Government Finance in the Wake of Currency Crises*

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Abstract

We address three questions: (i) Can classical models be reconciled with the fact that many crises are marked by high rates of depreciation and small increases in seignorage revenue? (ii) What are the implications of different financing methods for post-crisis rates of inflation and depreciation? (iii) How do governments pay for the fiscal costs associated with currency crises? To study these questions we use a general equilibrium model in which prospective government deficits trigger a currency crisis. We then use our model in conjunction with fiscal data to interpret government financing in the wake of three recent currency crises: Korea (1997), Mexico (1994) and Turkey (2001).

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1. Introduction

A classical view of currency crises is that they arise because governments print money to finance ongoing or prospective deficits. This view is embodied in so-called first-generation models and their modern variants.[1] Despite their usefulness, these models suffer from a key shortcoming: they generally predict that seignorage should rise significantly in the aftermath of a currency crisis. Our examination of six recent currency crises indicates that this prediction is generally inconsistent with the data (see Table 1). Even though rates of depreciation in all the episodes we consider are very large (see Table 2), the increase in seignorage revenues is, at best, modest.

This evidence raises three questions:

- How do governments actually pay for the fiscal costs associated with currency crises?
- What are the implications of different financing methods for post-crisis rates of inflation and depreciation?
- Can we reconcile classical models with the fact that many crises are marked by high rates of depreciation and small increases in seignorage revenue?

We address these questions using a general equilibrium model in which a currency crisis is triggered by prospective government deficits. We then use our model, in conjunction with fiscal data, to interpret government financing in the wake of three recent currency crises: Korea (1997), Mexico (1994), and Turkey (2001).

Standard currency crisis models assume, for convenience, that the only source of depreciation-related revenue available to a government is seignorage. Our case studies show that in reality, governments have access to other types of depreciation-related revenue. First, they can deflate the dollar value of outstanding nonindexed debt. Second, they can engage in what we call an "implicit fiscal reform." Such reforms happen when some government expenditures are denominated in units of local currency. As long as the government does not raise these expenditures at the rate of depreciation, their dollar value declines. This implicit fiscal reform can be quantitatively important even if government expenditures rise

[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), Burnside, Eichenbaum and Rebelo (2001), and Lahiri and Végh (2003).

at the same rate as domestic inflation because post-crisis inflation rates are often much lower than the rate of depreciation (see Table 2).

Our case studies indicate that for the three countries that we consider, seignorage was not the dominant source of additional government revenue in the aftermath of the crisis. In all cases, debt deflation was more important than seignorage and there were large declines in the dollar value of transfers. Indeed, in Korea and Mexico, these declines were the single most important source of government revenue after the crisis.

Motivated by these findings, our model incorporates a version of the government's budget constraint that is more realistic than the highly stylized representations typically used in the literature. We consider a small open economy populated by a representative, infinitely lived agent who can borrow and lend at a fixed interest rate in world capital markets. Agents in the economy consume tradable and nontradable goods and receive endowments of both goods. In addition to allowing for nonindexed public debt and government spending, we assume that some government spending is on nontradable goods. This type of spending is important because, in reality, the dollar price of nontradable goods falls dramatically in the aftermath of a currency crisis (see Table 3). This fall has two effects on the government's intertemporal budget constraint. First, it lowers the dollar value of taxes collected from the nontradable sector. This effect underlies the conventional wisdom that a devaluation leads to a deterioration of the government's fiscal position. Second, the fall in the dollar price of nontradable goods reduces the dollar value of government expenditures on such goods. This second effect, which has not been stressed in the literature, leads to an improvement of the government's fiscal position. Since most governments' expenditures are on nontradable goods (e.g., health and education), the latter effect may, in practice, be very important.

Consistent with the data, we also assume that nontradable prices are sticky for a brief period of time. In addition, we suppose that distributing tradable goods requires the use of nontradable distribution services (retailing, wholesaling, and transportation). Given these assumptions, the model implies that the rate of depreciation in the first year after the crisis is larger than the rate of inflation. The presence of this wedge magnifies the post-crisis reduction in the dollar value of transfers and government purchases. This decline goes a long way toward offsetting the fall in the dollar value of taxes.

We show that a version of our model calibrated to Korean data is consistent with the post-crisis behavior of seignorage, inflation, and depreciation rates in Korea. Based on this analysis, we conclude that classical models can be reconciled with observed seignorage, inflation, and depreciation rates in the aftermath of currency crises.

Finally, we use the model to address the question, how large would post-crisis Korean inflation have been if the government had relied solely on seignorage revenue to finance the costs of the crisis? Our model implies that inflation would have been dramatically higher. In the first year of the crisis inflation would have been more than twice as high, and long run inflation would have risen by a factor of ten.

To focus attention on the impact of alternative government financing strategies, our model has a very stark information structure. Indeed, in our model the timing of the currency crisis is perfectly predictable. Clearly, this assumption is an oversimplification. Various authors (see Chari and Kehoe (2003) and the references therein) have emphasized the role of informational frictions in introducing a stochastic element to the timing of currency crises. Although we are sympathetic to the importance of these frictions, the issues of government finance that we emphasize in this paper are equally relevant for models with a more realistic information structure. These issues are also relevant for stochastic first-generation models (e.g., Flood and Garber (1984)) and in second-generation models in which currency crises emerge as multiple equilibrium phenomena (see Jeanne (1999) for a survey).

The paper is organized as follows. Section 2 discusses the government budget constraint. Section 3 embeds this budget constraint into a general equilibrium model of a currency crisis. Section 4 presents the properties of the model. In section 5 we summarize the results of our case studies. Section 6 contains our concluding remarks.

2. The Government Budget Constraint

Explicit default aside, a government must satisfy its lifetime budget constraint. We derive a version of this constraint that we can use for discussing the different strategies that a government can use to pay for the fiscal costs associated with a currency crisis. Doing so requires that we distinguish between traded and nontraded goods. Since the prices of these goods play an important role in our analysis, we first lay out our notation and assumptions about purchasing power parity (PPP).

Purchasing Power Parity Burstein, Eichenbaum, and Rebelo (2005a) argue that for large devaluations, PPP is a reasonable assumption for the producer price of tradable goods.

In light of this we assume that:

$$\bar{P}_t^T = S_t \bar{P}_t^{T*}. \tag{2.1}$$

Here, $\bar{P}_t^T$ and $\bar{P}_t^{T*}$ denote the domestic and foreign producer prices of tradable goods, respectively. The variable S_t denotes the exchange rate, defined as units of local currency per dollar. For convenience, we abstract from foreign inflation so $\bar{P}_t^{T*} = 1$ and $\bar{P}_t^T = S_t$.

We know that PPP does not hold at the level of the CPI. Here, we emphasize two reasons for this failure of PPP: nontradable goods and distribution costs associated with the sale of tradable goods. With nontradable goods, the CPI is given by:

$$P_t = (P_t^T)^{\omega}(P_t^N)^{1-\omega}. \tag{2.2}$$

Here, ω is the weight of tradable goods in the index, P_t^N is the price of nontradable goods, and P_t^T is the retail price of tradable goods.

