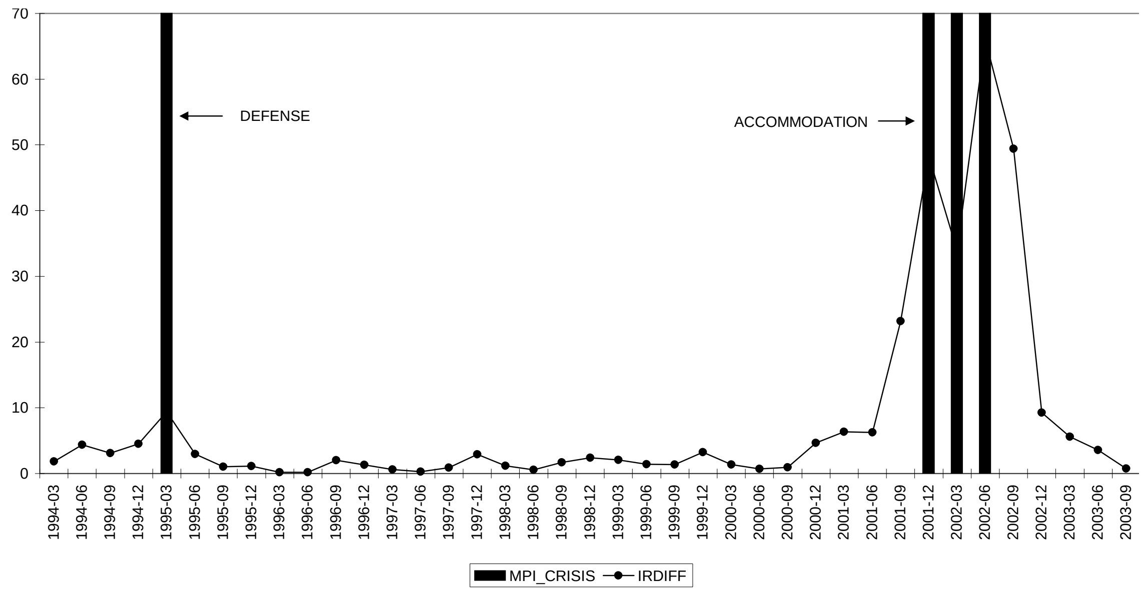

Figure 2: Argentina, a Signalling Country

change during or shortly after the crisis, the lower differential following the successful defence indicates that the signalling effect prevailed. A few years later in the last quarter of 2001, there was another crisis, which this time was accommodated, as the peg was abandoned. The subsequent increase in the interest rate again indicates that the signalling effect dominates the debt burden effect.[10]

This procedure places Argentina, Hong Kong, India, Malaysia, the Philippines and South Korea in the signalling group and Brazil, the Czech Republic, Mexico, Peru, Poland, Singapore, South Africa, Thailand and Turkey in the debt burden group.[11]

4.3 The Effects of Short-term Debt

When there is little uncertainty over the authority's preferences and the level of debt is high, a devaluation leads to a lower interest rate. Thus, the likelihood of a first-period devaluation increases with the share of short-term debt, as the greater the amount of short-term debt there is to be rolled over, the greater is the incentive to devalue and exploit the lower rate. On the other hand, when the uncertainty about the authority type

[10] Of course, there is nothing in principle that would preclude a country from facing both signalling and debt burden effect episodes. We turn to this issue in the econometric analysis.

[11] Hungary, Russia and Taiwan cannot be classified, as they have not registered a crisis in the period 1993:Q3–2001:Q4.

is substantial, a lower interest rate results from the decision not to devalue. In that case, the probability of a first-period devaluation decreases with the proportion of short-term debt. Therefore, the effect of the debt maturity on the probability of a current devaluation depends on whether the signaling or the debt burden effect prevails (see Proposition 6).[12]

Equation (A-40) shows that the expected second-period devaluation formed in period 0 is independent of the debt maturity. In other words, the proportion of short-term debt does not affect the forward interest rate, which only depends on fundamentals. The reputational incentive lowers the short-term interest rate but has no impact on the forward rate. Therefore, when there is substantial uncertainty about the authority's preferences, a higher ratio of short-term debt implies lower current interest rates and a steeper yield curve. In contrast, if the fundamentals outweigh the reputational considerations, a higher proportion of short-term debt is associated with higher current interest rates and a flatter yield curve (see Proposition 7).

Graphs of the debt to GDP ratio, the share of short-term debt and the interest rate differential for the countries included in the estimations for the signaling and debt-burden groups are presented in Figures 3 and 4, respectively. Inspection of these figures in conjunction with the descriptive statistics in Table 1 reveals that on the aggregate level the two groups do not seem to differ in any particular way in terms of the model's key variables.

The methodology we adopt to test the predictions discussed above is the generalized method of moments (GMM) for dynamic panel data (see Arellano and Bond, 1991). The specification is of the form

$$y_{it} = \alpha y_{i(t-1)} + x'_{it}\beta + \lambda_i + \epsilon_{it} \tag{8}$$

where y_{it} is the dependent variable, x'_{it} is a vector of explanatory variables, λ_i represents country-specific effects and ϵ_{it} is a non-autocorrelated error term.

As Arellano and Bond (1991) argue, when ϵ_{it} is heteroscedastic, simulations suggest that the asymptotic standard errors for the two-step estimators can be a poor guide for hypothesis testing in typical sample sizes. In our case, both the interest rate differential

[12]Of course, the considerations affecting the decision about the maturity structure of public debt are not exhausted in analyzing its potential effects on the government's reputation and the real value of public debt. Other factors, like the cost of borrowing in international markets, are likely to play an important role as well –see, e.g. Broner *et al.* (2004).

