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ON THE FISCAL IMPLICATIONS OF TWIN CRISES

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ABSTRACT

This paper explores the implications of different strategies for financing the fiscal costs of twin crises for inflation and depreciation rates. We use a first-generation type model of speculative attacks which has four key features: (i) the crisis is triggered by prospective deficits; (ii) there exists outstanding non-indexed government debt issued prior to the crises; (iii) a portion of the government's liabilities are not indexed to inflation; and (iv) there are nontradable goods and costs of distributing tradable goods, so that purchasing power parity does not hold. We show that the model can account for the high rates of devaluation and moderate rates of inflation often observed in the wake of currency crises. We use our model and the data to interpret the recent currency crises in Mexico and Korea. Our analysis suggests that the Mexican government is likely to pay for the bulk of the fiscal costs of its crisis through seignorage revenues. In contrast, the Korean government is likely to rely more on a combination of implicit and explicit fiscal reforms.

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1. Introduction

The classical view of currency crises is that they arise because governments print money to finance ongoing or prospective deficits. This view, embedded in so-called first generation models and their modern variants, is especially appealing for explaining twin banking-currency crises.[1] These crises entail large fiscal costs, associated with restructuring and recapitalizing failing banking systems, that are not typically financed by large explicit fiscal reforms. Despite the appeal of these models, they suffer from an important empirical shortcoming: they generally predict that inflation rates should be high *after* a currency crisis. In reality, many large devaluations are followed by moderate rates of money growth and inflation. This raises three questions. First, how do governments actually pay for the fiscal costs of twin banking-currency crises? Second, what are the implications of different financing methods for post-crisis inflation rates? Finally, can the inflation predictions of first generation type models be reconciled with the data?

To pay for the fiscal costs of twin crises, a government must use a combination of the following strategies: (i) implement an explicit fiscal reform by raising taxes or reducing spending; (ii) explicitly default on outstanding debt; (iii) print money to generate seignorage revenues; (iv) deflate the real value of outstanding nonindexed nominal debt; or (v) engage in an implicit fiscal reform by deflating the real value of government outlays that are fixed, at least temporarily, in nominal terms (e.g. civil servant wages or social security payments).[2] In a world of forward looking economic agents, different mixes of these strategies have different implications for both the severity of a currency crisis and for post-crisis inflation rates.

We analyze these implications using a version of the model in Burnside, Eichenbaum and Rebelo (2001) in which a currency crisis is triggered by prospective government deficits. To simplify our exposition we reduce the model to its essential elements: a money demand specification, a government budget constraint, a rule for exiting the fixed exchange rate regime, and an assumption about the nature of monetary policy after the devaluation. We show that a government which pursues strategies (iii)-(v) can pay for large fiscal costs associated with

[1] See, for example, Krugman (1979), Flood and Garber (1984), Obstfeld (1986), Calvo (1987), Drazen and Helpman (1987), Wijnbergen (1991), Corsetti, Pesenti and Roubini (1999), Dooley (2000), Lahiri and Végh (2000), and Burnside, Eichenbaum, and Rebelo (2001).

[2] The fiscal costs could also be paid for with international aid, namely through subsidized loans granted by institutions such as the International Monetary Fund (IMF). Jeanne and Zettelmeyer (2000) argue that the subsidy element of IMF lending is small. For Korea and Mexico they estimate that this subsity amounted to less than 1 percent of GDP.

large devaluations while generating very moderate degrees of post-crisis inflation. So models in which prospective deficits are the root cause of large currency crises can be reconciled with observed post currency crisis inflation rates.

We begin our theoretical analysis with a version of the model where purchasing power parity (PPP) holds and all government liabilities are perfectly indexed to inflation. This model predicts much lower devaluation rates and much higher inflation rates than those observed during currency crisis episodes.

We then consider two extensions to the basic model. First, we introduce two types of nonindexed government liabilities: (i) domestic bonds issued before agents learned about prospective deficits; and (ii) public spending whose value is preset in units of domestic currency. With these elements, the model can generate more plausible implications for the behavior of inflation but can only produce moderate rates of devaluation.

Second, we eliminate the assumption of PPP. This breaks the link between domestic inflation and exchange rate depreciation. We introduce three departures from PPP: (i) nontradable goods (e.g. housing, education, and health); (ii) costs associated with distributing tradable goods (e.g. transportation, wholesaling and retailing); and (iii) nominal rigidities in the prices of nontradable goods. These elements allow the model to account more closely for the high rates of devaluation and low rates of inflation that are often observed in the wake of currency crisis episodes.

We use our model to interpret two recent currency crises: Mexico in 1994 and Korea in 1997. Our analysis suggests that the Mexican government will likely pay for most of the fiscal cost of its crisis by printing money. In contrast, the Korean government is likely to do so via a mixture of future implicit and explicit fiscal reforms.

Estimates of the cost of the Mexican crisis vary widely, but, as a benchmark, we put it at roughly 15 percent of Mexico's 1994 GDP. We estimate that the government has so far paid for about 30 percent of the fiscal cost of the crisis via a mix of debt deflation, fiscal reforms, and seignorage. We show that the rest of the fiscal cost can be paid for by seignorage revenues if the government prints money at historically typical rates. Consistent with what our model predicts for a crisis financed primarily by printing money, Mexico's twin crises was associated with a relatively large rise in the rate of inflation.

The fiscal cost of the Korean crisis is thought to be roughly 24 percent of 1997 GDP.[3]

[3] This estimate is from Standard and Poor's Sovereign Ratings Services. See Goldstein (1998) for a discussion of various estimates of nonperforming bank loans that underlie the banking crisis in Korea.

Our calculations indicate that the government has so far paid for roughly 25 percent of this cost via a mix of debt deflation, fiscal reforms, and seignorage revenue. Consistent with this estimate, the Korean government has accumulated a great deal of new debt–17.3 percent of GDP–to finance its crisis in the short run. Our model can account for the large devaluation and modest post-crisis inflation rates in Korea under the assumption that much of the remaining fiscal cost of the crisis will be financed through future explicit and implicit fiscal reforms.

The remainder of the paper is organized as follows. Section 2 uses the government's intertemporal budget constraint to discuss the different financing strategies available to the government. Section 3 presents our basic model. Section 4 discusses two extensions: incorporating nonindexed government liabilities and eliminating the PPP assumption. Section 5 contains our discussion of the Mexico 1994 and Korea 1997 crises. Section 6 contains concluding remarks.

2. The Government Budget Constraint

Explicit default aside, a government must satisfy its intertemporal budget constraint. In this section we display a version of this constraint that is useful for discussing the different strategies that a government can use to pay for the fiscal costs of a twin crisis. Later we adopt a particular model of speculative attacks to study how these strategies impact on the severity of a currency crisis and post-crisis inflation rates.

We consider a continuous time, perfect foresight economy populated by an infinitely lived representative agent and a government. All agents, including the government, can borrow and lend in international capital markets at a constant real interest rate r.

For now we assume that there is a single consumption good in the economy and no barriers to trade, so that PPP holds:

$$P_t = S_t P_t^*. \tag{2.1}$$

Here P_t and P_t^* denote the domestic and foreign price level respectively, while S_t denotes the exchange rate (defined as units of domestic currency per unit of foreign currency). For convenience we assume that $P_t^* = 1$.

In each period the government purchases goods, levies lump sum taxes, and makes transfers to the representative agent. In addition, the government can print money and issue debt.

Government spending, taxes and transfers have an indexed component, with real values g_t, τ_t and v_t, respectively. These variables also have nonindexed components with nominal values G_t, T_t, and V_t, respectively. It is convenient to define the variable, X_t:

$$X_t = T_t - G_t - V_t.$$

The government issues two types of debt. The first type is dollar-denominated so that its real value is invariant to the domestic rate of inflation. We denote the dollar debt at the beginning of time t by b_t. The second type of debt is denominated in local currency and is not indexed to the domestic rate of inflation. To simplify matters we assume that this debt takes the form of consols, issued before time zero. Each consol has a constant coupon denominated in local currency. Since expected inflation was zero when the bonds were issued, the coupon rate or nominal interest on the bonds equals to the real interest rate, r. We denote the nominal value of the consols by B. To simplify notation we assume that the stock of nominal debt remains constant and all new debt is dollar denominated.

We consider an economy that is initially operating under a fixed exchange rate so that $S_t = S$. At time zero, news arrives that the government's future liabilities will be higher than previously anticipated. We interpret the rise in liabilities as reflecting transfer payments associated with bank bailouts or with other fiscal liabilities of the government.

To be concrete, before time zero, private agents assumed that $v_t = v$ for all t. At time zero they learn that transfers will increase permanently after date T':

$$\begin{cases} v_t = v & \text{for } 0 \leq t < T', \\ v_t \geq v & \text{for } t \geq T', \end{cases}$$

where T' is a positive scalar. The precise value of T' is irrelevant for our results. We use ϕ to denote the present value of the increase in transfers:

$$\phi = \int_{T'}^{\infty} e^{-rt}(v_t - v)dt. \tag{2.2}$$

The government's flow budget constraint is:

$$\begin{array}{ll} \Delta b_t = -\Delta m_t & \text{if } t \in I, \\ \dot{b}_t = rb_t + rB/S_t - \tau_t + g_t + v_t - X_t/S_t - \dot{m}_t - \pi_t m_t & \text{if } t \notin I. \end{array} \tag{2.3}$$

Throughout the paper $\dot{x}_t$ denotes dx/dt. Here π_t is the inflation rate, $\dot{P}_t/P_t$. The variable m_t represents the dollar value of money balances, defined as $m_t = M_t/S_t$, where M_t denotes nominal money holdings. Note that $\dot{m}_t + \pi_t m_t$ is equal to the dollar value of seignorage,

$\dot{M}_t/S_t$. As in Drazen and Helpman (1987), equation (2.3) takes into account the possibility of discrete changes in m_t and b_t at a finite set of points in time, I. Below we discuss the points at which these discrete changes occur.