We introduce distribution costs (wholesaling, retailing, and transportation) by assuming that selling one unit of the tradable good requires using δ units of the nontradable good. Given perfect competition in the retail sector, the retail price of tradable goods is:

$$P_t^T = \bar{P}_t^T + \delta P_t^N. \tag{2.3}$$

As long as $\delta > 0$, PPP does not hold at the retail level.

The Government's Flow Budget Constraint Government spending, other than on interest payments, consists of purchases of tradable and nontradable goods, and transfer payments. In period t, the government purchases g_t^T units of tradables and g_t^N units of nontradables. We assume that the government purchases goods at producer prices. Total government purchases of goods and services, measured in dollars, are:

$$g_t = \frac{\bar{P}_t^T g_t^T + P_t^N g_t^N}{S_t}. \tag{2.4}$$

The government makes two types of transfers to domestic households: transfers indexed to the CPI, $\hat{v}_t$, and transfers indexed to the exchange rate, $\tilde{v}_t$. Total domestic transfer payments, in local currency, are $P_t \hat{v}_t + S_t \tilde{v}_t$. Given these assumptions, total government transfers, measured in dollars, are:

$$v_t = \frac{P_t \hat{v}_t}{S_t} + \tilde{v}_t. \tag{2.5}$$

The government finances its expenditures by collecting taxes, printing money, and issuing debt. We assume that the government collects taxes on output at the rate τ^y. The dollar value of tax revenues at time t, τ_t, is given by:

$$\tau_t = \tau^y \frac{\bar{P}_t^T y_t^T + P_t^N y_t^N}{S_t} + \tau_t^L. \tag{2.6}$$

Here, y_t^T and y_t^N denote exogenous endowments of output in the tradable and nontradable sectors, respectively, and τ_t^L represents lump-sum taxes.

We denote the stock of domestic money as M_t. The government's seignorage revenue at date t is $\dot{M}_t$ in local currency or $\dot{M}_t/S_t$ in dollar terms. Throughout the paper, $\dot{x}_t$ denotes dx/dt. We denote real money balances measured in dollars by $m_t \equiv M_t/S_t$.

The government can borrow and lend in dollars at a fixed interest rate, r. We denote the stock of dollar-denominated bonds at time t by b_t. We assume that before agents can foresee any possibility of a devaluation, the government issues a fixed stock of consols with a face value of B units of local currency and coupon rate r.

The government's flow budget constraint is:

$$\begin{array}{ll} \Delta b_t = -\Delta m_t, & \text{if } t \in I, \\ \dot{b}_t = rb_t + rB/S_t + g_t + v_t - \tau_t - \dot{M}_t/S_t, & \text{if } t \notin I. \end{array} \tag{2.7}$$

Equation (2.7) 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 list the points in time at which these discrete changes might occur.

The Government's Lifetime Budget Constraint The flow budget constraint, (2.7), together with the condition $\lim_{t\to\infty} e^{-rt} b_t = 0$, implies the following intertemporal budget constraint:

$$b_0 + \int_0^\infty \frac{rB}{S_t} e^{-rt} dt = \int_0^\infty (\tau_t - g_t - v_t) e^{-rt} dt + \int_0^\infty \frac{\dot{M}_t}{S_t} e^{-rt} dt + \sum_{i \in I} e^{-ri} \Delta m_i. \tag{2.8}$$

This constraint requires that the initial dollar value of the debt plus the present value of consol payments measured in dollars be equal to the present value, in dollars, of primary surpluses plus seignorage revenue.

A Sustainable Fixed-Exchange-Rate Regime We assume that for all $t < 0$, $S_t = S$ and agents believe that this fixed-exchange-rate regime is sustainable. We suppose agents anticipate that the government will satisfy its intertemporal budget constraint, (2.8), without abandoning the fixed exchange rate at any date $t \geq 0$. Given PPP, (2.1), this assumption is equivalent to agents believing that the government will pursue fiscal and monetary policies that are consistent with zero inflation in the producer price of tradables.

To simplify, we assume that for all $t < 0$, $g_t^T = g^T$, $g_t^N = g^N$, $\hat{v}_t = \hat{v}$, $\tilde{v}_t = \tilde{v} = 0$, $\tau_t^L = \tau^L$, $y_t^T = y^T$, and $y_t^N = y^N$. These assumptions imply that in equilibrium, the price of nontradables, the CPI, and the nominal money supply are also constant: $P_t^N = P^N$, $P_t = P = (S + \delta P^N)^{\omega}(P^N)^{1-\omega}$, and $M_t = M$. Agents believe that these variables will continue to be constant for $t \geq 0$. Under these assumptions the government's lifetime budget constraint reduces to:

$$b_0 + \frac{B}{S} = \frac{\tau - g - v}{r}. \tag{2.9}$$

Here τ, g, and v are constants given by (2.4), (2.5), and (2.6). Equation (2.9) requires that the present value of current and future real primary surpluses equals the initial real net liabilities of the government.

A Crisis At $t = 0$ agents learn that the government will have to increase its future dollar transfers, say, because of loan guarantees to the creditors of failing banks. We denote by ϕ the dollar present value of these increased transfers:

$$\phi = \int_0^\infty (\tilde{v}_t - \tilde{v})e^{-rt}dt.$$

We assume that these new transfers will not be financed with an explicit fiscal reform. By such a reform we mean changes in g_t^T, g_t^N, $\hat{v}_t$, or τ^y that would offset the effects of the increase in dollar transfers. Absent an explicit fiscal reform the fixed-exchange-rate regime must be abandoned.

At time zero, agents also learn the new paths of tradable and nontradable output. We assume that tax rates, as opposed to tax revenues, remain constant. This assumption is consistent with the observation that explicit tax reforms are relatively minor in the aftermath of currency crises.

To see the impact of the crisis on the government's lifetime budget constraint we use

(2.9) to rewrite (2.8) as:

$$\begin{aligned}\phi &= \int_0^\infty (\tau_t - \tau)e^{-rt}dt + \int_0^\infty (g - g_t)e^{-rt}dt + \int_0^\infty \left(\frac{P\hat{v}}{S} - \frac{P_t\hat{v}_t}{S_t}\right)e^{-rt}dt \\ &\quad + \left[\frac{B}{S} - \int_0^\infty \frac{rB}{S_t}e^{-rt}dt\right] + \left[\int_0^\infty \frac{\dot{M}_t}{S_t}e^{-rt}dt + \sum_{i\in I} e^{-ri}\Delta m_i\right]. \end{aligned} \tag{2.10}$$

According to (2.10), the present value of the increase in transfers must be financed by changes in the dollar value of tax revenues, government expenditures, CPI-indexed transfers, nonindexed debt, and seignorage revenues. We discuss each of these components in turn.