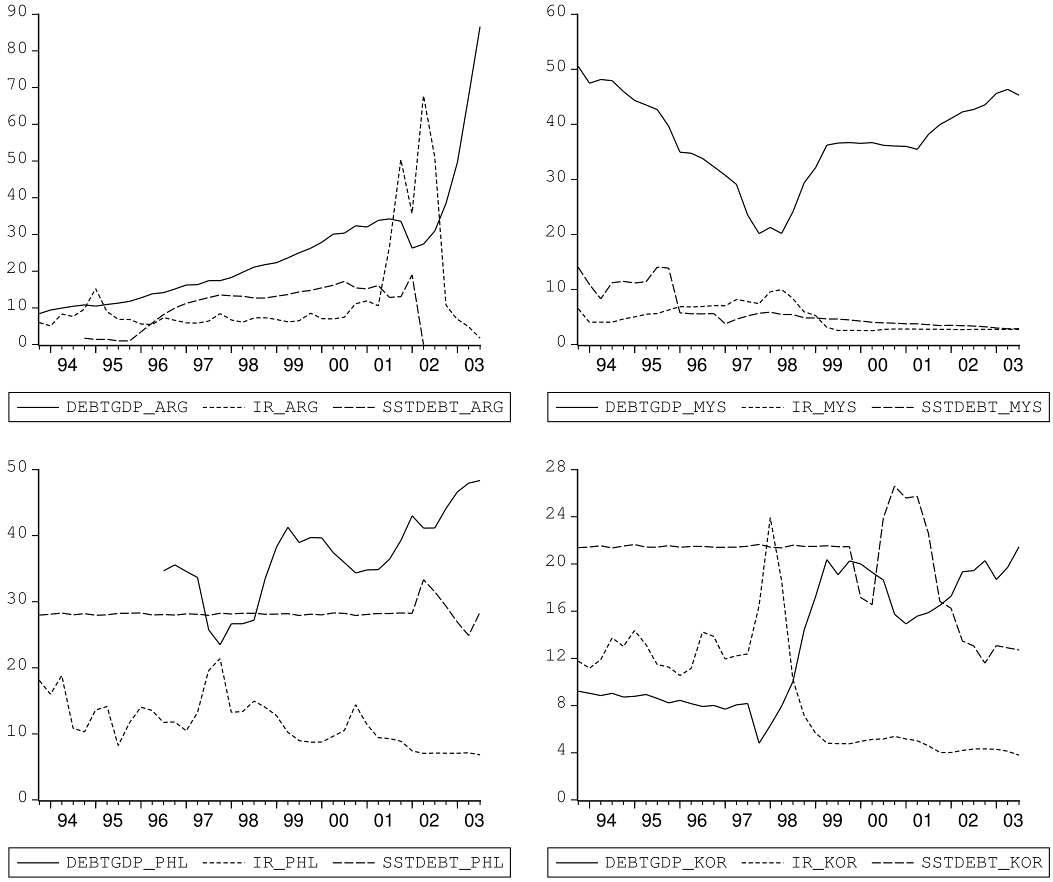

Figure 3: Signalling Countries – Argentina, Malaysia, Philippines and Korea

and our measure for the yield curve appear to be more volatile during crises compared to the relatively stable periods. Therefore, we focus on the one-step GMM estimators with the asymptotic heteroscedasticity consistent standard errors, for which the inference tests are more reliable.[13]

The first set of regressions involves the interest rate differential with the US (*irdif*) on the left hand-side, as a measure of devaluation expectations. If the market perceives that the probability of a devaluation has increased, then the differential should rise. The explanatory variables include the lagged dependent variable, the share of short-term debt as a fraction of domestic debt (*sstdebt*), the debt to GDP ration (*debtgdp*) along with monetary and international liquidity variables as controls. These include the reserves to GDP ratio (*resgdp*), the current account balance as a fraction of GDP (*cabalgdp*) and

[13]See Blundell and Bond (1998) for further discussion.