According to (2.3), the change in b_t is equal to the primary deficit, $g_t + v_t - \tau_t - X_t/S_t$, plus the interest cost of servicing the indexed government debt (rb_t) plus the real cost of paying interest on the nonindexed consols, rB/S_t, minus seignorage revenue, $\dot{m}_t + \pi_t m_t$.

The flow budget constraint, together with the condition $\lim_{t\to\infty} e^{-rt} b_t = 0$, implies the intertemporal budget constraint:

$$\begin{aligned} b_0 \; = \; & \int_0^\infty (\tau_t - g_t - v_t) e^{-rt} dt + \int_0^\infty \frac{X_t}{S_t} e^{-rt} dt \\ & + \int_0^\infty (\dot{m}_t + \pi_t m_t) e^{-rt} dt + \sum_{i\in I} e^{-ri} \Delta m_i \\ & - \int_0^\infty \frac{rB}{S_t} e^{-rt} dt. \end{aligned} \tag{2.4}$$

According to (2.4), the initial stock of real indexed government debt is equal to the real present value of current and future surpluses and seignorage revenue minus the real present value of the consol payments.

It is useful to derive the conditions under which a fixed exchange rate is sustainable, so that $S_t = S$ for all t. For now we assume that there is no output growth and foreign inflation is zero (we relax these assumptions in section 5). Consequently, the government does not collect seignorage under a fixed exchange rate regime and its intertemporal budget constraint is given by:

$$b_0 = \int_0^\infty (\tau_t - g_t - v_t) e^{-rt} dt + \int_0^\infty \frac{X_t}{S} e^{-rt} dt - \int_0^\infty \frac{rB}{S} e^{-rt} dt. \tag{2.5}$$

We assume that this sustainability condition holds before agents receive information at $t = 0$ about the new, higher, level of future deficits.

To see how prospective deficits can generate a currency crisis, recall our assumption that at $t = 0$ private agents learn that the present value of the deficit has increased by ϕ. Also suppose that private agents correctly believe that the government will not undertake an explicit fiscal reform that fully pays for ϕ. To simplify, suppose that $\int_0^\infty (\tau_t - g_t - v_t) e^{-rt} dt$

remains constant.[4] Then we can use (2.2) and (2.5) to re-write (2.4) as:

$$\begin{aligned}\phi &= \int_0^\infty (\dot{m}_t + \pi_t m_t) e^{-rt} dt + \sum_{i \in I} e^{-ri} \Delta m_i \\ &+ \left[\frac{B}{S} - \int_0^\infty \frac{rB}{S_t} e^{-rt} dt \right] - \left[\int_0^\infty \left(\frac{X_t}{S} - \frac{X_t}{S_t} \right) e^{-rt} dt \right].\end{aligned} \tag{2.6}$$

According to (2.6), the present value of the prospective deficits, ϕ, must be financed by a combination of: (i) seignorage revenues ($\int_0^\infty (\dot{m}_t + \pi_t m_t) e^{-rt} dt + \sum_{i \in I} e^{-ri} \Delta m_i$); (ii) a reduction in the real value of nonindexed debt ($B/S - \int_0^\infty (rB/S_t) e^{-rt} dt$); and (iii) an implicit fiscal reform that increases the real value of the nonindexed component of the fiscal surplus ($\int_0^\infty (X_t/S - X_t/S_t) e^{-rt} dt$). It follows that the *only* way that the government can satisfy its intertemporal budget constraint is to use monetary policy to generate a present value of seignorage revenues and implicit fiscal reform equal to ϕ.

To see this, suppose for a moment that the fixed exchange rate could be sustained once new information about higher deficits arrived. Then the money supply would never change and the government could not collect any seignorage revenues. This in conjunction with the fact that the price level would be fixed implies that all of the terms on the right hand side of (2.6) would equal zero. But then the government's budget constraint would not hold. This would contradict the assumption that the fixed exchange rate regime was sustainable. We conclude that the government *must* at some point move to a floating exchange rate system.

The particular characteristics of a crisis depend on the financing mix chosen by the government. For example, the government could pay for most of the bank bailout by reducing the real value of outstanding nominal debt with a devaluation at time zero. Under these circumstances, the currency crisis would be associated with little future money growth or inflation. This scenario is closely related to the work of Cochrane (2001), Sims (1994) and Woodford (1995) on the fiscal theory of the price level.[5] In contrast, if the government does not have any nonindexed liabilities, then the bank bailout would have to be financed entirely via seignorage revenues. This would have potentially very different implications for money growth and inflation. To analyze the implications of different financing strategies we must make additional assumptions about government policy and the behavior of private agents. We discuss these assumptions in the following section.

[4] Our basic result would not be affected by a fiscal reform as long as the present value of the change in the primary surplus induced by the reform was less than ϕ.

[5] See Corsetti and Mackowiak (1999), Daniel (2000), and Dupor (2000) for applications of the fiscal theory to open economies.

3. The Basic Model

In this section we analyze a simple benchmark model in which PPP holds and the government does not have any nonindexed liabilities.

In addition to borrowing and lending in international capital markets, private agents can also borrow and lend domestic currency at the nominal interest rate, R_t. Under perfect foresight:

$$R_t = r + \pi_t. \tag{3.1}$$

where r and π denote the real rate of interest and inflation.

The demand for domestic money has the form suggested by Cagan (1956):

$$\ln(\frac{M_t}{P_t}) = \ln(\theta) + \ln(Y) - \eta R_t. \tag{3.2}$$

Here M_t denotes the beginning of period t domestic money supply, and θ is a positive constant. The parameter η represents the semi-elasticity of money demand with respect to the interest rate. To simplify we assume that domestic agents' per period real income, Y, is constant over time.[6]

The Fixed Exchange Rate Regime

Suppose that the home country is initially in a fixed exchange rate regime so that $S_t = S$. Equation (2.1) implies that the domestic rate of inflation π_t, is equal to the foreign rate of inflation, which we assumed to be zero. It follows from (3.1) that the nominal rate of interest is equal to the constant real interest rate: $R_t = r$ for all $t \geq 0$. Under a fixed exchange rate, the money supply must equal money demand:

$$M = S\theta Y \exp(-\eta r). \tag{3.3}$$

Since the money supply is constant the government cannot generate seignorage revenues. Of course if there were growth in either the foreign price level or domestic real income, the government would collect some seignorage revenue in a fixed exchange rate regime. This possibility does not affect our basic argument. The present value of such seignorage revenues would have already been incorporated into the government's pre-crisis intertemporal budget constraint.

[6] See Lahiri and Végh (2000) for a discussion of the output effects of currency crises.

A Currency Crisis

In the presence of prospective deficits the government *must* at some point move to a floating exchange rate system. The precise time at which this occurs depends on (i) the government's rule for abandoning fixed exchange rates and (ii) the government's new monetary policy.

With respect to (i) we follow a standard assumption in the literature that the government abandons the fixed exchange rate regime according to a threshold rule on government debt.[7] Specifically, we assume that the government floats the currency at the first point of time, t^*, when its net debt hits some finite upper bound. This is equivalent to abandoning the fixed exchange rate when the amount of domestic money sold by private agents in exchange for foreign reserves exceeds χ percent of the initial money supply. In addition to being a good description of what happens in actual crises, the threshold rule can be interpreted as a short-run borrowing constraint on the government: it limits how many reserves the government can borrow to defend the fixed exchange rate.[8] Rebelo and Végh (2001) discuss the circumstances in which it is optimal for a social planner to follow a threshold rule.[9] While they use a general equilibrium model, their framework is similar in spirit to the model used here.

With respect to post-crisis monetary policy, we assume that at some point in the future, $(t = T)$ the government will engineer a discrete increase in the money supply equal to γ percent of M, defined in (3.3). Thereafter, the money supply will grow at rate μ. These assumptions imply that the money supply evolves according to:[10]

$$M_t = \begin{cases} e^{-\chi}M, & \text{for } t^* \leq t < T \\ e^{\gamma+\mu(t-T)}M, & \text{for } t \geq T. \end{cases} \quad (3.4)$$

This specification decouples the endogenous timing of the speculative attack from the time at which the government undertakes its new monetary policy. In equilibrium the parameters μ and γ must be such that the government's intertemporal budget constraint, (2.6), holds.

[7] See, for example, Krugman (1979) and Flood and Garber (1984).

[8] Drazen and Helpman (1987), as well as others, have proposed a different rule for the government's behavior: fix future monetary policy and allow the central bank to borrow as much as possible provided the present value budget constraint of the government is not violated. This rule ends up being equivalent to a threshold rule. See Wijnbergen (1991) and Burnside, Eichenbaum and Rebelo (2001) for a discussion.

[9] This result emerges when there are significant real costs associated with a devaluation, such as loss of output.

[10] Implicit in this description is the assumption that a solution for t^* such that $t^* < T$ exists. We will see that this assumption holds in our analysis.

Note that the rate of inflation, the money supply and the level of government debt can be discontinuous. However, the exchange rate path must be continuous. To see why, suppose to the contrary that there was a discontinuous increase in the exchange rate at time t^*. Since PPP implies that $P_t = S_t$, inflation would be infinity at t^*. This would imply that the nominal interest rate would also be infinity at t^* and that money demand would fall to zero. Since the government is only willing to buy χ percent of the money supply this cannot be an equilibrium. We utilize the continuity of S_t extensively in the derivations below.