Since we exclude explicit fiscal reforms, the only way in which the government can satisfy its intertemporal budget constraint is to use monetary policy to generate depreciation-related revenues.[2] To see this, suppose for the moment that the fixed exchange rate could be sustained once new information about higher deficits arrives. Then the money supply would never change and the government could not collect any seignorage revenues. Since the price level would be constant, all of the terms on the right-hand side of (2.10) would equal zero.[3] But then the government's budget constraint would not hold, which contradicts the assumption that the fixed-exchange-rate regime is sustainable. We conclude that the government must at some point move to a floating-exchange-rate system or at least abandon its peg at the fixed rate S.

Tax Effects

The change in the present value of tax revenues is given by:

$$\int_0^\infty (\tau_t - \tau)e^{-rt}dt = \int_0^\infty e^{-rt}[\tau^y(y_t^T + y_t^N P_t^N/S_t) + \tau_t^L]dt - \tau/r. \tag{2.11}$$

Recall that we assume tax rates are constant. If y_t^N, y_t^T, and τ_t^L were constant and P_t^N/S_t did not change, this term would be zero. We do not expect either of these conditions to hold, in general. First, large devaluations are typically followed by significant changes in the output of the tradable and nontradable sectors. Second, devaluations are also followed by large drops in the dollar price of nontradable goods (see Table 3). These effects can lead to either a fiscal improvement or a fiscal deterioration. For example, a drop in the value of

[2] The government can also explicitly default on outstanding debt. We ignore this possibility since we are interested in episodes in which explicit default did not occur. International bailouts are an additional source of crisis financing, but in practice the value of these bailouts is not very significant. See Jeanne and Zettelmeyer (2000) who show that the subsidy component of IMF programs is quite small.

[3] This statement assumes that tax revenue does not change absent a devaluation.

nontradable output $(P_t^N y_t^N / S_t)$ induces a decline in real tax revenues, thus exacerbating the fiscal consequences of the initial crisis. On the other hand, if most tax revenue comes from the tradable sector and this sector booms after a devaluation, there could be a net rise in the present value of tax revenues.

Government Purchases Effects

The change in the present value of government purchases is given by:

$$\int_0^\infty (g - g_t) e^{-rt} dt = \int_0^\infty \left(g^T - g_t^T + \frac{P^N}{S} g^N - \frac{P_t^N}{S_t} g_t^N \right) e^{-rt} dt. \tag{2.12}$$

Suppose that g_t^T and g_t^N remain constant at their pre-crisis values. If P_t^N / S_t also remains constant, then the term above would be zero. But a drop in P_t^N / S_t generates an automatic decline in the dollar value of government spending on nontradable goods. This type of automatic fiscal reform is important, because most government purchases are on nontradables, such as health and education.

Government Transfers Effects

The change in the present value of CPI-indexed government transfers is given by:

$$\int_0^\infty \left(\frac{P \hat{v}}{S} - \frac{P_t \hat{v}_t}{S_t} \right) e^{-rt} dt. \tag{2.13}$$

Suppose $\hat{v}_t$ remains constant at its pre-crisis value. If P_t / S_t also remains constant, then the term above would be zero. But any drop in P_t / S_t generates an automatic decline in the dollar value of CPI-indexed transfers.

Nonindexed Debt Effects

The reduction in the dollar value of nonindexed debt is given by:

$$\frac{B}{S} - \int_0^\infty \frac{rB}{S_t} e^{-rt} dt. \tag{2.14}$$

All else equal, a devaluation generates an implicit fiscal reform by reducing the value of this debt. This channel has been emphasized in the literature on the fiscal theory of the price level.[4]

[4] Sims (1994), Woodford (1995) and Cochrane (2001) discuss the fiscal theory in a closed economy context. Dupor (2000), Daniel (2001), and Corsetti and Mackowiak (2005) analyze the implications of the fiscal theory for open economies.

Seignorage Effects

The dollar value of seignorage is given by:

$$\int_0^\infty \dot{M}_t/S_t e^{-rt}dt + \sum_{i\in I} e^{-ri}\Delta m_i. \tag{2.15}$$

Post-Crisis Inflation

The post-crisis behavior of inflation depends critically on the financing mix chosen by the government. For example, suppose that the government could pay for most of its fiscal costs by reducing the dollar value of outstanding nominal debt with a devaluation at time zero. Then the currency crisis would be associated with little future money growth or long-run inflation. In contrast, suppose that the government finances most of the new transfers with seignorage revenues. This financing strategy would have very different implications for money growth and inflation.

It is also clear that post-crisis inflation rates depend on the types of goods that the government purchases and on the nature of the tax system. Suppose, for example, that the government raises most of its tax revenues from the nontradable sector and that the dollar value of production in this sector falls precipitously after a devaluation. Then a devaluation would magnify the initial fiscal crisis so that money growth rates and inflation would be higher than otherwise. In contrast, suppose that most government spending is devoted to nontradable goods. Then a crisis that leads to a decline in P_t^N/S_t generates a fiscal improvement.

The Government's Lifetime Budget Constraint in Local Currency We base our previous arguments on (2.8), which expresses the government's intertemporal budget constraint in dollar terms. However, we emphasize that none of our conclusions depend on this choice of numeraire. For completeness, we show the analogue to (2.8) expressed in units of local currency and then show that it is equivalent to (2.8).

Since uncovered interest parity holds from time zero on, the local currency interest rate, which is the relevant rate for discounting local currency cash flows, is given by:

$$R_t = r + \dot{S}_t/S_t. \tag{2.16}$$

The government's flow budget constraint in local currency terms is given by:

$$\begin{array}{ll} \Delta D_t = -\Delta M_t & \text{if } t \in I, \\ \dot{D}_t = R_t D_t + rB + (g_t + v_t - \tau_t)S_t - \dot{M}_t, & \text{if } t \notin I, \end{array} \tag{2.17}$$

where D_t is the local currency value of dollar-denominated government debt ($D_t = S_t b_t$). We define the discount factor, d_t, as:

$$d_t \equiv \int_0^t R_s ds. \tag{2.18}$$

Equations (2.18) and (2.17) imply that the government's intertemporal budget constraint in local currency is given by:

$$S_0 b_0 + \int_0^\infty rBe^{-d_t}dt = \int_0^\infty (\tau_t - g_t - v_t)S_t e^{-d_t}dt + \int_0^\infty \dot{M}_t e^{-d_t}dt + \sum_{i \in I} e^{-d_i}\Delta M_i, \tag{2.19}$$

Equation (2.19) is equivalent to the dollar-denominated budget constraint, (2.8). To see this equivalence we note that equations (2.16) and (2.18) imply:

$$e^{-d_t} = e^{-rt}S_0/S_t. \tag{2.20}$$

Substituting (2.20) into (2.19), we obtain (2.8) multiplied by the constant S_0 on both sides of the equation.

According to (2.19), the initial value of the debt plus the present value of consol payments must be equal to the present value of primary surpluses plus seignorage revenue. From the perspective of (2.19), the gains from debt deflation, measured in local currency, are $\int_0^\infty rBe^{-d_t}dt - \int_0^\infty rBe^{-rt}dt = \int_0^\infty rBe^{-d_t}dt - B$. A currency crisis reduces the value of the outstanding debt, because flows of future debt payments are discounted at higher rates ($d_t > rt$, for all $t > t^*$). All elements of the primary surplus in local currency (that is $(\tau_t - g_t - v_t)S_t$) are also discounted at higher rates. These considerations imply that if the government is running a constant deficit in local currency, its present value will be automatically reduced.