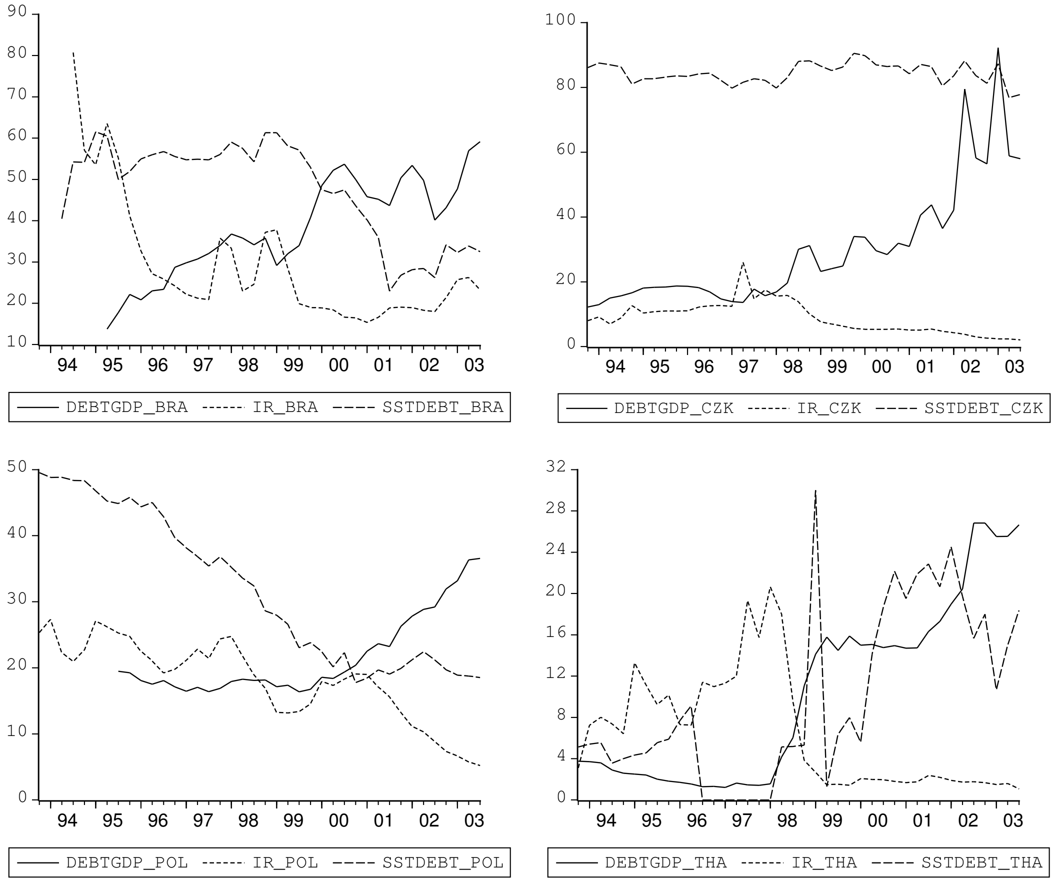

Figure 4: Debt-burden Countries – Brazil, Czech Republic, Poland and Thailand

the ratio of quasi money to GDP (*qmongdp*).[14] The RHS variables were chosen for their intuitive relevance and are often cited in the currency crisis literature as important determinants of crises.[15] A higher current account deficit and amount of money, as well as lower international reserves should *ceteris paribus* lead to a higher domestic interest rate. The results for the signalling and debt burden groups are shown in the first two columns of Table 3.

They indicate that in countries where the relative importance of debt is higher than the

[14]We have not been able to obtain data on foreign currency debt. Instead, we used the share of international debt (which, in addition, contains domestic currency debt issued by foreign residents or aimed at foreign residents) as a proxy in the above regressions. The results were either counter-intuitive or insignificant.

[15]The currency crisis literature is considerable and a more detailed review would be beyond the scope of this paper. The role of our chosen control variables in the context of crisis models is examined in several empirical contributions; see, among others, Sachs *et al.* (1996), Kaminsky *et al.* (1998) and Kumar *et al.* (2002).

uncertainty over the authority's preferences, the probability of a crisis increases with the ratio of short-term debt. In contrast, in the signalling group, the relationship between the probability of a crisis and the ratio of short-term debt is negative, as predicted by BM's theory. The lagged dependent variable is highly significant in both regressions, indicating a degree of persistence in the direction of movement of the differential. The debt to GDP ratio does not appear to have a significant effect on the probability of crisis. Reserves enter the debt burden equation with the right sign but the coefficients are insignificant. The current account balance is rightly signed in both equations but is significant only in the debt burden group. The quasi money variable is incorrectly signed, but significant only in the signalling group.

Could these results be the outcome of reverse causality? For example, it could be argued that fears of a devaluation may induce higher holdings of short-term debt by investors. In the signalling regression this line of argument would predict a positive sign for *sstdebt*. However, what we find and report is a negative coefficient. Hence, there is strong *prima facie* evidence that the results for the signalling group capture the effects described in Proposition 6. In the debt burden regression, changes in the expectation of devaluation will only have an effect on newly issued debt, which is a small proportion of outstanding debt. Even if there is an issue with endogeneity in the levels relationship the first-differences transformation that has been applied should successfully deal with the issue.

The second set of regressions has a measure of the term structure of interest rates on the LHS. We use as a proxy the long-term government bond yield divided by the short-term (money market) interest rate. We have shown that emerging economies facing substantial uncertainty about the government's type should reap lower short-term interest rates when they show their anti-inflation intentions with a shorter maturity. As the long-term rate is determined only by fundamentals, these countries should face a steeper yield curve. In contrast, in countries where the levels of debt are high relative to the uncertainty over preferences, the short-term interest rates are higher because the incentive to roll over large amounts of maturing debt at a lower-than-expected rate is greater. As a result of the fact that the debt maturity does not affect the forward rate, these countries face a flatter yield curve.

Table 3: GMM Estimation Results

Variable	**I(a)**	**I(b)**	**II(a)**	**II(b)**
lag dependent	0.58***	0.84***	0.61***	0.61***
	(0.12)	(0.08)	(0.02)	(0.02)
sstdebt	-1.29**	0.10**	2.31*	-0.55***
	(0.54)	(0.04)	(1.24)	(0.08)
debtgdp	0.03	0.04	-1.20**	-1.98
	(0.37)	(0.05)	(0.58)	(1.55)
resgdp	-0.27	-0.29	3.83***	7.58*
	(0.41)	(0.25)	(0.47)	(3.94)
cabalgdp	-0.61	-0.91**	2.03	7.06***
	(0.54)	(0.42)	(1.21)	(1.46)
qmongdp	-0.04**	-0.06	-0.02	0.90***
	(0.01)	(0.04)	(0.09)	(0.07)
N	122	123	79	51
Panels	4	4	3	2

Notes: Panels are unbalanced. The dependent variable in regressions I(a) and I(b) is the (short-term) interest rate differential with the US; in regressions II(a) and II(b) it is the domestic long-term government yield divided by the domestic short-term rate. (a) denotes signalling countries and (b) denotes debt burden countries. Parameters with '***' are significant at the 1% level, '**' at the 5% level and '*' at the 10% level. Estimators are one-step GMM estimators, with p-values based on their asymptotic heteroscedasticity consistent standard errors (reported in parentheses). The transformation applied is the first difference of the level equations.

Results of the estimations are reported in the last two columns of Table 3. We have kept the methodology and RHS the same as in the previous estimations. With the qualification that the sample size reduces substantially due to lack of sufficient data on long-term yields, it appears that a shorter maturity of debt steepens the yield curve of the signalling countries, whereas it flattens the yield curve of the debt burden countries, both effects consistent with the theory. The sign of the debt ratio is negative, which implies that the long term effect of increased indebtedness is to increase the long rates. However, this effect is only significant for the signalling countries. The rest of the control variables do not feature in the theoretical model so interpreting their effects should be done with caution. Assuming that changes in the current account balance and the level of reserves only affect short rates, the results are as expected. The results regarding the effect of *qmongdp* are more ambivalent, with the significant coefficient in the debt burden regression having an incorrect sign.