Solving for the Time of the Speculative Attack (t^*)

The key equation in determining the time of the speculative attack is the money demand function, (3.2) which implies:[11]

$$\ln P_t = \eta r - \ln(\theta Y) + \frac{1}{\eta}\int_t^{\infty} e^{-(s-t)/\eta}\ln(M_s)ds. \tag{3.5}$$

Since the exchange rate must be a continuous function of time, PPP implies that the price level too must be continuous. We now exploit this continuity requirement to solve for t^*.

By definition, the fixed exchange rate regime ends at time t^*. The price level an instant after t^* is given by:

$$\ln P_{t^*} = \eta r - \ln(\theta Y) + \frac{1}{\eta}\int_{t^*}^{\infty} \ln(M_s)e^{-(s-t^*)/\eta}ds. \tag{3.6}$$

An instant before the devaluation money demand implies that:

$$\ln M - \ln P = \ln(\theta Y) - \eta r. \tag{3.7}$$

Continuity of the price level at t^* requires that $\ln P_{t^*} = \ln P$. Using equations (3.6) and (3.7), we obtain:

$$\ln M = \frac{1}{\eta}\int_{t^*}^{\infty} \ln(M_s)e^{-(s-t^*)/\eta}ds. \tag{3.8}$$

Using (3.4) and the fact that the currency is devalued when the money demand falls by χ percent, we obtain:

$$\frac{1}{\eta}\int_{t^*}^{\infty} \ln M_s e^{-(s-t^*)/\eta}ds = \ln M - \chi\left[1 - e^{-(T-t^*)/\eta}\right] + (\gamma + \mu\eta)e^{-(T-t^*)/\eta}. \tag{3.9}$$

Substituting (3.9) into (3.8) we can solve for the time of the speculative attack:[12]

$$t^* = T - \eta \ln\left[\frac{\chi + \gamma + \mu\eta}{\chi}\right]. \tag{3.10}$$

[11] See Sargent and Wallace (1973) for a derivation.

[12] It can be shown that if the value of t^* implied by (3.10) is less than 0, the attack happens immediately, i.e. $t^* = 0$. In this case the exchange rate is discontinuous at time zero.

This formula implies that the speculative attack occurs before any money is printed: $t^* < T$.

So, other things equal, t^* is larger the longer the government delays implementing its new monetary policy (the larger is T) and the more willing the government is to accumulate debt (the higher is χ). In addition, the higher is the interest rate elasticity of money demand (the larger is η) and the more money the government prints in the future (the higher are γ and μ), the smaller is t^*.[13] The intuition underlying these results is as follows. Once the fixed exchange rate regime is abandoned, inflation rises in anticipation of the increase in the money supply that occurs from time T on. A higher elasticity of money demand (η) makes it easier for the money supply to fall by χ percent. This means that the threshold rule is activated sooner, thus reducing the value of t^*. Higher values of μ and γ also reduce t^* because they lead to higher rates of inflation making it possible for a drop of χ percent in the money supply to happen sooner.

Solving for the Equilibrium

Given fixed values for T and γ, the value of μ must be such that the government's intertemporal resource constraint, (2.6), holds. Since we initially abstract from nonindexed government liabilities ($B = 0$, $X_t = 0$), this constraint simplifies to:

$$\phi = \int_T^\infty (\dot{m}_t + \pi_t m_t) e^{-rt} dt + e^{-rt^*} \Delta m_{t^*} + e^{-rT} \Delta m_T. \tag{3.11}$$

Here we have used the fact that no seignorage is collected between t^* and T because the money supply is constant during this time interval. We also used the fact that there are two jumps in real balances, the first at t^*, which triggers the devaluation, and the second at time T, when the government engineers a discrete jump in the money supply.

After time T the rate of inflation is constant and equal to the money growth rate, μ. This in turn implies that real balances are also constant and equal to: $\theta Y \exp[-\eta(r + \mu)]$. Using this result we can rewrite constraint (3.11) as:

$$\phi = e^{-rT} \frac{\mu}{r} \theta Y \exp[-\eta(r + \mu)] + e^{-rt^*} \Delta m_{t^*} + e^{-rT} \Delta m_T. \tag{3.12}$$

Solving for the equilibrium of the model amounts to solving (3.10) and (3.12) for the two unknowns (t^*, μ).

[13] Some caution is required in interpreting these results because we are not free to vary the parameters on the right-hand side of (3.10) independently of each other. When one parameter is varied γ or μ must be adjusted to ensure that the government resource constraint is satisfied.

A Numerical Example

To discuss the properties of the model it is useful to present a numerical example. The parameter values that we use, summarized in Table 1, are loosely based on Korean data. We normalized real income, Y, and the initial exchange rate, S, to 1. We set the semi-elasticity of money demand with respect to the interest rate, η, equal to 0.5. This is consistent with the range of estimates of money demand elasticities in developing countries provided by Easterly, Mauro and Schmidt-Hebbel (1985). We set the constant $\theta = 0.06$ so that the model is consistent with the ratio of the monetary base to GDP in Korea before the crisis (6 percent). We set the real interest rate, r, to 4 percent.

Next we discuss the initial value of the debt, the fiscal cost of the currency crisis, and threshold rule parameters b_0, ϕ, and χ. Consistent with the assumptions of the basic model we abstract, for now, from nonindexed debt and focus on the real consolidated foreign debt of the Korean government and the central bank. The Korea Institute for International Economic Policy estimated that the foreign debt of the public sector in June 1997 was equal to 2.0 trillion won.[14] According to the IMF's International Financial Statistics, the value of the central bank's net foreign assets was approximately 28.0 trillion won. This suggests that the net foreign assets of the consolidated public sector was equal to roughly 26.0 trillion won or 6.7 percent of 1996 GDP. For now we ignore the government's domestic debt and set b_0 to -0.067 (we incorporate domestic debt into the analysis in section 4). The parameter ϕ was set to 0.24, which is, in our view, a conservative estimate of the fiscal cost of Korea's banking crisis relative to its GDP.[15] The value of χ was set to 0.12 to match the fall in the monetary base between December 1996 and December 1997. We also set the value of γ to 0.12 to match the ratio of the average value of the monetary base in the second half of 1999 versus the first half of 1997. We set $T = 1$. Finally, we solved for the value of μ that satisfies the government's intertemporal budget constraint, which is $\mu = 0.18$. We emphasize that there is considerable uncertainty about the true values of all the aforementioned parameters. But in practice we found that the qualitative characteristics of the results that we stress are robust to reasonable perturbations of the benchmark parameterization.

The first row of Table 2 summarizes the implications of the benchmark model for inflation and the rate of devaluation. Figure 1 depicts the paths for the exchange rate, the price level,

[14] The data are published on the Web at http://kiep.go.kr.

[15] See Burnside, Eichenbaum and Rebelo (2000) for a discussion.

and the money supply in the benchmark model. Several features are worth noting. First, the attack happens after agents learn about prospective deficits (at $t = 0$) but before new monetary policy is implemented (at $T = 1$). As in Burnside, Eichenbaum and Rebelo (2001), the model is consistent with the currency crisis not being predictable on the basis of classical fundamentals such as past inflation, deficits, and money growth. An observer of this economy might be tempted to attribute the crisis to self-fulfilling expectations. In fact the collapse was caused by fundamentals–the need to finance prospective deficits with seignorage revenues. Second, as in all first generation models, there is a discrete drop in net foreign assets at the time of the attack. Third, the model reproduces the fact that inflation initially surges in the wake of the exchange rate collapse and then stabilizes at a lower level.

We conclude this section by discussing some obvious shortcomings of the model. First, the timing of the devaluation is deterministic–everybody knows the precise time at which the fixed exchange rate regime will collapse. This shortcoming can be remedied by introducing some element of uncertainty into the model, such as money demand shocks.[16] Second, the model predicts counterfactually large rates of inflation after a crisis. In our example inflation is 35 percent in the year of the crisis and 20 percent in steady state. This is inconsistent with the post-crisis inflation experience of countries like Mexico and Korea (see section 5). Finally, the model implies that the rate of inflation coincides with the rate of exchange rate depreciation. This too is inconsistent with the evidence. After a speculative attack, rates of devaluation are typically much larger than the corresponding rates of inflation.

4. Model Extensions

This section incorporates two extensions of our framework designed to address the second and third shortcomings of the benchmark model. First, we introduce nonindexed government liabilities. Second, we eliminate the assumption of PPP. With these modifications the model can account for two key features of the data: (i) the rate of devaluation in a currency crisis is typically much larger than CPI inflation; and (ii) the rate of inflation can be quite moderate in the wake of a currency crisis.

[16] See Flood and Garber (1984) and Drazen and Helpman (1988) for a discussion of speculative attack models with uncertainty.

4.1. NonIndexed Government Liabilities

We consider two types of nonindexed government liabilities: (i) domestic bonds (B) issued before agents learned about prospective deficits; and (ii) public spending whose value is preset in units of domestic currency (X_t). In the presence of these liabilities the government budget constraint, (3.12), is replaced by:

$$\begin{aligned} \phi &= e^{-rT}\frac{\mu}{r}\theta Y\exp[-\eta(r+\mu)] + e^{-rt^*}\Delta m_{t^*} + e^{-rT}\Delta m_T \\ &\quad + \left[\frac{B}{S} - \int_0^\infty \frac{rB}{S_t}e^{-rt}dt\right] - \left[\int_0^\infty \left(\frac{X_t}{S} - \frac{X_t}{S_t}\right)e^{-rt}dt\right]. \end{aligned} \tag{4.1}$$

Recall that the term $B/S - \int_0^\infty (rB/S_t)e^{-rt}dt$ is the revenue obtained from deflating nonindexed debt. The term $\int_0^\infty (X_t/S - X_t/S_t)\, e^{-rt}dt$ is the value of the implicit fiscal reform accomplished by deflating the nonindexed components of the fiscal surplus.