3. The Model

To go beyond general statements about the effects of a devaluation on the government budget constraint, we must embed that constraint into a fully articulated model.[5] Here, we describe our model.

The representative agent maximizes lifetime utility, which we define as:

$$U = \int_0^\infty \frac{[(c_t^T)^\omega (c_t^N)^{1-\omega}]^{1-\sigma} - 1}{1-\sigma} e^{-\rho t}dt. \tag{3.1}$$

[5] Burnside, Eichenbaum and Rebelo (2003) provides a preliminary discussion of these questions using a simple reduced form model featuring a Cagan (1956) money demand function, a simplified government budget constraint, and preliminary data from Korea and Mexico.

Here, c_t^T and c_t^N denote the consumption of tradables and nontradables, respectively. In addition, $\rho > 0$ is the discount factor and $\sigma > 0$ is the inverse of the elasticity of intertemporal substitution.

The representative agent can borrow and lend in international capital markets at a constant real interest rate, r. To eliminate trends in the current account, we assume that $r = \rho$. The representative agent's flow budget constraint for $t \geq 0$ is given by:

$$\begin{aligned} &\Delta f_t = -\Delta m_t && \text{if } t \in I, \\ &\dot{f}_t = r f_t + rB/S_t + y_t + v_t - c_t - \tau_t - \dot{M}_t/S_t && \text{if } t \notin I. \end{aligned} \tag{3.2}$$

Here, f_t denotes the net dollar-denominated assets held by the representative agent and $y_t = y_t^T + y_t^N P_t^N/S_t$ represents the dollar value of the household's endowments of tradable and nontradable goods. The variable $c_t = (P_t^T c_t^T + P_t^N c_t^N)/S_t$ represents the dollar value of the household's consumption. As with the government, the household's budget constraint (3.2) takes into account the possibility of discrete changes in m_t and f_t at a finite set of points in time, I. The flow budget constraint, together with the condition $\lim_{t\to\infty} e^{-rt} f_t = 0$, implies the following intertemporal budget constraint for the household:

$$f_0 + \int_0^\infty e^{-rt}(y_t + v_t + rB/S_t)dt = \int_0^\infty e^{-rt}(c_t + \tau_t + \dot{M}_t/S_t)dt + \sum_{i\in I} e^{-ri}\Delta m_i. \tag{3.3}$$

According to (3.3), when measured in dollars, the household's initial assets plus the present value of endowment and transfer income must equal the present value of expenditures, including taxes and changes in money balances.

Finally, the representative agent faces the following continuous time analogue to a cash-in-advance constraint on consumption purchases:

$$\eta(P_t^T c_t^T + P_t^N c_t^N) \leq M_t. \tag{3.4}$$

By using the constant η, our model can generate empirically plausible predictions for average velocity. Since the nominal interest rate is positive in all the scenarios that we consider, (3.4) holds with strict equality.

The problem of the representative household is to maximize (3.1) subject to (3.2) and (3.4) by choice of time paths for c_t^T, c_t^N, m_t and f_t given known time paths for S_t, P_t^N, P_t^T and P_t.[6]

[6] In the Technical Appendix we describe the solution to a discrete time version of the household's problem which limits to the solution of the continuous time problem as the interval between time periods goes to 0.

3.1. The Exchange Rate Crisis

Prior to time zero, agents anticipate zero inflation and the economy is in a steady state with constant values of S, y^T, y^N, g^T and g^N. In the Technical Appendix we show that in the steady state P_t^N, c_t^T and c_t^N are constant over time. At time zero, agents learn about the new government transfers that make the fixed-exchange-rate regime unsustainable.

To characterize the time at which the fixed-exchange-rate regime collapses and how the economy behaves after the crisis, we make particular assumptions about government policy. Here, there are two possibilities. First, we can specify a post-crisis monetary policy and a rule for abandoning the fixed exchange rate. Second, we can specify a path for the exchange rate and then reverse-engineer a path for monetary policy that can support the exchange rate path as an equilibrium. Computing this reverse mapping is difficult in our context, since we have to ensure that the government's intertemporal budget constraint holds. For this reason, we follow the first strategy, which has the additional advantage of preserving a tight link with the large literature on currency crises.

Abandoning the Fixed Exchange Rate

We assume that the government floats the currency at the first point in time, t^*, when net debt reaches some finite upper bound or, equivalently, when the domestic money supply falls by χ percent of the initial money supply.

We work with this rule for three reasons. First, it is a good description of what actually happens in a currency crisis. Second, it can be interpreted as a short-run borrowing constraint on the government. Thirdly, Rebelo and Végh (2002) show that this rule can be optimal for an interesting class of economies.

Post-Crisis Monetary Policy

We assume that the government will raise seignorage revenues by a combination of a one-time increase in the stock of money at time T to a level M_T, and growth in the money supply at rate μ from period T on. We express the path of M_t as:

$$M_t = M_T e^{\mu(t-T)}, \text{ for } t \geq T. \tag{3.5}$$

Given T, the pair (M_T, μ) must satisfy the government's budget constraint.

Competitive Equilibrium A competitive perfect foresight equilibrium for this economy is a set of allocations, M_t, f_t, b_t, c_t^T, c_t^N; a set of prices, P_t, P_t^T, P_t^N, $\bar{P}_t^T$, and S_t; and a set of paths for the fiscal variables, τ^y, τ_t^L, g_t^T, g_t^N, $\tilde{v}_t$, and $\hat{v}_t$; such that the following conditions hold: the paths for M_t, f_t, c_t^T, and c_t^N solve the household's problem, given the paths for prices and fiscal variables; the government's intertemporal budget constraint (2.8) holds; $S_t = S$ for $t \leq t^*$; the PPP conditions (2.1), (2.3), and (2.3) hold; the monetary base follows the process:

$$M_t = \begin{cases} \underline{M} & \text{for } 0 \leq t < t^* \\ \underline{M}(1-\chi) & \text{for } t^* \leq t < T \\ M_T e^{\mu(t-T)} & \text{for } t \geq T \end{cases} . \tag{3.6}$$

According to (3.6), the money supply is constant before t^* and drops by χ percent at the time of the speculative attack, t^*. The money supply then remains constant up to time T, at which point the government increases M_t, which then starts to grow at the rate μ.

In the flexible-price model, the following market clearing condition for nontradable goods holds:

$$y_t^N = c_t^N + \delta c_t^T + g_t^N. \tag{3.7}$$

Here, δc_t^T are the nontradable goods used in the process of distributing tradable goods. Consolidating this equation with the resource constraints of the government and the household yields the aggregate intertemporal resource constraint for tradable goods:

$$f_0 - b_0 + \int_0^\infty e^{-rt} y_t^T dt = \int_0^\infty e^{-rt}(c_t^T + g_t^T)dt.$$

In the model with sticky nontradable goods prices, these prices are given by:

$$P_t^N = \begin{cases} P^N & \text{for } t \leq T \\ P^N(S_t/S_T) & \text{for } t > T \end{cases} ,$$

where P^N denotes the pre-crisis level of the nominal price of nontradable goods.