As a further check, we included in all four regressions a variable capturing the *size* of devaluation. This was created by interacting a dummy variable capturing the crisis incidents in the sample with a variable measuring the percent change in the exchange rate over time. The estimated coefficient of this variable was insignificant in all regressions with the exception of I(b): in the debt burden group, the size of devaluation is positively associated with the probability of a current crisis. The rest of the estimated parameters (including *sstdebt*) retain their significance and magnitude of effects in all estimations and, hence, the empirical results reported in Table 3 are robust to the inclusion of the size of devaluation. However, the significance of the size parameter in one of the equations should serve as a stimulus for further research on the theoretical conjecture of fixed size devaluations.

At this point it would be useful to raise a caveat: the categorization of a country as signalling or debt burden following a given crisis incident cannot be thought of as being permanent. After all, policymakers and their policies change and subsequent episodes may have different effects. This line of thinking would be consistent with a different approach, where instead of classifying countries one would need to classify episodes. Intuitively, however, this would not make a difference in our dataset, as most countries only experience one crisis incident; for those countries facing more than one crisis incidents the effects are not in conflict with each other and consistent categorization is facilitated. This may not be the case with larger datasets.

A final limitation of the empirical analysis is that it does not allow for the effects of a successful (or unsuccessful) defence on policymakers' attitudes towards structural reforms. These reforms could be limited to the fiscal side (in an effort to induce debt sustainability) or include broader supply-side changes to stimulate output and increase revenues. If structural reforms are indeed implemented as a result of exposure to currency crises then the equations in table 3 may be misspecified. However, there is not conclusive evidence available about the extent and effectiveness of such reforms and their role in limiting future devaluations. We leave this interesting issue for future research.

Summarizing, the econometric analysis has provided evidence of support for propositions 6 and 7. In the next section, we offer some concluding remarks.

5 Conclusions

As shown in Benigno and Missale (2004) whether a future devaluation is more likely following a successful defence of the parity is uncertain and depends on the relative importance of the effects on the government's reputation ('signalling' effects) vis-a-vis the effects on the real value of public debt ('fundamental' effects). In this paper we revisit BM's results and adopt a more general framework that allows us to distinguish between commitment and discretionary optimal escape clauses.

We then define an empirical framework in which the main predictions of the theory are tested. More specifically, we examine the hypothesis that the share of short-term debt has different effects on the probability of a currency crisis depending on whether signalling or fundamental effects are dominant. A related hypothesis concerning the effect of the share of short-term debt on the slope of the yield curve is also tested. GMM estimation of a dynamic panel specification provides substantial evidence in support of the predictions of the theory.

The lack of data, especially in relation to debt, has limited the country coverage of the empirical analysis. But even though the tests in the paper are far from comprehensive, they do constitute a first step in the direction of understanding the tension between signalling and debt effects in the real world.

A Proofs

Proposition 1: Let $f(u)$ be the probability density function for the disturbance $u_t, t = 1, 2$ in (1) and (4). Then the probability, at the beginning of period 1, of a second-period devaluation is given by

$$\rho_2(h) = \Pr[u_2 > \hat{u_2}(h)] = \int_{\hat{u}_2(h)}^{\infty} f(u)du \tag{A-1}$$

where $\hat{u}_2(h)$ is a threshold value such that if $u_2 > \hat{u}_2(h)$ devaluation occurs in period 2. As before, the index $h = D, F$ indicates that the authority devalued or maintained the fixed parity in period 1. We assume that the shock u_2 is uniformly distributed over the interval $[-v, v]$, then $f(u) = \frac{1}{2v}$. So we can rewrite (A-1) as

$$\rho_2(h) = \frac{v - \hat{u}_2(h)}{2v} \tag{A-2}$$

where $\hat{u}_2(h) \in [-v, v]$. Similarly the probability of a devaluation in period 1 is

$$\rho_1 = \frac{v - \hat{u}_1}{2v} \tag{A-3}$$

If the bounds for the shocks are large then $\rho_1, \rho_2(h) \in [0, 1]$ is ensured. In fact in what follows we assume that $2v > dm$ which (recalling $m \equiv \alpha + \mu B$ and $S \equiv \alpha + \mu B_{10}$) implies that $2v > dS$.

The expected inflation in period 2 formed in period 1 is now

$$E_1\pi_2(h) = d\rho_2(h) + 0 \times (1 - \rho_2(h)) = d\rho_2(h) \tag{A-4}$$

Using backward induction, we can then obtain the expectation of inflation in periods 2 and 1 formed at in period 0:

$$\begin{aligned} E_0\pi_2 &= \rho_1 E_1\pi_2(D) + (1 - \rho_1)E_1\pi_2(F) = [\rho_1\rho_2(D) + (1 - \rho_1)\rho_2(F)]d & \text{(A-5)} \\ E_0\pi_1 &= \rho_1 d & \text{(A-6)} \end{aligned}$$

The expected inflation rates ($E_0\pi_1$, $E_0\pi_2$) are then a measure of the *yield curve* over the 2 periods. Integrating $L_2(h) = \theta\pi_2^2 + [y_2(h) - y^*]^2$ over the interval $[-v, v]$ and using (A-3), we can evaluate the expected loss $E_1L_2(h)$ in period 2, $h = D, F$, as

$$E_1L_2(h) = \frac{1}{2v}\left\{\int_{-v}^{\hat{u}_2(h)} (y_2 - y^*)^2\, du_2 + \int_{\hat{u}_2(h)}^{v} [\theta d^2 + (y_2 - y^*)^2]\, du_2\right\} \tag{A-7}$$

because $\pi_2 = 0$ if $h = F$, and $\pi_2 = d$ if $h = D$. This expectation in period 1 is formed knowing the history $h = D, F$, but not yet knowing the realization of the shock u_2.