As in the basic model, t^* is given by (3.10) so the equilibrium values of t^* and μ can be computed using equations (3.10) and (4.1). Finally, equation (3.5) allows us to compute the equilibrium path for the price level and the exchange rate.

NonIndexed Debt

To see the impact of nonindexed debt on the model's implications for inflation and devaluation rates we now turn to a numerical example. We assume that nonindexed debt is equal to 5 percent of GDP ($B = 0.05$). As with our other parameter values, this number is loosely motivated by the Korean experience. Recall that nominal debt in the model is a perpetuity, so its duration is different from that of Korea's debt. For this reason it is not appropriate to use the measured stock of nonindexed debt on the eve of the crisis to calibrate B. We chose B so that the amount of revenue from debt deflation is roughly consistent with the evidence from Korea presented in section 5.

Table 2 shows that introducing nonindexed debt lowers the growth rate of money μ that is necessary to pay for ϕ. As a result, steady state inflation declines from 20.0 percent in the base model to 16.1 percent. Obviously with more initial nonindexed debt, the crisis could be financed with less recourse to inflation. For example if B equaled 0.5, the rate of inflation would be 15.5 percent in the first year after the currency crisis and 2.1 percent thereafter. The government would only raise 14.6 percent of the fiscal cost of the crisis from seignorage revenues. The balance would come from debt deflation. So, in principle, allowing for nonindexed debt can reconcile our basic model with the observation that inflation is often quite moderate after a currency crisis. But for the countries involved in the Asian crisis of 1997 and Mexico there was not enough nonindexed debt for this to be a complete resolution of the problem.

Implicit Fiscal Reform

We now allow for an implicit fiscal reform as a source of revenue for the government. Specifically we assume that $G = 0.02$, i.e. nonindexed government spending is about 2 percent of GDP. In addition we assume that G is fixed in nominal terms for roughly 2.5 years after the crisis and then starts growing at the rate of inflation. So in this example the implicit fiscal reform amounts to a permanent reduction in the real value of government spending relative to GDP. In our case study of Korea we examine the sensitivity of our results to alternative mixes of implicit and explicit fiscal reforms.

Table 2 makes clear that allowing for an implicit fiscal reform has a significant impact on the model's predictions. Relative to the scenario where the only nonindexed liability is nominal debt, year 1 inflation falls from 30.9 percent to 20.2 percent. Long run inflation falls from 16.1 percent to 6.1 percent. The percentage of total fiscal costs raised by seignorage falls from 83.4 percent to 35.9 percent, while the importance of debt deflation falls from 16.6 percent to 13.1 percent. Even though nonindexed government spending represents only 2 percent of GDP, the implicit fiscal reform pays for over 50 percent of the cost of the crisis.[17]

Allowing for debt deflation and implicit fiscal reform can render our model consistent with the observation that inflation rates are often moderate after a currency crisis. However, these extensions cannot explain the other shortcoming of the benchmark model: actual inflation is often much lower than the rate of devaluation associated with a currency crisis. We turn to this challenge next.

4.2. Deviations from Purchasing Power Parity

Up to this point, all of the models that we have considered assume that PPP holds. So by construction the rate of inflation coincides with the rate of devaluation. To break the link between domestic inflation and exchange rate depreciation we introduce two departures

[17] To assess the robustness of our results we re-did our calculations assuming that G is fixed in nominal terms for only 5 months. In this case the implicit fiscal reform raises 33 percent of the total fiscal cost of the crisis. In this experiment the value of t^* is 0.57. The rate of inflation is 23.7 percent in the first year and 9.2 percent in the following years.

from PPP into the model described in section 4.1: (i) nontradable goods; and (ii) costs of distributing tradable goods (e.g. transportation, wholesaling and retailing).

Nontradable Goods

In the presence of nontradable goods the consumer price index (CPI), P_t is given by:

$$P_t = (P_t^T)^\omega (P_t^{NT})^{1-\omega}. \tag{4.2}$$

Here P_t^{NT} denotes the price of nontradable goods and P_t^T the price of tradable goods. By assumption PPP holds for tradable goods, so $P_t^T = S_t$ for all t. Absent an explicit model of the nontradable goods sector we assume that P_t^{NT} remains fixed for the first 5 months after the currency crisis. Thereafter P_t^{NT} moves one to one with the exchange rate. Consequently a currency crisis is associated with a permanent decline in the relative price of nontradable goods. This assumption is motivated by the Korean experience. The price of nontradables in Korea increased by only 4.8 percent between October 1997 and April 1998 while it increased only by 5.6 percent between October 1997 and October 1998. Finally, we set $\omega = 0.5$ which corresponds to the share of tradables in Korea's CPI.[18]

Since we defined m_t as M_t/S_t, equation (4.1) remains unchanged. Equation (3.5) describes the evolution of the CPI. Equations (3.5) and (4.2), together with the path for P_t^{NT}, determine the behavior of the exchange rate. The equilibrium values of t^* and μ can be computed using equations (3.10) and (4.1).

Table 2 indicates that these modifications of the model have two effects. First, there is a relatively small decline in the amount of inflation induced by a currency crisis. Inflation is 17.7 percent in the first year after the crisis, while steady state inflation is 4.0 percent. Second, and more importantly, the model now generates a large wedge between the initial rate of inflation and the rate of depreciation. Specifically, the currency crisis is now associated with a 35.4 percent rate of depreciation in the first year.

Distribution Costs

To induce an even larger wedge between inflation and depreciation we now allow for distribution costs in tradable goods. Proceeding as in Burstein, Neves and Rebelo (2000)

[18] This information was obtained from the Annual Report on the Consumer Price Index, National Statistical Office Republic of Korea, 1998. Food, Fuel, Light and water, Furniture and Utensils, Clothing and footwear, Cigarettes and Toilet articles were classified as tradable goods. Medical care, Education, Culture and Recreation, Transportation and Communication, and Personal Care services were classified as nontradables.

we assume that δ units of nontradables (transportation, wholesale and retail) are required to distribute tradable goods. As in their paper we assume that PPP holds for the import prices but not for the retail prices of tradable goods. The latter are given by: $P_t^T + \delta P_t^{NT}$ so that the CPI is:

$$P_t = (S_t + \delta P_t^{NT})^{\omega} (P_t^{NT})^{1-\omega}.$$

The last line of Table 2 displays results for this version of the model under the assumption that $\delta = 1$.[19] Figure 2 depicts the paths for the exchange rate, the price level, and the money supply. Notice the stark difference between this model and the benchmark model discussed in section 3. In the benchmark model inflation in the first year after the crisis is equal to 34.9 percent and declines to 20 percent in steady state. In addition the rate of devaluation coincides with the rate of inflation. In contrast, the modified model implies first year inflation roughly equal to 14 percent while the currency devalues by over 50 percent. Moreover, steady state inflation is only 1 percent. Clearly this version of the model can account for large devaluations without generating grossly counterfactual implications for inflation.

5. Two Case Studies

We now examine in some detail two recent crises, Mexico 1994 and Korea 1997, and discuss how the governments in these countries are paying for the fiscal costs associated with the crises. Our calculations suggest that Mexico will finance most of the fiscal costs associated with its crisis through seignorage revenues. In contrast our best guess is that Korea will pay for the bulk of the fiscal cost of its crisis through future explicit and implicit fiscal reforms.

5.1. The Government Budget Constraint Revisited

Up to now we have abstracted from output growth and foreign inflation. To interpret the data we must amend the government budget constraint (2.6) to incorporate these elements. To this end suppose that domestic output and the US price level grow at constant rates ζ and π^*, respectively. We normalize the US price level at $t = 0$ to one. Consequently P_t^* evolves according to:

$$P_t^* = e^{\pi^* t}.$$

The presence of output growth and foreign inflation implies that, in a sustainable fixed exchange rate regime, real balances grow at rate ζ and domestic inflation, π, is equal to π^*.

[19] This value of δ is consistent with the evidence presented in Burstein, Neves and Rebelo (2000).

It also implies that the government can collect seignorage under a fixed exchange rate regime. To see this it is convenient to focus on the benchmark model. Given PPP the demand for real balances is given by:

$$\begin{aligned} \frac{M_t}{P_t} &= \frac{M_0}{P_0} e^{\zeta t}, \\ \frac{M_0}{P_0} &= \theta Y_0 \exp[-\eta(r+\pi^*)]. \end{aligned}$$

Here M_0/P_0 and Y_0 denotes real balances and output at time zero, respectively.