In the experiments that we consider below, when prices are sticky, the demand for nontradable goods exceeds the supply and we drop the household's first-order condition for nontradable goods from the set of equilibrium conditions.

4. Properties of the Model

Here we discuss the properties of a version of our model calibrated to Korean data. We do so with four objectives in mind. First, we ascertain whether this model can generate low inflation rates in conjunction with high rates of depreciation. Second, we use the model to study the implications of different financing strategies for the government.[7] Third, we deconstruct the model to understand how it accounts for post-crisis inflation and exchange rates. Finally, our analysis serves as a useful backdrop for our case study of Korea.

4.1. Calibration of the Model

Table 4 summarizes our assumptions about parameter values. We set $\sigma = 1$, so that utility is logarithmic. We set r equal to 0.055. We note that calibrating the dollar interest rate for Korea is difficult. Most internal lending is denominated in won for regulatory reasons. We find that, across a wide variety of domestic instruments, the dollar rate of return, although volatile, averages between 5 and 6 percent in the period 1991 to 2002.

We normalize the initial exchange rate to $S = 1$. Without loss of generality we set $y^T = y^N = 1$. This implies that the level of real GDP is $y = 1 + p^N$, where $p^N = P^N/S$ is the dollar price of nontradable goods.

Our data for Korea suggest that the share of tradable goods in GDP, s^T, is 0.358. This value is roughly the average share of agriculture, forestry, mining, and manufacturing in Korean GDP for 1993–97. Since the share of tradable goods in GDP is $s^T = 1/(1 + p^N)$, this implies $p^N = 1/s^T - 1 = 1.79$.

Between 1993 and 1997, government purchases averaged about 15.4 percent of GDP in Korea. So we set $g = 0.154y$. We estimate that roughly 13.2 percent of government purchases are tradable goods, implying $g^T = 0.132g$ and $g^N = (g - g^T)/p^N$. In the Technical Appendix we show that the steady state values of net foreign assets, f_0, the consumption of tradables, c^T, and the consumption of nontradables, c^N, are uniquely pinned down, given the values of y^T, y^N, g^T, g^N, and p^N that we have already chosen.

In the four years prior to Korea's crisis, the average ratio of the monetary base to GDP was 0.067. In the benchmark model, we set $\eta = 0.067y/[(1 + \delta p^N)c^T + p^N c^N] = 0.097$ so that the ratio of the monetary base to GDP in the initial steady state is consistent with this value.

Between 1993 and 1997, total government revenue averaged about 23.7 percent of GDP in Korea, while tax revenue averaged about 19.4 percent of GDP. Since some nontax revenue might also be tied to real activity, we set the income tax rate, τ^y, equal to 0.216. Spending

[7] See Persson, Persson and Svensson (1998) for a careful analysis of the effects of inflation on the budget constraint of the Swedish government that considers inflation-related sources of revenue other than seignorage.

on transfers averaged 4.3 percent of GDP between 1993 and 1997, so we set steady state transfers, v, equal to $0.043y$. In section 5 we argue that it is appropriate to set the steady-state value of CPI-indexed transfers $(P\hat{v}/S)$ equal to $0.027y$, or 2.7 percent of GDP.

To calibrate b_0, we use data on the real consolidated foreign debt of the government and central bank. The Korea Institute for International Economic Policy (http://kiep.go.kr) estimates that the foreign debt of the public sector in June 1997 was equal to 2 trillion won. According to the International Financial Statistics (IFS), the value of the central bank's net foreign assets was approximately 28 trillion won. These values suggest that the net foreign assets of the consolidated public sector were roughly equal to 26 trillion won, or 5.7 percent of 1997 GDP, so we set b_0 equal to $-0.057y$.

Nominal debt in the model (B) 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 set $B = 0.075y$ so that the revenue from debt deflation is commensurate with the empirical estimates we describe in section 5. We choose the level of lump sum taxes, $\tau^L = r(b_0 + B/S) + g + v - \tau^y y = -0.05$, to ensure that the government's lifetime budget constraint, (2.9), holds in the initial steady state of our model.

We now consider the parameters that govern post-crisis monetary policy. We identify period zero as the end of June 1997, when the Thai banking crisis culminated in a currency crisis. Like Thailand, Korea was undergoing a severe crisis in its banking industry. For our purposes it seems reasonable to assume that the outbreak of the Thai crisis led Koreans to anticipate that they too would undergo a currency crisis. This crisis occurred at the end of October 1997, roughly four months after the Thai crisis. To match this fact, and given the difficulty of obtaining direct evidence on the value of χ, in the benchmark model we set $\chi = 0.09$ so that $t^* = 0.33$.

We set the time at which there is a remonetization, T, to 0.5 (this corresponds to the end of December 1997). To abstract from month-to-month variation in the monetary base, we set $M_T/M = 1.12$, which corresponds to the ratio of the average monetary base in November 1997–January 1998 to the average monetary base in May–July 1997. Finally, we solve the model to endogenously determine the steady-state money growth rate, μ, that is consistent with the government's intertemporal budget constraint.

According to Standard and Poor's (2000), the cost of the banking sector bailout was about 24 percent of 1997 GDP. In our case study of Korea we estimate that between 1998 and 2002 output losses due to the recession induced losses of tax revenue amounting to 13.4 percent of GDP while explicit fiscal reforms equaled roughly 17.6 percent of GDP, reducing the cost that must be financed from depreciation-related revenue by 4.2 percent of GDP. With the assumption that future explicit fiscal reforms net of recession costs will yield an additional 6.3 percent of GDP, we estimate that the amount that needs to be financed from depreciation-related revenue is about 13.5 percent of GDP. Therefore, we set $\phi = 0.135y$.

We set $\omega = 0.5$ to match the weight that tradables receive in the Korean CPI. Nontradable goods affect the predictions of our model only if there is a change in the dollar price of nontradable goods after a crisis. Here, we pursue a strategy to generate such a change: consistent with the data, we assume that the domestic currency price of nontradables remains constant for two months after the crisis and then starts growing at the rate of depreciation.[8] In the presence of these nominal rigidities, the market for nontradable goods does not clear; there is excess demand for nontradable goods. We make the simplifying assumption that nontradables are rationed and that there is no resale market for these goods. While admittedly stark, this modeling strategy allows us to capture, in a parsimonious way, the effects of a fall in the price of nontradable goods without fully modeling the production side of the economy.

Finally, we set the distribution cost parameter δ to 0.5, which implies that the pre-crisis distribution margin, $\delta P^N/(\bar{P}^T + \delta P^N)$, is 50 percent. This value is within the range of estimates presented in Burstein, Neves, and Rebelo (2003).