After considerable algebra we obtain from (A-7):

$$E_1L_2(h) = \frac{v^2}{3} + [\Pi(h)]^2 + d\rho_2(h)[\theta d + 2m\Pi(h) + 2mv(\rho_2(h) - 1) + dm^2] \tag{A-8}$$

where $\Pi(h) = -mE_0\pi_2 + (\pi_1(h) - E_0\pi_1)B - (E_1\pi_2(h) - E_0\pi_2)S - K$, which depends on the history $h = D, F$ at the end of period 1. We can now rewrite (4) as

$$y_2 - y^* = m\pi_2 + \Pi(h) - u_2 \tag{A-9}$$

In period 0, the expected welfare loss for the first period is

$$E_0 L_1 = \frac{1}{2v}\left\{\int_{-v}^{\hat{u}_1} (y_1 - y^*)^2 \, du_1 + \int_{\hat{u}_1}^{v} [\theta d^2 + (y_1 - y^*)^2] \, du_1\right\} \tag{A-10}$$

Let $\Theta = -\alpha E_0 \pi_1 - k = -\alpha\rho_1 d - k$. Then $y_1 = y^* + \alpha(\pi_1 - E_0\pi_1) - k - u_1 = y^* + \alpha\pi_1 + \Theta - u_1$. Then using (A-8), we can rewrite $E_0 L_1$ as

$$E_0 L_1 = \frac{v^3}{3} + \Theta^2 + d\rho_1[\theta d + 2v\alpha(\rho_1 - 1) + 2\alpha\Theta + \alpha^2 d] \tag{A-11}$$

Note that $E_0 L_2(h) = E_0(E_1 L_2(h)) = E_1 L_2(h)$, since $L_2(h)$ is independent of the first-period shock u_1 that is the only random variable in period 1.

Substituting from (A-4) – (A-6) and noting that $m = \alpha + \mu B = \alpha + \mu(B_{20} + B_{10})$, $S = \alpha + \mu B_{10}$, we arrive at

$$\Pi(F) = -\mu B_{20}(\rho_1\rho_2(D) + (1-\rho_1)\rho_2(F))d - \rho_1 d\mu B - \rho_2(F) dS - K \tag{A-12}$$

$$\Pi(D) = -\mu B_{20}(\rho_1\rho_2(D) + (1-\rho_1)\rho_2(F))d + (1-\rho_1) d\mu B - \rho_2(D) dS - K \tag{A-13}$$

It is convenient to treat these expressions as *constraints* that the monetary authority faces when it minimizes its loss function Λ_0 with respect to its instruments $\rho_1, \rho_2(h)$ in period 0. Therefore, we form a Lagrangian:

$$\begin{aligned}\mathcal{L}_0 &= \Lambda_0 + \lambda_F(\Pi(F) + \mu B_{20}(\rho_1\rho_2(D) + (1-\rho_1)\rho_2(F))d + \rho_1 d\mu B + \rho_2(F) dS + K) \\ &+ \lambda_D(\Pi(D) + \mu B_{20}(\rho_1\rho_2(D) + (1-\rho_1)\rho_2(F))d - (1-\rho_1) d\mu B + \rho_2(D) dS + K)\end{aligned} \tag{A-14}$$

Minimizing $\mathcal{L}_0$ with respect to $\rho_1, \rho_2(h), \Pi(h)$, the five first-order conditions (f.o.c.) are:

$$\begin{aligned}\frac{\partial \mathcal{L}_0}{\partial \rho_1} &= d[(\theta + \alpha^2)d + 2\alpha\rho_1(2v - \alpha d) - 2\alpha v)] + \beta(E_0 L_2(D) - E_0 L_2(F)] \\ &+ (\lambda_F + \lambda_D)(\mu B_{20}(\rho_2(D) - \rho_2(F)) + \mu B)d = 0 \end{aligned} \tag{A-15}$$

$$\begin{aligned}\frac{\partial \mathcal{L}_0}{\partial \rho_2(D)} &= \beta\rho_1 d[\theta d + 2m\Pi(D) + 2mv(2\rho_2(D) - 1) + dm^2] \\ &+ (\lambda_F + \lambda_D)\mu B_{20}\rho_1 + \lambda_D dS = 0 \end{aligned} \tag{A-16}$$

$$\begin{aligned}\frac{\partial \mathcal{L}_0}{\partial \rho_2(F)} &= \beta(1-\rho_1)d[\theta d + 2m\Pi(F) + 2mv(2\rho_2(F) - 1) + dm^2] \\ &+ (\lambda_F + \lambda_D)\mu B_{20}(1-\rho_1) + \lambda_F dS = 0 \end{aligned} \tag{A-17}$$

$$\frac{\partial \mathcal{L}_0}{\partial \Pi(D)} = 2\beta\rho_1(\Pi(D) + md\rho_2(D)) + \lambda_D = 0 \tag{A-18}$$

$$\frac{\partial \mathcal{L}_0}{\partial \Pi(F)} = 2\beta(1-\rho_1)(\Pi(F) + md\rho_2(F)) + \lambda_F = 0 \tag{A-19}$$

These five equations plus (A-12) and (A-13) can now be solved for the seven variables ρ_1,

$\rho_2(D)$, $\rho_2(F)$, $\Pi(D)$, $\Pi(F)$, λ_D and λ_F. This is the commitment solution for the monetary authority: in other words, in period 0 the authority commits to the 'policy rules' in the form of escape clauses $\rho_1, \rho_2(h)$ which are carried out in period 1 and 2.