For S to remain constant, the money supply must grow at rate $\bar{\mu} = \zeta + \pi^*$. Under these circumstances the dollar value of seignorage flows at time t is:

$$\frac{\dot{M}_t}{S_t} = (\zeta + \pi^*) \frac{M_0}{P_0} e^{(\zeta+\pi^*)t}.$$

The present value in dollars at time zero of seignorage revenues collected under a sustainable fixed exchange rate regime is given by:

$$\int_0^\infty \frac{\dot{M}_t}{S_t} e^{-(r+\pi^*)t} dt = (\zeta + \pi^*) \frac{M_0}{P_0} \frac{1}{r-\zeta}.$$

Finally, the new version of the government budget constraint (2.6) is:

$$\begin{aligned} \phi = & \int_0^\infty \frac{\dot{M}_t}{S_t} e^{-(r+\pi^*)t} dt + \sum_{i \in I} \frac{\Delta M_i}{S_i} e^{-(r+\pi^*)i} - (\zeta + \pi^*) \frac{M_0}{P_0} \frac{1}{r-\zeta} \\ & + \left[\frac{B}{S} - \int_0^\infty \frac{(r+\pi^*)B}{S_t} e^{-(r+\pi^*)t} dt \right] - \left[\int_0^\infty \left(\frac{X_t}{S} - \frac{X_t}{S_t} \right) e^{-(r+\pi^*)t} dt \right]. \end{aligned} \tag{5.1}$$

The key implication of (5.1) is that not all of the seignorage collected in the post-crisis period ($\int_0^\infty (\dot{M}_t/S_t) e^{-(r+\pi^*)t} dt + \sum_{i \in I} (\Delta M_i/S_i) e^{-(r+\pi^*)i}$) contributes to financing the crisis. Part of those revenues ($(\zeta + \pi^*) \frac{M_0}{P_0}/(r-\zeta)$) would have been collected under the fixed exchange rate regime. These revenues were required to fulfill the government's pre-crisis budget constraint. Only the difference between the seignorage collected in the presence of the crisis and the hypothetical seignorage that would have been collected in the absence of the crisis can be used to finance the new spending, ϕ. Inevitably, some assumptions are required to compute this hypothetical seignorage.

5.2. Mexico, 1994

Figure 3 displays four quarterly series for the period 1993 to 2000: the peso/dollar exchange rate, the CPI, and the export and import price deflators. Between December 20th and

December 31st 1994 the peso/dollar exchange rate increased by 44 percent. By January 2nd, 1996 the cumulative increase in the peso/dollar exchange rate reached 121 percent. While the export and import price indices moved closely with the exchange rate, the rate of CPI inflation was much lower than the rate of depreciation.

The currency crisis exacerbated an ongoing banking crisis.[20] The net result was a large rise in the Mexican government's prospective deficits associated with an impending bank bailout. Lindgren et. al. (1996) estimate the fiscal cost of the crisis to be 6.5 percent of GDP, which amounts to 27 billion dollars. On the other hand, Caprio and Klingebiel (1996) estimate the cost to be between 12 and 15 percent of GDP, with the upper bound translating into 63 billion dollars. More recently Caprio and Klingebiel have revised their estimate to 20 percent of GDP. This corresponds to 84.3 billion dollars.[21]

In what follows we provide a rough estimate of what the Mexican government has done to date to finance its fiscal costs. In addition we discuss what the future growth rate of money would have to be to finance the remainder of the costs.

Seignorage Revenues

We begin by discussing the seignorage revenues raised by the Mexican government in the post-crisis period. Using monthly data on the monetary base we computed the present value of the seignorage collected between November 1994 and December 2000.[22] The flows of seignorage were discounted with a dollar interest rate $R^* = 0.065$.[23] Under our assumptions the present value in 1994 of the seignorage revenue collected between November 1994 and December 2000 was 20.2 billion dollars.

To calculate the part of this seignorage that can be used to cover the fiscal costs of the crisis, we must compute the hypothetical seignorage that Mexico would have collected during this period had the crisis not occurred. We compute the present value in 1994, measured

[20] Difficulties associated with rolling over short-run dollar denominated debt no doubt played some role in the exact timing of the crisis. Here we are more concerned with understanding how the fiscal costs of the crisis were financed. See Krueger and Tornell (1999), and Sachs, Tornell and Velasco (1996) for detailed discussions of the Mexico 1994 crisis.

[21] We use 1994 GDP to compute the dollar amounts.

[22] We used the IMF's International Financial Statistics database. The series we used for the monetary base is 14...ZF, Reserve Money. This differs slightly from the Banco de Mexico's series for definitional reasons.

[23] The average dollar return on 28-day Mexican treasury peso-denominated securities was 6.5 percent from December 1994 to December 2000. This rate of return is similar to US rates of interest. The average 1-year US Treasury bill yield from December 1994 to January 2000 was roughly 5.5 percent. So was the 30 year zero coupon yield estimated by J. Huston McCulloch for February 2001 and reported in http://www.econ.ohio-state.edu/jhm/ts/ts.html.

in dollars, of this hypothetical seignorage flow by making two assumptions. First, in the absence of the crisis, the growth rate of money from 1994 on would have been constant and equal to the average year-on-year growth rate of the monetary base in the period January 1989 to November 1994. This equals 18 percent per annum.[24] Second the demand for real balances measured in dollars, M_t/S_t, would have grown at the average growth rate of output from 1980 to 2000 (roughly $\zeta = 0.027$). This implies that the present value of hypothetical seignorage that would have been collected between November 1994 (time 0) and December 2000 is 13.9 billion dollars.[25] So the net increase in seignorage revenues collected up to December 2000 that can be used to finance the fiscal cost of the crisis is 6.3 billion dollars.

Debt Devaluation

At the end of September 1994 the government owed 138.7 billion pesos worth of securitized debt and 10.1 billion pesos of non-securitized debt. Since we have no information on the indexation provisions of non-securitized debt we adopted the conservative assumption that all of it was indexed. The securitized debt can be broken down into the following categories. Cetes, which are zero-coupon Mexican Treasury Bills, represented 34 percent of securitized debt. Tesobonos, which are dollar-denominated zero-coupon bonds, represented 33 percent. Ajustabonos, which are inflation-indexed coupon bonds, represented 21 percent. Bondes, which are adjustable coupon bonds, represent 12 percent. To simplify we treated both Bondes and Tesobonos as if they were perfectly indexed to the dollar. To compute the revenue in dollars generated by the debt deflation we considered only Cetes, which are not indexed, and Ajustabonos, which are indexed to the CPI, not to the dollar.

We consolidated the securitized debt of the government and the central bank. We only have information on the composition of securities held by the central bank for the end of 1994. At this time the Banco de Mexico held 2.5 billion pesos of Cetes and held a negative position of 0.5 billion pesos in Ajustabonos.

To compute the reduction in the dollar value of the outstanding Cetes in the aftermath of the crisis we assumed that the these bonds were distributed equally across 4 maturities: 1, 3, 6 and 12 months. Within each maturity we assumed that the bonds were distributed equally

[24] This corresponds to a continuously compounded rate $\mu = 0.166$.

[25] This was computed using the formula $\mu(M_0/S_0)[1 - e^{-(R^* - \zeta)h}]/(R^* - \zeta)$, where M_0 and S_0 are the Nov. 1994 values of the monetary base and exchange rate and $h = 6.083$ (the number of years between November 1994 and December 2000) .

across all possible expiration dates.[26] Consider a Cetes of a given maturity and expiration date that was outstanding at date t. We compute its loss in dollar value between dates t and $t+1$ as $F/S_t - F/S_{t+1}$ where F is the face value in pesos and S_t is the peso-dollar exchange rate at time t. We make similar assumptions with regard to Ajustabonos which come in maturities of 3 and 5 years. Specifically we compute the loss in dollar value between dates t and $t+1$ as $F_t/S_t - F_{t+1}/S_{t+1}$ where $F_t = F_{t-1}P_t/P_{t-1}$ and P_t is the CPI at date t.

These assumptions imply that the total revenue generated by debt deflation was 8.4 billion dollars. Most of this revenue (90 percent) was generated in the first month after the devaluation. This means that our calculations are not very sensitive to our timing assumptions about maturities and expiration dates.

Implicit and Explicit Fiscal Reform

Despite several changes in the tax code it is difficult to find evidence of large explicit or implicit fiscal reforms.[27] According to Burnside (2000) the average cyclically adjusted primary surplus was 3.5 percent of GDP in the pre-crisis period 1991-94.[28] In the period 1995Q1-98Q2 the average cyclically adjusted primary surplus was 4.2 percent of GDP. These estimates suggest that overall the net effect of any fiscal reform was small.[29]

Here, using a simple methodology described in the appendix, we decompose the primary budget surplus, Δ_t, into three components

$$\Delta_t = \bar{\Delta}_t + (\hat{\Delta}_t - \bar{\Delta}_t) + (\Delta_t - \hat{\Delta}_t), \tag{5.2}$$

where $\bar{\Delta}_t$ is the primary fiscal surplus that would have occurred in the absence of any crisis, and $\hat{\Delta}_t$ is the cyclically-adjusted primary surplus. We describe the second term on the right-hand side of (5.2) as the fiscal reform component, while the third term is the cost-of-recession component.

We estimate that fiscal reforms $(\hat{\Delta}_t - \bar{\Delta}_t)$ generated roughly 5.8 billion dollars in additional funds for the government. Since the nominal value of the Mexican government's nonindexed

[26] In other words for the 3 month maturity we assumed that one third of the Cetes would expire within 1, 2 and 3 months, respectively.

[27] Fiscal reforms included an increase in the general value-added tax rate from 10 to 15 percent, as well as increases in the prices of public goods and services in 1995.

[28] These estimates incorporate the impact of changes in the price of oil on Mexico's fiscal situation. See Kletzer (1997) for a discussion of the fiscal implications of external shocks.

[29] These calculations take into account the decline in the real value of taxes due to inflation, known as the Tanzi effect.

liabilities quickly began to rise after the crises, most of these reforms were explicit rather than implicit. We estimate the recession costs $(\Delta_t - \hat{\Delta}_t)$ to have been about 2.2 billion dollars.