4.2. The Benchmark Model

Figure 1(a) depicts the equilibrium paths for the exchange rate, the CPI and money balances. We note in particular four key features of Figure 1(a). First, the speculative attack happens after agents learn about deficits, but before the government implements the new monetary policy. Thus, the attack is unpredictable on the basis of classical fundamentals such as past deficits or inflation. Second, inflation rises in the wake of the exchange-rate collapse, well before the change in monetary policy. As in Sargent and Wallace (1981), this rise reflects agents' anticipation of the increase in money supply that takes place at time T. Third, there is a discrete drop in the money supply at the time of the attack. This drop reflects agents' decisions to exchange their domestic money holdings for dollars at the fixed exchange rate.

[8] Burstein, Eichenbaum, and Rebelo (2005b) discuss several mechanisms that can cause a fall in the dollar price of nontradable goods.

It is this drop in the money supply that triggers the threshold rule and leads the government to abandon the fixed-exchange-rate regime. Fourth, there is a large wedge between the rate of inflation and the rate of depreciation.

Table 5(a) summarizes the key implications of the model for inflation, depreciation, and government financing in the wake of the crisis. A number of results are notable. First, inflation in the first year after the crisis is only 12.5 percent and long-run inflation is only 1.9 percent. Inflation in the first year is higher than the 7.2 percent observed in the data. However, Burstein, Eichenbaum, and Rebelo (2005a) argue that there was a significant downward bias in measured Korean inflation. Although it is difficult to provide precise measures of this bias, it is clear that taking it into account would move the model closer into conformity with reality. Second, despite the low rate of inflation, the rate of depreciation in the model is 45.6 percent, more than three times higher than inflation in the first year after the crisis.

The model predicts that long-term interest rates should rise as agents learn about the government's prospective deficits. In reality, interest rates started to rise from July 1997 on, although not by nearly as much as a perfect foresight model would predict. In part, this mismatch between theory and data may reflect active government intervention in currency markets, including capital controls (see Park and Rhee (2001)). But the mismatch also reflects the stark simplicity of the perfect foresight assumption. At the same time, there is substantial evidence to support the view that there was widespread recognition among private agents that the Korean financial sector was failing, and that this failure was creating large prospective deficits for the government.

In terms of government financing, seignorage accounts for only 1.8 percent of pre-crisis GDP, or less than 15 percent of total depreciation-related revenues. By far the most important source of depreciation-related revenues is the fall in the dollar value of transfers (10.9 percent of pre-crisis GDP). This decline reflects the large wedge between the CPI and the exchange rate that comes in the immediate aftermath of the crisis.

Viewed overall, our results imply that the government can satisfy most of its financing needs by relying on an implicit fiscal reform. We conclude that the model is consistent with the observation that many large devaluations are associated with low rates of inflation, and that seignorage plays a modest role in government financing.

4.3. Implications of Alternative Financing Scenarios

Here, we use the benchmark model to assess the implications of three alternative financing scenarios. First, suppose that there is no outstanding nominal debt at the onset of the crisis ($B = 0$) so there are no revenues from debt deflation. In addition, assume that the government makes up for this shortfall in revenue by increasing the steady state growth rate of money. As Table 5(b) indicates, this alternative financing scenario implies a modest rise in short-run inflation (from 12.5 to 16.1 percent) and to a threefold increase in long run inflation (from 1.9 to 5.7 percent).

Second, suppose that all transfers are indexed to the dollar. In this case, the government does not benefit from a reduction in the dollar value of transfers. As above, we assume that the government makes up for this shortfall in revenue by raising the steady state growth rate of money. Table 5(c) shows that this alternative financing scenario leads to markedly different implications for post-crisis inflation and exchange rates. Relative to the benchmark scenario, inflation in the first year after the crisis rises from 12.5 to 22.0 percent. Steady state inflation rises from 1.9 to 12.1 percent. The rate of depreciation in the first year after the crisis climbs from 45.6 to 58.8 percent.

Third, for completeness we eliminate revenues from both debt deflation and reductions in the dollar value of transfers. Not surprisingly, under this scenario, inflation is very large both in the first year after the crisis (28.6 percent) and in the long run (19.4 percent). Moreover, the rate of exchange rate depreciation rises to 68.2 percent.

These experiments make clear that post-crisis rates of inflation and depreciation depend critically on the sources of depreciation-related revenue available to a government. In this sense our model is consistent with heterogeneity in post-crisis inflation and depreciation rates.

4.4. Deconstructing the Benchmark Model

Here, we use a sequence of numerical examples to show which features of our model allow it to account for the post-crisis behavior of inflation, exchange rates, and seignorage.

A Simple Textbook Model

We begin by eliminating all the features that distinguish our model from the simple textbook setup. We assume that there is no local currency debt ($B = 0$), all goods are tradable ($\omega = 1$), prices are perfectly flexible, and there are no distribution costs ($\delta = 0$). Given these assumptions, PPP holds at the level of the CPI, so that the price level coincides with the exchange rate. Also, the only depreciation-related source of revenue is seignorage.

Figure 1(b) shows the equilibrium paths for the exchange rate, the CPI and money balances. Table 5(e) summarizes the key implications of the model.

We note several results in particular. First, the rate of inflation in the first year after the crisis is counterfactually large: 22.7 percent. Second, the long run rate of inflation, 11.4 percent, is also counterfactually large. Third, inconsistent with the data, the rate of inflation coincides with the rate of depreciation.

Introducing Nominal Debt

Table 5(f) displays the impact of incorporating nominal government debt into the simple textbook model. Inflation in the first year after the crisis falls from 22.7 percent in the benchmark model to 18.8 percent. Long-run inflation declines from 11.4 percent to 7.3 percent. Mirroring these results, seignorage is now 9.1 percent of GDP, or about two thirds of total depreciation-related revenues. Although this version of the model performs better than the simple textbook model, it still suffers from important shortcomings: inflation is counterfactually large and the rate of depreciation is too low relative to the data.

Introducing Nontradable Goods with Sticky Prices

We now incorporate nontradable goods into the version of the model with nominal debt. As in our benchmark analysis, we assume that the price of these goods is sticky. Table 5(g) summarizes the properties of this version of the model. The key difference between this example and the version of the model with flexible prices is that the rates of depreciation and inflation are no longer the same. Now, the rate of depreciation in the first year after the crisis (34.0 percent) is much larger than the rate of inflation during the same period (20.1 percent).

Introducing CPI-indexed Transfers

We now add to the model with nominal debt and sticky prices government transfers that are indexed to the CPI (see Table 5(h)). The key impact of this change is that the importance of seignorage as a source of government finance drops: it now amounts to 6.1 percent of pre-crisis GDP. Since seignorage is less important, inflation declines to 16.2 percent in the first year after the crisis and to 5.3 percent in the new steady state. The problem is that the rate of depreciation in the first year declines to only 29.5 percent.

Introducing Distribution Costs

Once we add distribution costs, we are back to our benchmark model. Distribution costs improve the performance of the model along two key dimensions. First, the model does a much better job of accounting for the wedge between the rate of inflation and the rate of depreciation. Second, seignorage plays a much smaller role in government financing and the fall in the dollar value of transfers plays a much larger role.