It is of particular interest to examine the effect of devaluation or not in period 1 on the probability of devaluation in period 2. Eliminating the Lagrangian multipliers from (A-18) and (A-19) in (A-16) and (A-17) and subtracting, after a little algebra we arrive at

$$\rho_2(F) - \rho_2(D) = \frac{d\mu^2 B B_{20}}{(\alpha + \mu B)(2v - dS) - \mu B_{20} dS} \tag{A-20}$$

Our condition $2v > dm$ ensures that $(\alpha + \mu B)(2v - dS) - \mu B_{20} dS > 0$. Thus under commitment $\rho_2(F) - \rho_2(D) \geq 0$ so the probability of a devaluation following a fixed parity in period 1 is at least as big as that following a devaluation. If there is no long-term debt $B_{20} = 0$ then debt has no effect of ρ_2 and $\rho_2(F) = \rho_2(D)$ and as the long-term composition of debt increases to the point where $B = B_{20}$ and $S \equiv \alpha + \mu B_{10} = 1$ then $\rho_2(F) - \rho_2(D)$ increases to $\frac{2dB^2}{2v(\alpha+\mu B) - d(\alpha+2\mu B)}$. QED

Proposition 2: Once private expectations of inflation are formed in period 0, $\pi_1 = \rho_1 d$ where ρ_1 is found from the f.o.c. above, is no longer optimal if the monetary authority can re-optimize. Similarly, in period 2, $\pi_2(h) = \rho_2(h)d$ is no longer optimal policy for the authority after private sector revises their expectation of the second-period inflation where again $\rho_2(h)$ is the commitment rule in period 2. With discretion the monetary authority must minimize its loss function taking private expectations of inflation in all periods as given, i.e., taking Θ and $\Pi(h)$ as given. This means that the constraints (A-12) and (A-13) do not bind; i.e., $\lambda_F = \lambda_D = 0$ in our original Lagrangian function (A-14).

To solve the discretionary case, we first examine the impact of a first-period devaluation on the probability of a second-period devaluation and then go back to the first-period problem. Putting $\lambda_F = \lambda_D = 0$ in our f.o.c (A-16) and (A-17) above, we arrive at

$$\rho_2(h) = \frac{1}{2} - \frac{1}{2v}\left[\frac{\theta d}{2m} + \frac{dm}{2} - mE_0\pi_2 + (\pi_1 - E_0\pi_1)B - (E_1\pi_2(h) - E_0\pi_2)S - K\right] \tag{A-21}$$

The probability of a devaluation in period 2, $\rho_2(h)$, depends on whether the authority has devalued in period 1, both directly through, π_1, and through a revision in expectations, $E_1\pi_2(h) - E_0\pi_2$. A devaluation in period 1, i.e. $\pi_1 = d$, reduces the likelihood of a second-period devaluation as unexpected inflation reduces the real debt burden. This is also because a downward revision in expected inflation, $E_1\pi_2$, and thus in the interest rate, decreases the debt burden in the second period to the extent that the debt is short-term.

Using equation (A-21) and (A-4), we have

$$\rho_2(D) = \frac{1}{2v - dS}[v + K + \mu B_{20} E_0\pi_2 - d\mu B + \mu B E_0\pi_1 - \frac{\theta d}{2m} - \frac{dm}{2}] \tag{A-22}$$

$$\rho_2(F) = \frac{1}{2v - dS}[v + K + \mu B_{20} E_0\pi_2 + \mu B E_0\pi_1 - \frac{\theta d}{2m} - \frac{dm}{2}] \tag{A-23}$$

which leads to

$$\rho_2(F) - \rho_2(D) = \frac{d\mu B}{2v - dS} > 0 \tag{A-24}$$

Thus under discretion, the probability of a second-period crisis after maintaining the parity, $\rho_2(F)$, is greater than that after a devaluation, $\rho_2(D)$. Once again, it is shown that –given complete information– a first-period devaluation always at least improves the likelihood that the new parity will be maintained. But in the discretion case, we can now see that $\rho_2(F)$ is always *greater* than $\rho_2(D)$ no matter what the composition of debt is. Let $\Delta\rho_2^C$ and $\Delta\rho_2^D$ be the difference in probabilities under commitment and discretion respectively. Then from (A-20) and (A-24) we have

$$\Delta\rho_2^D - \Delta\rho_2^C = \frac{d\mu BS(2v - dm)}{(2v - dS)[(\alpha + \mu B)(2v - dS) - \mu B_{20} dS]} > 0 \tag{A-25}$$

since by the large shock condition $2v - dm > 0$ and the numerator has been shown to be positive. QED

Proposition 3: Now consider the authority's choice in period 1. We can rewrite equation (A-8) as

$$E_1 L_2(h) = \frac{v^2}{3} - 2vdm[\rho_2(h)]^2 + \Pi(h)^2 \tag{A-26}$$

substituting $\lambda_D = \lambda_F = 0$ into (A-15) and noting that $E_0 L_2(h) = E_1 L_2(h)$, we arrive at the following probability of a first-period devaluation:

$$\rho_1 = \frac{1}{2\alpha(2v - \alpha d)d}\{d(2\alpha(k + v) - (\theta + \alpha^2)d) - \beta[E_1 L_2(D) - E_1 L_1(F)]\} \tag{A-27}$$

which is equivalent to a threshold value for the first-period shock of

$$\hat{u}_1 = \frac{1}{2\alpha d}\{\theta^i d^2 + \alpha^2 d - 2\alpha d(E_0 \pi_1 + k) - \beta[E_1 L_2^i(F) - E_1 L_2^i(D)]\}$$

From (A-5), which still applies, (A-22) and (A-23) we have

$$E_0 \pi_2 = \frac{d}{2v - dm}[v + K - \frac{\theta d}{2m} - \frac{dm}{2}] \tag{A-28}$$

which shows that expected inflation and thus the probability of a devaluation in period 2 do not depend on either the term structure of debt or ρ_1, the probability of the first-period devaluation. This is because the maturity of the debt affects both the probability of a devaluation in period 1 and (both short- and long-term) interest rates. For given interest rates, a shorter maturity, which increases the probability of a devaluation in period 1, tends to reduce the likelihood of a second devaluation. However, a shorter maturity also increases interest rates and tax distortions with offsetting effects on the probability of a second-period devaluation.