Summary of what has been done to date

Adding up additional seignorage (6.3 billion dollars), the revenue from debt devaluation (8.4 billion dollars), and the revenue from the fiscal reforms, net of recession costs (3.5 billion dollars), we estimate that, to date, the Mexican government has raised 18.2 billion dollars. This corresponds to 4.3 percent of 1994 Mexican GDP, which is close to Lindgren, et. al.'s (1996) estimate of the size of the crisis. If one accepts this estimate, the Mexican government has almost finished paying for the fiscal costs of the crisis. However, if one accepts Caprio and Klingebiel's (1996) estimates much is left to be done.

Financing the Remaining Costs

Absent any indication of large impending fiscal reforms, it seems reasonable to suppose that the remainder of the fiscal costs will be paid for with seignorage revenues. We estimate that the monetary base would have to grow at an annual rate of 21.2 percent, from 2001 on, to raise the additional 10.6 percent of GDP required to finance a crisis of the size estimated by Caprio and Klingebiel (1996).

We arrived at this number as follows. First, we estimated the seignorage that would have been collected absent a crisis from January 2001 onwards. We used the same assumptions that we employed to estimate hypothetical seignorage for the period Nov. 1994–Dec. 2000. These assumptions imply that the Mexican government would have raised seignorage with a present value in 1994 equal to 55.9 billion dollars. Second, we estimated the present value (as of 1994) of the seignorage revenues resulting from a constant growth rate of the monetary base from January 2001 onwards. Here we assumed that the growth rate of real balances measured in dollars would be equal to the historical average growth rate of real GDP from 1980 to 2000 (2.7 percent) and that the dollar interest rate would be 6.5%. Given these assumptions, a growth rate of the nominal base equal to 21.2 percent yields a present value of hypothetical seignorage equal to 100.9 billion dollars. So the extra seignorage that can be used to pay for the crisis would equal 45.0 billion dollars (100.9–55.9). This is equivalent to 10.6 percent of 1994 GDP.

We emphasize that our estimate of the required growth rate of money is sensitive to the assumptions underlying our calculations. For example, if Mexico grows more quickly or the dollar interest rate is lower than we assumed, then the government will be able to cover the fiscal costs of the crisis with lower future money growth rates.

The key point is that absent any sign of fiscal reforms, it seems quite likely that the bulk of the costs will be covered via explicit seignorage revenues. This implies that the rate of inflation in Mexico is higher than it would have been had the implicit fiscal reform or the initial domestic debt been larger. We use our model to illustrate this point more concretely in the case of Korea, which we turn to next.

5.3. Korea, 1997

Figure 4 displays four quarterly series for the period 1996 to 2000: the won/dollar exchange rate, the CPI, and the export and import price indices. Between September 1997 and September 1998 the won/dollar exchange rate increased by 52.1 percent. Figure 4 shows that while the export and import price indexes moved closely with the exchange rate, CPI inflation was significantly lower than the rate of depreciation. Between September 1997 and September 1998 the CPI increased by just 6.9 percent.

As in Mexico, the currency crisis in Korea exacerbated existing problems in the banking system. As of December 1999, Standard and Poor's Ratings Service's estimated that the fiscal cost of the banking crisis would be roughly 24 percent of GDP. In terms of 1997 GDP, this corresponds to 114.4 billion dollars.

In what follows we provide rough estimates of what the Korean government has done to date to finance the fiscal costs of the crisis. We then discuss the implications of alternative strategies for financing the remainder of the costs.

Seignorage Revenues

Using monthly data on the monetary base and a dollar interest rate of 5.5 percent, we estimate that the present value of the seignorage raised between October 1997 and October 2000 is equal to 5.6 billion dollars.

To compute the hypothetical seignorage that the government would have raised absent a crisis we make several assumptions. First, in the absence of the crisis, the growth rate of money from late 1997 on would have been constant and equal to the average year-on-year growth rate of the monetary base in the period October 1993–October 1997. This equals 0.6

percent per annum ($\mu = 0.006$). Second, the demand for real balances in dollar terms would have grown at the average growth rate of output from 1980 to 1999. This equals 7.3 percent ($\zeta = 0.07$). These assumptions imply that the present value of hypothetical seignorage that would have been collected between October 1997 and October 2000 is 0.4 billion dollars. So the net increase in seignorage revenues collected up to October 2000 that can be used to finance the fiscal cost of the crisis is 5.2 billion dollars.

Debt Devaluation

In Korea, as in Mexico, not all domestic public sector debt is securitized. Since we know very little about the indexation of non-securitized debt we adopted the conservative assumption that all of it was indexed. We focus narrowly on the following securities: government bonds and monetary stabilization bonds issued by the central bank. The outstanding amounts of these two types of bonds at the end of December 1996 were, respectively, 25.7 and 25.0 trillion won.[30] In addition the central bank held government bonds worth 2.1 trillion won. Consequently, we assume that the securitized debt was equal to 48.6 trillion won (25.7+25.0–2.1). We use this December 1996 measure of the stock of debt to benchmark the stock of debt in October 1997.

We know much less about the maturity structure of Korean debt than we do about Mexican debt. Korean treasury bonds are issued in maturities of 1, 3 or 5 years.[31] Monetary stabilization bonds are issued with maturities between 14 days and 18 months. If we assume average expiration dates between 6 months and 18 months across all types of bonds we obtain estimates of the amount of debt devaluation ranging from 13.7 to 16.4 billion dollars. Over this range, the estimate is actually decreasing in the average maturity of the bonds due to the rebound in the value of the won after January 1998.

Implicit and Explicit Fiscal Reform

The Korean government appears to have implemented a combination of explicit and implicit fiscal reforms. On the explicit side, tax revenue has recently risen sharply relative to GDP. This suggests that either tax rates have been raised, the tax base has expanded, or that enforcement has been improved. On the implicit side, the won value of expenditures

[30] For the figures on government bonds see IMF (2000). For central bank debt and holdings of treasury securities see the Bank of Korea website.

[31] The government has established the 3-year bond as a benchmark in the post-crisis period.

has risen very slowly since the crisis. For example, the public sector wage bill actually declined slightly between 1997 and 1999 in won terms, representing a 6 billion dollar saving to the government over 2 years. Of course, we cannot be certain whether such savings were implicit—the result of contracts set in nominal terms—or explicit—via job losses or ex-post wage freezes.

Using the same methodology as for Mexico, we put the present value of implicit and explicit fiscal reforms at roughly 34.4 billion dollars. Set against these gains are losses of 24.7 billion dollars in tax revenue due to the recession.

Summary of what has been done to date

Adding up additional seignorage (5.2 billion dollars), the revenue from debt devaluation (13.7 billion dollars), and the revenue from fiscal reforms (34.4 billion dollars) net of recession costs (24.7 billion dollars) we obtain a total of 28.6 billion dollars. This corresponds to 6 percent of Korea's 1997 GDP. Since our estimate of the fiscal cost of the crisis is 24 percent of 1997 GDP, or 114.4 billion dollars, this leaves a shortfall of 85.8 billion dollars that must be raised in the future. This figure is close to the amount of new debt issued by the Korean government via the Korea Asset Management Corporation and the Korea Deposit Insurance Corporation and in other forms since 1997. In present value terms this new debt is worth about 82 billion dollars.

Financing the Remainder of the Fiscal Cost

To finance the remainder of the fiscal cost Korea could use a combination of further fiscal reforms and increased seignorage. Suppose that the government raised all of the required revenue via seignorage. What kind of monetary policy would they have to pursue in the future? To answer this questions we make two assumptions. First, the growth rate of money from October 2000 equals 16.8 percent per annum. This is the average money growth rate between October 1998 and October 2000.[32] Second, from October 2000 on, real balances grow at 7.3 percent per annum. This is the average annual growth rate of real GDP between 1980 and October 2000. Under these assumptions Korea could raise the additional seignorage it requires in roughly 22 years. From the standpoint of our model, this scenario seems unlikely since inflation would have been much higher than it actually is. Our model suggests that a

[32] At the end of October 2000, the value of Korea's stock of base money was about 24.3 billion dollars.

more plausible scenario is the government will raise the remainder of the revenue it needs through a combination of future implicit and explicit reforms and a very moderate amount of seignorage.

To show this we ask the question: how big does the future explicit reform have to be to rationalize Korea's post-crisis inflation experience? Various experiments with our model suggest that the answer is roughly 16 percent of GDP or 66.7 percent of the fiscal cost of the crisis.[33] Table 3 summarizes the key features of the equilibrium path of the model economy under this assumption. This example has a number of striking features. It is consistent with the observation that, a year after the crisis, inflation in Korea became extremely low. In the model the steady state rate of inflation (attained after the first year) is 1.6 percent. Overall seignorage only accounts for 10.6 percent of the cost of the crisis. Nevertheless the model generates a realistically large depreciation of the won in the first year of the crisis (59.9 percent).

Understanding the Properties of the Extended Model

The ability of our model to rationalize large rates of devaluation along with moderate inflation is due to three features. First, even though seignorage plays a small role in government finance, inflation-related revenue includes the value of the implicit fiscal reform, debt devaluation as well as seignorage. Together these three sources of revenue account for roughly one third of the fiscal cost of the crisis. Eliminating the first two revenue sources and relying exclusively on seignorage would result in substantially larger rates of inflation. In particular, inflation in the first year would jump to 20 percent and steady state inflation would exceed 6 percent. Second, distribution costs play a key role in magnifying the rate of depreciation. To see this suppose that we eliminate distribution costs ($\delta = 0$). Then the depreciation in the first year would only equal 32 percent instead of 59.9 percent. Inflation in the first year would rise to over 15 percent and steady state inflation would climb to 1.6 percent. If we also eliminate nontradables ($\omega = \delta = 0$) the model implies that the rate of depreciation in the first year is roughly 16 percent. Since PPP holds in this version of the model the rate of inflation coincides with the depreciation rate. Finally, the model assumes that there is a period of very rapid money growth at some point after the crisis. This is captured by the assumption that there is a discrete increase in the money supply at

[33] In these experiments we set $G = 0.003$ so that the fraction of the fiscal cost financed by the implicit reform is roughly 12 percent.