Summary

To summarize, introducing nonindexed debt and CPI-indexed transfers allows the benchmark model to generate low inflation rates, especially in the steady state. Nonindexed debt and CPI-indexed transfers reduce the government's need to rely on seignorage revenues. Introducing nontradable goods and distribution costs allows the benchmark model to generate large devaluations along with low rates of inflation. In combination, these features allow the benchmark model to account for the salient features of data on post-crisis seignorage, inflation, and depreciation rates.

4.5. Allowing for Time-Varying Interest Rates

In our benchmark model, the dollar interest rate is constant. In reality, Korean dollar interest rates rose temporarily in the aftermath of the crisis. For example, between November 1997 and December 1998, the average strip yield on Korean U.S. dollar bonds increased by 3.2 percentage points relative to the pre-crisis period (from January 1997 through October 1997).[9] This rise was completely reversed between January 1999 and December 2001, with average yields returning to their pre-crisis values.

Here, we modify our model to allow the interest rate on dollar-denominated securities to vary over time. With time-varying interest rates the government's flow budget constraint, (2.7), becomes:

$$\begin{aligned} &\Delta b_t = -\Delta m_t, && \text{if } t \in I, \\ &\dot{b}_t = r_t b_t + rB/S_t + g_t + v_t - \tau_t - \dot{M}_t/S_t, && \text{if } t \notin I. \end{aligned} \tag{4.1}$$

[9] Source: HSBC Markets USD Asian Emerging Market Bond Strip Yields, Datastream mnemonic HKYLKRW.

Here r_t is the time t interest rate. We define the discount factor: $\xi_t \equiv \int_0^t r_s ds$. Equation (4.1), together with the condition $\lim_{t\to\infty} e^{-\xi_t} b_t = 0$, implies that the government's intertemporal budget constraint is:

$$b_0 + \int_0^\infty \frac{rB}{S_t} e^{-\xi_t} dt = \int_0^\infty (\tau_t - g_t - v_t) e^{-\xi_t} dt + \int_0^\infty \frac{\dot{M}_t}{S_t} e^{-\xi_t} dt + \sum_{i \in I} \Delta m_i e^{-\xi_i}. \qquad (4.2)$$

The representative agent's flow budget constraint for $t \geq 0$ is given by:

$$\begin{array}{ll} \Delta f_t = -\Delta m_t & \text{if } t \in I, \\ \dot{f}_t = r_t f_t + rB/S_t + y_t + v_t - c_t - \tau_t - \dot{M}_t/S_t & \text{if } t \notin I. \end{array} \qquad (4.3)$$

This constraint, together with the condition $\lim_{t\to\infty} e^{-\xi_t} f_t = 0$, implies that the household's intertemporal budget constraint is:

$$f_0 + \int_0^\infty (y_t + v_t + rB/S_t) e^{-\xi_t} dt = \int_0^\infty (c_t + \tau_t + \dot{M}_t/S_t) e^{-\xi_t} dt + \sum_{i \in I} \Delta m_i e^{-\xi_i}. \qquad (4.4)$$

Consistent with our baseline experiment, we assume that $P_t^N = P^N$ for $t \leq T$ and $P_t^N = P^N e^{\mu(t-T)}$ for $t > T$.

Finally, to mimic the behavior of Korean dollar interest rates in the wake of the crisis we assume the path of r_t is given by:

$$r_t = \begin{cases} r & \text{for } t < t^*, \\ \bar{r} & \text{for } t^* \leq t \leq T_r, \\ r & \text{for } t > T_r. \end{cases}$$

Here $T_r = T + 1$ and $\bar{r} = r + 0.032$. We calibrate the model using the same parameter values as in our benchmark calibration.

Figure 1(c) shows the equilibrium paths for the exchange rate, the CPI and the level of money balances. We note that the paths of the exchange rate and the monetary base are nearly indistinguishable from those implied by our benchmark model.

Table 5(i) summarizes the key implications of the model for inflation, depreciation, and government financing in the wake of the crisis. Again, the results are similar to those in our benchmark experiment. Inflation in the first year after the crisis is 13.5 percent, and long-run inflation is 1.9 percent, compared to 12.5 and 1.9 percent in the benchmark model. The rate of depreciation in the first year after the crisis is 49.7 percent, compared to 45.6 percent in the benchmark model.

In terms of government financing, seignorage accounts for only 1.5 percent of pre-crisis GDP, slightly less than the 1.8 percent implied by the benchmark model. Even though the long-run money growth rate is higher in this experiment, the decline in the present value of seignorage can be explained by the fact that most of this revenue is raised in the long-run steady state, and therefore is discounted more than in our benchmark experiment. Debt deflation increases from 3.5 percent of GDP to 3.7 percent of GDP due to the greater degree of real depreciation implied by the model with time-varying interest rates.

Finally, total implicit fiscal reforms (transfers plus purchases minus tax revenue) represent 8.3 percent of GDP in both experiments. We note that the changes in the present values of transfers, and purchases net of taxes are both larger in absolute value in the experiment with time-varying r_t.for two reasons: the degree of real depreciation is greater in this case, and expenditure and revenue streams beyond date t^* are discounted more in the experiment with time-varying r_t. However, these effects appear to roughly cancel each other out.

We conclude that when we allow for realistic changes in the dollar interest rate, there are only modest changes in the model's implications. These changes are modest even though our experiment overstates the effects of a rise in dollar interest rates on the government budget constraint. In our experiment the government rolls over 100 percent of its debt each year so that a rise in the interest rate applies to all of its outstanding debt. In reality, governments only roll over a fraction of their debt on a yearly basis.

5. Case Studies: Korea, Mexico, and Turkey

We now present three case studies to assess how governments actually financed the fiscal costs associated with currency crises. We use these results to assess the plausibility of our model's predictions for post-crisis rates of inflation and depreciation.

In our theoretical analysis, the government finances crisis costs via a combination of seignorage revenues, debt deflation, reductions in the dollar value of government transfers, and reductions in the dollar value of the government's purchases net of tax revenue. In reality, two other factors come into play: explicit fiscal reforms that raise tax revenue or reduce spending, and revenue losses associated with post-crisis declines in real activity.

It is difficult to precisely quantify the importance of the difference sources of government finance. The basic problem is that we must compare actual revenues and expenditures with what they would have been absent the crisis. Inevitably, doing so requires relying on debatable assumptions about how economic aggregates would have evolved if a crisis had not occurred. In practice, we find that the breakdown of fiscal reforms between explicit and implicit reforms is particularly sensitive to these assumptions. Even seignorage calculations can be sensitive to the assumptions made about what money growth and depreciation rates would have been if there had been no crisis. Nevertheless, we think that our calculations are informative.