Using (A-26), (A-27) and (A-28), the probability of a first-period devaluation is follows:

$$\rho_1 = \frac{1}{2} + \frac{(2\alpha k - \theta d)(2v - dS)^2 + 4v\beta(2v - dS)\mu B(k + B)}{2\alpha(2v - \alpha d)(2v - dS)^2 - 4v\beta(2v - dm)d(\mu B)^2} \tag{A-29}$$

The probability of a devaluation decreases with its cost to the authority, θ, and increases with distortions, chiefly, with the debt burden, B. By differentiating ρ_1 with respective to B_{10} while holding the total debt constant, we can get

$$\frac{\partial \rho_1}{\partial B_{10}} = k + \mu B + \frac{2v - dm}{2v - dS}(2E_0\pi_1 - d)\mu B \geq 0. \tag{A-30}$$

QED

Proposition 5: Private sector beliefs now become

$$\begin{aligned} E_0\pi_1 &= [q_0\rho_1^T + (1-q_0)\rho_1^W]d & \text{(A-31)} \\ E_0\pi_2 &= q_0 d[\rho_1^T\rho_2^T(D) + (1-\rho_1^T)\rho_2^T(F)] & \\ &+ (1-q_0)d[\rho_1^W\rho_2^W(D) + (1-\rho_1^W)\rho_2^W(F)] & \text{(A-32)} \\ E_1\pi_2(h) &= (1-q_1(h))d\rho_2^W(h) + q_1(h)d\rho_2^T(h) & \text{(A-33)} \end{aligned}$$

where the history $h = [j, u_1], j = D, F$ consists of two observations by the public, the exchange rate change or not and the shock. We can now show

$$E_1\pi_2(F \cap u_1) - E_1\pi_2(D \cap u_1) = \frac{d^2}{2v - dS}\left[\mu B - q_1(F \cap u_1)\frac{(\theta^T - \theta^W)}{2m}\right] \tag{A-34}$$

Then using (A-22) and (A-23), we have

$$\begin{aligned} \rho_2^i(F \cap u_1) - \rho_2^i(D \cap u_1) &= \frac{d\mu B}{2v} + [E_1\pi_2(F \cap u_1) - E_1\pi_2(D \cap u_1)]\frac{S}{2v} \\ &= \frac{d\mu B}{2v} + \frac{d^2 S}{2v(2v - dS)}\left[\mu B - q_1(F \cap u_1)\frac{(\theta^T - \theta^W)}{2m}\right] \end{aligned} \tag{A-35}$$

The right-hand-side of (A-35) can be either positive or negative. On the one hand, a first-period devaluation may diminish the likelihood of a second-period devaluation by easing the debt burden. If a devaluation in period 1 leads to a lower interest rate than defense, then the authority gets a second-period gain. That is because the short-term debt, μB_{10}, is rolled over at a lower-than-expected interest rate. This is exactly what we see in the case of complete information. Intuitively, for the debt burden effect to dominate the level of the inflation-sensitive debt must be high relative to the uncertainty about the government type.

On the other hand, a devaluation in period 1 could send a signal of a weak authority who heads for further devaluation and thus may lead to higher-than-expected inflation and interest rates in period 2. In the case that the interest rate rises following a devaluation turn the (A-35) negative, the authority expects a second-period loss from abandoning the fixed parity. This case is relevant when the uncertainty over monetary authority preferences is great (or the difference between preferences, $\theta^T - \theta^W$ is large) relative to the level of deflatable debt, μB and a successful defense of the current exchange rate regime sends a strong signal of the authority's determination not to devalue, that is, when the signaling effect prevails over the debt burden effect.

Interestingly, (A-35) shows that whether the exchange rate regime gains or loses credibility does not depend on the maturity of the debt; instead, the short-term debt, B_{10}, increases the difference in the probabilities of a second-period devaluation, since the costs or benefits of first-period devaluation are magnified by the amount of debt that is rolled over. In addition, comparing (A-24) with (A-34) we arrive at Proposition 5. QED

Proposition 6: The separating equilibrium is summarized by the following equations:

$$\rho_1^i = \frac{1}{2\alpha(2v-\alpha d)d}\{d(2\alpha(k+v)-(\theta^i+\alpha^2)d)-\beta[E_1^i L_2(D)-E_1^i\ L_1(F)]\};\ i=W,T \quad \text{(A-36)}$$

where $E_1^i[\cdot]$ signifies the private expectations of the monetary authority of type i.

$$E_1^i L_2^i(h) = \frac{v^2}{3}+[\Pi(h)]^2+d\rho_2^i(h)[\theta^i d+2m\Pi(h)+2mv(\rho_2^i(h)-1)+dm^2]\,;\ h=D,F \quad \text{(A-37)}$$

where, as before $\Pi(h) = -mE_0\pi_2 + (\pi_1(h) - E_0\pi_1)\mu B - (E_1\pi_2(h) - E_0\pi_2)S - K$, where $\pi_1(D) = d$ and $\pi_1(F) = 0$.