$T = 1$.[34] If this money injection did not occur then the rate of depreciation in the first year would be only 8.3 percent, a number far lower than observed in the data. We conclude that non-seignorage inflation related revenue, distribution costs, nontradable goods, and short run monetization all play important roles in allowing the model to generate large rates of depreciation along with moderate inflation.

We conclude this section with a brief discussion of some of the model's empirical shortcomings. The most obvious is that it significantly overstates inflation in the first year after the crisis. The model predicts inflation on the order of 15 percent while actual inflation in Korea was roughly 7 percent. This problem may reflect: (i) the fact that we abstracted from the severe recession that occurred in Korea after the crisis; (ii) the presence of measurement problems in the Korean CPI;[35] and (iii) the fact that the prices of many nontradable services like medical care and education are controlled by the government.[36] In ongoing work Burstein, Eichenbaum and Rebelo (2001) use disaggregated CPI data to explore the quantitative importance of these factors.

A final shortcoming of the model is that it does not account for the different patterns of depreciation in Korea and Mexico. As is evident from Figures 3 and 4 the Korean exchange rate displays a strong overshooting pattern that is completely absent in the Mexican case.[37] Understanding this difference strikes us as an important area for future research.

6. Conclusion

This paper explored the implications of different strategies for financing the fiscal costs of twin crises for inflation and depreciation rates. We do this using a first generation type model of speculative attacks which has four key features. First, the currency crises is triggered by prospective deficits. Second, there exist outstanding nonindexed government debt whose real

[34] Recall that the value of γ used in our example was motivated by Korean data. Burnside, Eichenbaum and Rebelo (2001) discuss the patterns of money growth across different countries in the aftermath of the Asian currency crisis.

[35] Devaluations may lead to a flight from quality as agents substitute away from imported items to lower quality, locally produced, substitutes. The methods used in Korea to choose the brands included in the CPI and the treatment of items that are no longer available may lead measured inflation to significantly understate actual inflation.

[36] According to the Annual Report on the Consumer Price Index (National Statistical Office Republic of Korea, 1998) the weight of government controled prices in the Korean CPI is 20.8 percent. This includes goods and services in the following categories: Medical care (5.1 percent), Education (9.2 percent), Culture and recreation services (3.4 percent), and Public Transportation (3.1 percent).

[37] The Thai baht exhibited an overshooting patern similar to that of the Korean won.

value can be reduced through a devaluation. Third, some government's liabilities are not indexed to inflation and their real value declines after a currency crises. Fourth, there are nontradable goods and costs of distributing tradable goods, so that purchasing power parity does not hold.

We use our model and the data to interpret the recent currency crises in Mexico and Korea. Our analysis suggests that the Mexican government is likely to pay for the bulk of the fiscal costs of its crisis through seignorage revenues. As a consequence rates of inflation have been relatively high. We anticipate that inflation will continue to be high in the future. In contrast, the Korean government is likely to rely more on a combination of implicit and explicit fiscal reforms. Under this assumption our model can account both for the large devaluation of the Korean won in 1997 and the fact that current rates of inflation in Korea are extremely low.

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7. Appendix: Estimating the Size of Fiscal Reforms

Our procedure for computing the size of the fiscal adjustment after a crisis consists of 2 main ingredients.

1. Estimating the cyclically adjusted primary budget surplus.
2. Estimating what the budget surplus would have been in the absence of the crisis.

Estimating the Cyclically Adjusted Budget Surplus

Define the standard measure of the primary budget surplus as $\Delta_t \equiv R_t - E_t$, where R_t is revenue and E_t is primary expenditure. A cyclically-adjusted measure of the primary surplus is $\hat{\Delta}_t \equiv \hat{R}_t - \hat{E}_t$, where $\hat{R}_t$ and $\hat{E}_t$ are cyclically-adjusted measures of R_t and E_t.

Standard procedures for computing cyclically-adjusted revenue and expenditure dictate that there are specific revenue and expenditure components that adjust automatically to the business cycle, while there are others that only move according to the government's discretion. To illustrate suppose there are K revenue categories, of which K_1 adjust according to the business cycle and $K - K_1$ which do not. Then revenue is given by

$$R_t = \sum_{i=1}^{K_1} R_{it} + \sum_{i=K_1+1}^{K} R_{it}.$$

Cyclically-adjusted revenue is given by

$$\hat{R}_t = \sum_{i=1}^{K_1} \hat{R}_{it} + \sum_{i=K_1+1}^{K} R_{it},$$

where $\hat{R}_{it}$ is the ith cyclically-adjusted revenue component. Note that some revenue categories are not adjusted as they are deemed to be purely discretionary or at least invariant to the business cycle. Typically tax revenues and transfers to households are the types of categories that are cyclically adjusted. An adjusted revenue category would typically be estimated as

$$\hat{R}_{it} = R_{it} \exp[-\alpha_i(\ln Y_t - \ln \bar{Y}_t)]$$

where $\ln \bar{Y}_t$ is some measure of trend real GDP, and α_i is a measure of the elasticity of this category of revenue with respect to the output gap, $\ln Y_t - \ln \bar{Y}_t$.

In developing countries it is typical for tax revenue to move closely in proportion to GDP, while few if any of the expenditure categories exhibit a strong elasticity with respect to GDP.

Motivated by this fact, and to simplify our analysis, we use a very simple procedure and compute $\hat{\Delta}_t = \hat{R}_t - E_t$, where $\hat{R}_t = [R_t/(P_t Y_t)]P_t\bar{Y}_t$, where P_t represents the GDP deflator. In other words, we assume that all changes in the ratio of revenue to GDP are discretionary. Thus we have $\hat{\Delta}_t = R_t(\bar{Y}_t/Y_t) - E_t$. To obtain trend GDP we fit a linear trend to data on the logarithm of real GDP from 1980 to 2000.

The part of the budget surplus due to the business cycle is $\Delta_t - \hat{\Delta}_t$.

The Budget Surplus in the Absence of the Crisis

We denote the budget surplus in the absence of the crisis by $\bar{\Delta}_t$. We let $\bar{\Delta}_t = dP_t\bar{Y}_t$, where d is the average primary surplus (as a fraction of GDP) in an N-year window prior to the crisis. We set $N = 4$ so that for Mexico the window is 1991–94, while for Korea it is 1994–97.

The Size of the Fiscal Reform

Suppose we have observed government finance data for H years after the crisis. We compute the size of the fiscal reform, in dollars, as

$$FR = \sum_{t=1}^{H}(1+R)^{-t}\frac{\hat{\Delta}_t - \bar{\Delta}_t}{S_t}$$

where S_t is the local currency-dollar exchange rate and R is the assumed dollar interest rate.

Recession Costs

We estimate recession costs as

$$RC = \sum_{t=1}^{H}(1+R)^{-t}\frac{\Delta_t - \hat{\Delta}_t}{S_t}.$$

Decomposition of the Budget Surplus

Our decomposition of the budget data means that

$$\Delta_t = \bar{\Delta}_t + (\hat{\Delta}_t - \bar{\Delta}_t) + (\Delta_t - \hat{\Delta}_t)$$

where the first component is the trend, the second is the fiscal reform, and the last is the cyclical.

TABLE 1

PARAMETERS FOR THE NUMERICAL EXAMPLES

(a) Benchmark Case	
$\eta = 0.5$	interest elasticity of money demand
$\chi = 0.12$	threshold rule parameter
$S = 1$	initial exchange rate
$\theta = 0.06$	constant in the money demand function
$r = 0.04$	real interest rate
$Y = 1$	constant level of output
$\phi = 0.24$	present value of new transfers
$b_0 = -0.067$	initial debt level
$T = 1$	time of switch to new monetary policy
$\gamma = 0.12$	% increase in M at T relative to $t = 0$
$\delta = 0$	distribution cost of tradables
$\omega = 1$	share of tradables in CPI
$Z = 0$	nominal transfers
$B = 0$	nominal debt
(b) Nominal Debt	
Same as (a) except	
$B = 0.05$	nominal debt
(c) Implicit Fiscal Reform	
Same as (b) except	
$Z = 0.022$	nominal transfers
$T_2 = T + 2$	date until which transfers stay constant
(d) Sticky Nontradables Prices	
Same as (c) except	
$\omega = 0.5$	share of tradables in CPI
$T_1 = T$	date until which nontradables prices are sticky
(e) Distribution Costs for Tradables	
Same as (d) except	
$\delta = 1$	distribution cost of tradables

Table 2

Results for Numerical Examples, No Explicit Fiscal Reform

	Inflation			Devaluation		t^*	Financing (% of Total)		
	Yr 1	Yr 2	Long-run	Yr 1	Yr 2		Seignorage	Nominal Debt Deflation	Implicit Fiscal Reform
a) Benchmark	34.9	20.0	20.0	34.9	20.0	0.49	100	0	0
b) Nominal Debt	30.9	16.1	16.1	30.9	16.1	0.52	83.4	16.6	0
c) Implicit Fiscal Reform	20.2	6.1	6.1	20.2	6.1	0.60	35.9	13.1	51.0
d) P^{NT} Sticky	17.7	4.0	4.0	35.4	4.0	0.61	21.4	12.4	66.2
e) Distribution	14.0	1.0	1.0	57.8	1.0	0.64	7.2	9.8	83.0

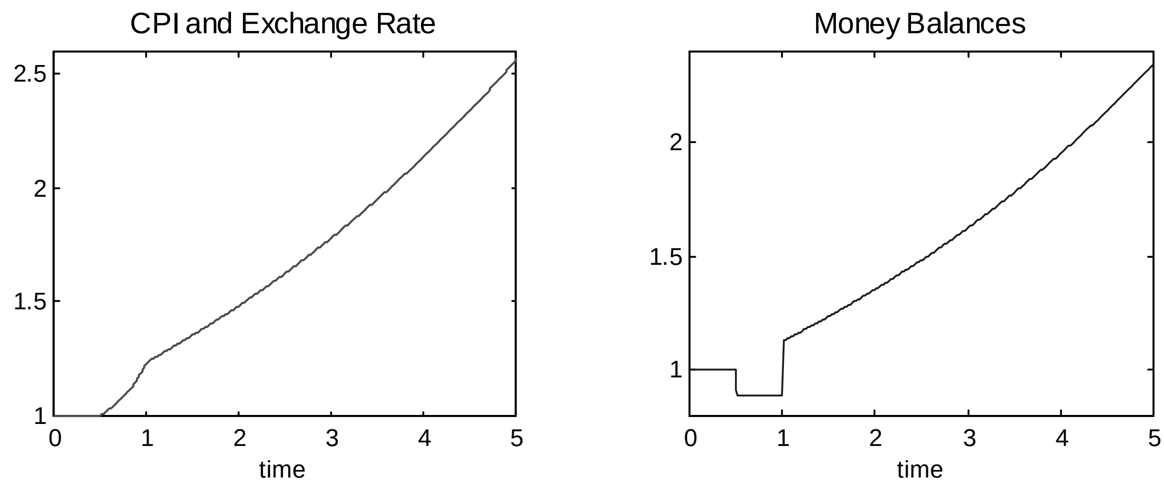
Table 3

Results for Numerical Example, Explicit Fiscal Reform (16 percent of GDP)

Inflation			Devaluation		t^*	Financing (% of Total)			
Yr 1	Yr 2	Long-run	Yr 1	Yr 2		Seignorage	Nominal Debt Deflation	Implicit Fiscal Reform	Explicit Fiscal Reform
14.8	1.6	1.6	59.9	1.6	0.64	10.6	11.0	11.7	66.7

FIGURE 1

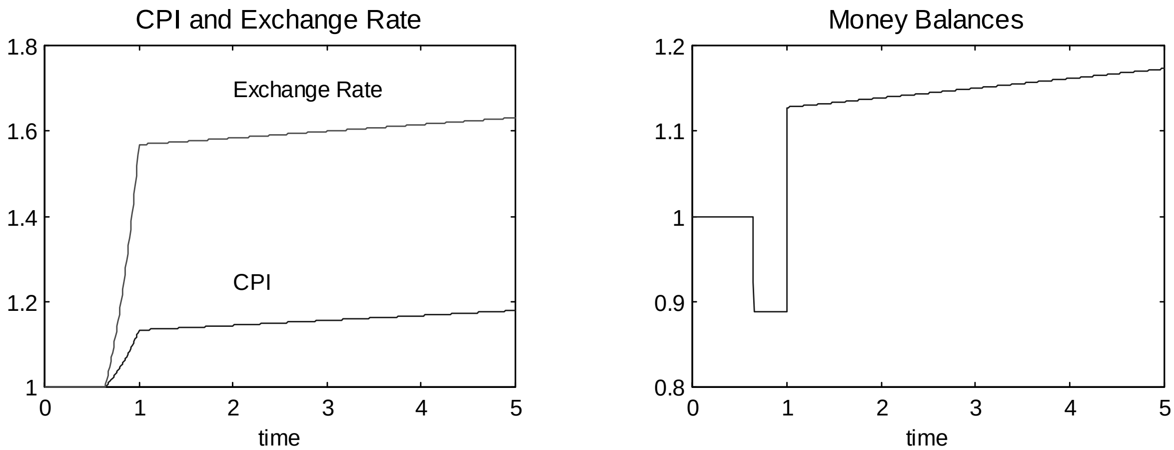
SOLUTIONS FROM THE BENCHMARK MODEL



Notes: Time in measured in years. Initial money balances are normalized to equal 1.

FIGURE 2

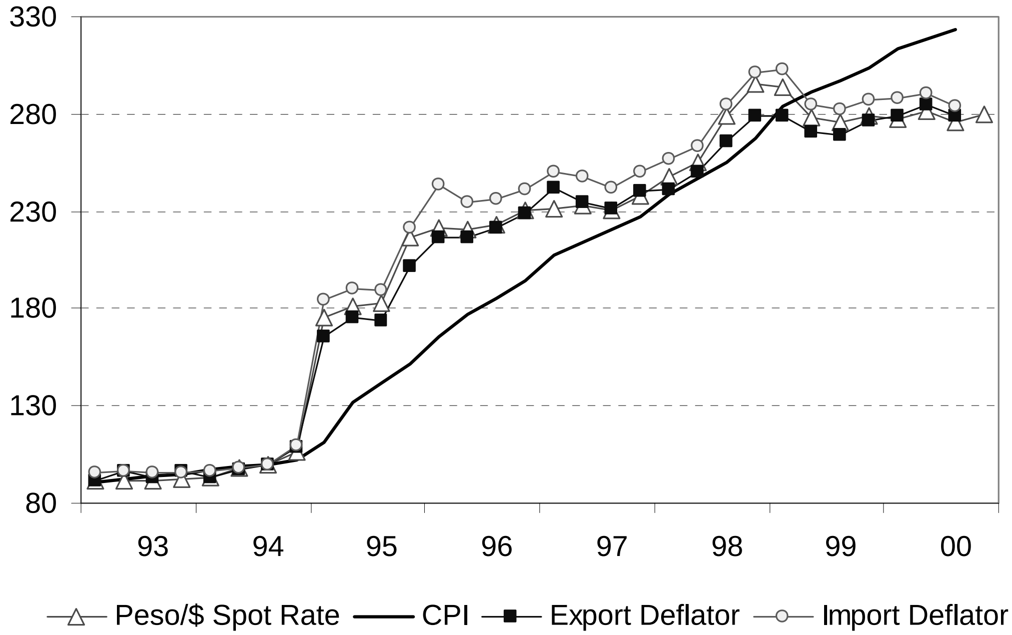
SOLUTIONS FROM THE MODEL WITH STICKY NONTRADABLES PRICES, DISTRIBUTION COSTS AND AN IMPLICIT FISCAL REFORM



Notes: Time in measured in years. Initial money balances are normalized to equal 1.

FIGURE 3

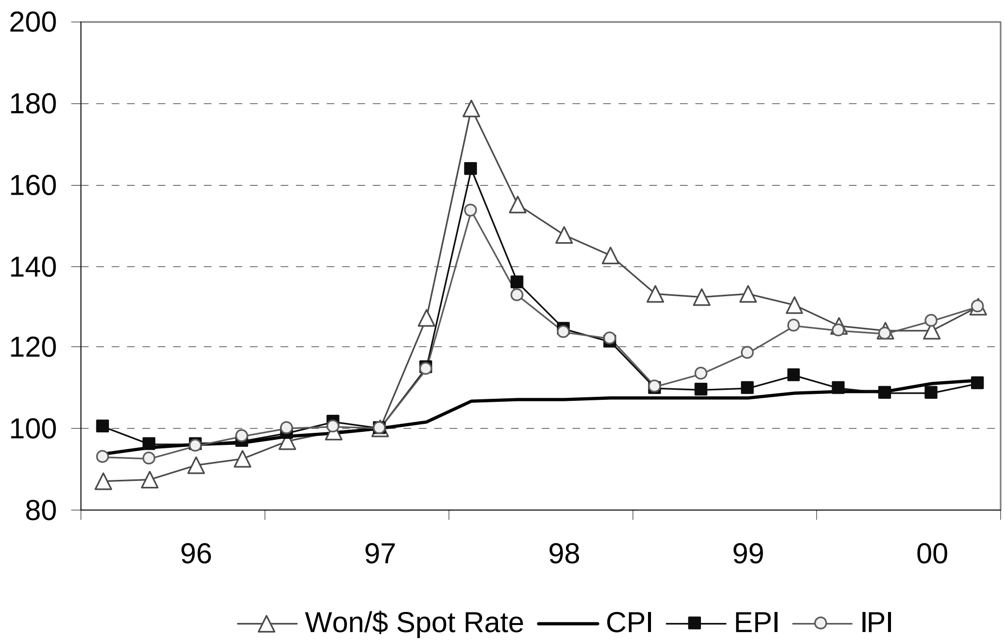
PRICE INDICES IN MEXICO 1993–2000
(1994Q3 = 100)



Notes and Sources: All series are normalized so that their value in 1994Q3 = 100 by creating a new series $Q_t = 100P_t / P_{1994Q3}$. The peso/$ spot rate is the IFS period-average market rate (AF...ZF). The consumer price index is from Hacienda. The import and export deflators are from the Mexican national accounts (Hacienda).

FIGURE 4

PRICE INDICES IN KOREA 1996–2000
(1997Q3 = 100)



Notes and Sources: All series are normalized so that their value in 1997Q3 = 100 by creating a new series $Q_t = 100P_t / P_{1997Q3}$. The won/$ spot rate is the IFS period-average market rate (AF...ZF). The consumer price index (CPI), export price index (EPI) and import price index (IPI) are all from the Bank of Korea website.