$$\rho_2^i(h) = \frac{1}{2} - \frac{1}{2v}[\frac{\theta^i d}{2m} + \frac{dm}{2} + \Pi(h)] \quad \text{(A-38)}$$

substituting (A-38) into (A-37), we can obtain

$$E_1^i L_2^i(h) = \frac{v^2}{3} + [\Pi(h)]^2 - 2dmv(\rho_2^i(h))^2 \quad \text{(A-39)}$$

which replaces (A-37). From (A-32) and (A-38) we now have

$$E_0\pi_2 = \frac{d}{2v-dm}\left[v + K - \frac{(q_0\theta^T + (1-q_0)\theta^W)d}{2m} - \frac{dm}{2}\right] \quad \text{(A-40)}$$

The second-period devaluation expected by the private sector in period 0 is the same as in the case of complete information, except for the cost of devaluation, θ, now is replaced by its expectation under asymmetric information. As before, the debt maturity does not affect $E_0\pi_2$. We also have

$$\begin{aligned} E_0\pi_1 &= [q_0\rho_1^T + (1-q_0)\rho_1^W]d && \text{(A-41)}\\ E_1\pi_2(h) &= [(1-q_1(h))\rho_2^W(h) + q_1(h)\rho_2^T(h)]d && \text{(A-42)} \end{aligned}$$

The equilibrium is completed with the up-dating equations

$$\begin{aligned} q_1(F) &= \frac{(1-\rho_1^T)q_0}{(1-\rho_1^T)q_0 + (1-\rho_1^W)(1-q_0)} && \text{(A-43)}\\ q_1(D) &= \frac{\rho_1^T q_0}{\rho_1^T q_0 + \rho_1^W(1-q_0)} && \text{(A-44)} \end{aligned}$$

and $q_0 = \frac{1}{2}$ (uniform distribution for the prior belief of the private sector that the authority is tough). Using Equations (A-36) to (A-44), we can solve for the likelihood of a first-period devaluation, $\rho_1^i, i = W, T$ as follows:

$$\rho_1^T = \frac{1}{2} - \frac{\frac{\beta\phi w^T}{d} + k + \frac{\lambda}{2} - \frac{\theta^T d}{2}}{d + \beta\mu B\eta\phi - 2v} - \frac{\lambda}{4v}\,;\ \rho_1^W = \frac{1}{2} - \frac{\frac{\beta\phi w^W}{d} + k - \frac{\lambda}{2} - \frac{\theta^W d}{2}}{d + \beta\mu B\eta\phi - 2v} + \frac{\lambda}{4v} \quad \text{(A-45)}$$

where $\lambda = \frac{d}{4v}(2v - \beta\phi)(\theta^T - \theta^W) \geq 0$, $\phi = 2\mu Bvdg - Z$, $Z = \frac{sd^2(\theta^T - \theta^W)}{2m(2v - dS)}$, $w^i = k - \frac{d^2}{8v}(\theta^T + \theta^W - 2\theta^i)$, $g = \frac{1}{2v - dS}$ and $\eta = \frac{2v - dm}{2v - dS} \leq 1$.

The expected devaluation in period 1 is then given by

$$E_0\pi_1 = \frac{d}{2} + \frac{kd - \frac{\theta^T d^2}{2} + \beta\phi w^T + \frac{d\lambda}{2}}{2v - d - \beta\mu B\eta\phi} \tag{A-46}$$

As in Benigno and Missale (2004), it is shown in (A-46) that apart from the first two terms inside the bracket capturing the first-period effects, the sign of $E_0\pi_1$ depends on $\phi = 2\mu Bvdg - Z$. The term $2\mu Bvdg$ captures the debt burden effect as μB is the level of inflation-sensitive debt, while the term Z represents the impact of the uncertainty over authority's preferences determined by the difference, $\theta^T - \theta^W$. Hence, the expectation of a first-period devaluation depends on whether the debt burden or the signalling effect prevails: it is smaller when there is substantial uncertainty about authority's types whereas it is greater when the debt level is high. Furthermore, we can show

$$\begin{aligned} E_1^i L_2(D) - E_1^i L_2(F) &= 2v[\rho_2^i(D) - \rho_2^i(F)][dm(\rho_2^i(D) + \rho_2^i(F)) + \Pi(D) + \Pi(F)] \\ &= 2v[\rho_2^i(D) - \rho_2^i(F)][E_1^i y_2(D) + E_1^i y_2(F) - 2y^*] \end{aligned} \tag{A-47}$$

where $y_2(h)$ is second-period output following $h = D, F$. Thus, the sign of the difference between the expected second-period loss from devaluation and that from parity maintenance in period 1 depends on $\rho_2^i(D) - \rho_2^i(F)$, which in turn, depends on whether the debt burden effect or the signaling effect dominates.

Differentiating $E_0\pi_1$ with respective to the short-term debt B_{10} while holding the total debt constant gives:

$$\frac{\partial E_0\pi_1}{\partial B_{10}} = \frac{\beta kg\phi' d + \beta Bdg\eta(\phi + \phi')(E_0\pi_1 - \frac{d}{2})}{2v - d - \beta B\eta\phi} \tag{A-48}$$

where $\phi' = 2Bvdg - Z' < \phi$ and $Z' = \frac{vd(\theta^T - \theta^W)}{m(2v - dS)} > Z$. As the sign of this derivative is determined by $\phi = 2\mu Bvdg - Z$ ($\phi' = 2Bvdg - Z'$), the effect of debt maturity on the expected devaluation in the first period depends on the relative importance of debt burden effect to signalling effect. When there is little uncertainty about the authority's type, so that $Z = \frac{sd^2(\theta^T - \theta^W)}{2m(2v - dS)}$ ($Z' = \frac{vd(\theta^T - \theta^W)}{m(2v - dS)}$) tends to zero, the short-term debt increases the probability, as perceived by the private sector, of a first-period devaluation, as it does under complete information. On the other hand, if the authority's resolve is uncertain–i.e., when ϕ and ϕ' are negative–the probability of a devaluation in period 1 decreases with short-term debt, as defending the exchange rate in adverse circumstances (larger short-term debt) sends a stronger signal of intentions. QED

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