Before we discuss the details of our calculations, we briefly summarize the main findings for the three countries that we study: Korea, Mexico, and Turkey. First, none of these countries has fully paid for all the costs associated with their currency crises. According to our estimates, Korea, Mexico, and Turkey had paid for roughly 52, 43, and 44 percent of the costs of their crises, respectively, by the end of 2002. Second, to date, in none of these countries has seignorage been the dominant source of revenues. Its importance has varied from less than 6 percent of net crisis costs in the case of Korea to roughly 11 percent in the case of Turkey. Third, debt deflation has been more important than seignorage in all three countries, ranging from a low of 6.4 percent of the total cost in Mexico to a high of 41 percent of the total cost in Turkey. Fourth, in all cases there was a substantial decline in the dollar value of tax revenues after the crisis, but the decline in the dollar value of government purchases was important in offsetting the tax revenue decline. Finally, our estimates suggest that there were large declines in the dollar value of transfers. Indeed, for Korea and Mexico this decline was the single most important source of revenue.

5.1. Case Study: Korea

Timing and Interest Rates We denote the month and year in which the crisis occurred as t_m and t_a, respectively. For the Korean case we set t_m to October 1997 and t_a to 1997. We make this distinction because some data is available at the monthly frequency (e.g. seignorage revenue), but other data (e.g., government purchases of goods and services) is available only at an annual frequency.

To simplify, we assume a constant annual dollar interest rate, r, equal to an estimate of the average dollar interest rate for government debt. Consistent with section 4.1 we set $r = 0.055$ in the Korean case.

Seignorage Revenue Recall that in our model, the government cannot raise seignorage revenue under a fixed-exchange-rate regime, because the demand for real and nominal balances is constant. In reality, governments can raise seignorage revenues under a fixed exchange rate, since the demand for real balances grows if output expands.

We measure actual seignorage revenue, $M_t - M_{t-1}$, using data on the monetary base, M_t. We compute the dollar value of seignorage revenue, $(M_t - M_{t-1})/S_t$, using the monthly average exchange rate. We assume that in the absence of a crisis, the money stock would have grown at a constant rate μ_m, so that the monetary base would be $M_t^e = M_{t_m}(1+\mu_m)^{t-t_m}$. Hypothetical seignorage revenue is given by $M_t^e - M_{t-1}^e$. We convert these flows to dollars using a forecast of what the monthly exchange rate would have been without a crisis, S_t^e. We assume that $S_t^e = S_{t_m}(1+\delta_m)^{t-t_m}$, where we set δ_m equal to a forecast of what the average depreciation rate of the currency would have been in the absence of the crisis. We note that many countries that experience currency crises do not literally have fixed exchange rates. So, for these countries, we must estimate a rate of depreciation that would have been consistent with the prior exchange rate regime.

The increase in the present value of seignorage revenue is given by:

$$\text{Change in seignorage} = \sum_{t=t_m+1}^{T_m} (1+r_m)^{-(t-t_m)} \left(\frac{M_t - M_{t-1}}{S_t} - \frac{M_t^e - M_{t-1}^e}{S_t^e} \right).$$

Here, T_m denotes December 2002.

In the Korean case we set $\mu_m = 0.0005$, which corresponds to the average monthly money growth rate for October 1992 through October 1997. In addition, we set $\delta_m = 0.0008$, which corresponds to the average monthly depreciation rate of the won between 1980 and 1997. This assumption implies that in the absence of the crisis the dollar would have been worth about 1012 won at the end of 2002, compared to its actual value of 1186 won and its value of 844 won at the end of 1996.

Given our assumptions, the increase in Korean seignorage revenue between November 1997 (t_m+1) and December 2002 (T_m) was 5.2 billion dollars, or 1.1 percent of Korea's GDP in 1997.

Debt Deflation To estimate the revenue from debt deflation, we must measure the change in the dollar value of outstanding domestic debt as a result of the crisis. Doing so requires data on the maturity structure of debt. Table 6 summarizes the value of the different bonds outstanding in Korea at the end of October 1997, along with information on maturities.

We do not have detailed data on the maturity of each bond. For bonds with multiple maturities, we assume that there were equal quantities of each maturity outstanding in October 1997. For example, within "Grain Securities" we assume that roughly 1.62 trillion won worth of the outstanding bonds were of one, three, and five year maturities, implying a total of 4.87 trillion won. Within each maturity we assume that the number of bonds within one month of their maturity date is the same as the number of bonds within two months, three months, etc., of their maturity dates. For example, for one year "Grain Securities" we assume that there were bonds worth roughly 0.135 trillion won that were one month, two months,... , 12 months from their maturity date at the end of October 1997. All bonds are treated as zero coupon bonds.

Given these assumptions, we construct a schedule of debt payments on Korean domestic debt outstanding as of October 1997. Total revenue from debt deflation is given by:

$$\text{Debt deflation} = \sum_{t=t_m+1}^{T_m} (1+r_m)^{-(t-t_m)} B_t \left(\frac{1}{S_t^e} - \frac{1}{S_t}\right) + \left(\frac{1}{S_{T_s}^e} - \frac{1}{S_{T_s}}\right) \sum_{t=T_m+1}^{T_b} (1+r_m)^{-(t-t_m)} B_t. \tag{5.1}$$

Here, B_t denotes the debt payment to be made in month t. The variable T_b denotes the period when all the outstanding debt will be paid off. The last term in (5.1) reflects revenue from debt deflation associated with debt maturing after T_m.

According to our data, the total value of outstanding Korean domestic debt at the end of October 1997 was roughly 73.9 trillion won, or 16.3 percent of 1997 GDP. Our estimates imply that revenue from debt deflation was about 16.6 billion dollars, or 3.5 percent of GDP.

Figure 2 illustrates the time series of Korea's revenue from debt deflation from 1997 through 2002. We note that most of the revenue from debt deflation accrued in the first few months after the crisis. This fact suggests that our calculations are not very sensitive to either the precise maturity structure of the debt or the fact that our data ends before all the domestic debt has been redeemed.

Changes in Tax Revenues To measure the change in taxes due to the crisis, we compute the difference between actual tax revenues, T_t, and what taxes would have been had there been no crisis, T_t^e. We assume that actual dollar tax revenue is given by $T_t = T_t^L + \tau p_t Y_t$, where T_t^L denotes lump sum taxes, Y_t is real GDP, $p_t = P_t/S_t$, and P_t is the GDP deflator (we note that $p_t Y_t$ is GDP measured in current dollars.) The presence of lump-sum taxes allows us to capture, in a simple way, the fact that tax revenues are not perfectly correlated with GDP. We assume that, up to an i.i.d. error, lump-sum taxes are proportional to trend GDP, i.e., $T_t^L = (\tau^L + \epsilon_t^L)\bar{p}_t \bar{Y}_t$, where $\bar{p}_t$ and $\bar{Y}_t$ are the fitted values from log-linear trends fit to p_t and Y_t over the period 1980–97. Assuming that ϵ_t^L is uncorrelated with $(p_t Y_t)/(\bar{p}_t \bar{Y}_t)$, we can estimate τ^L and τ by regressing $T_t/(\bar{p}_t\bar{Y}_t)$ on a constant and $(p_tY_t)/(\bar{p}_t\bar{Y}_t)$. Doing so over the period 1980–2002 yields $\tau^L = 0.051$ and $\tau = 0.162$.

We assume that in the absence of the crisis, tax revenue would have been expected to be $T_t^e = (\tau^L + \tau)p_t^eY_t^e$. Here, p_t^e and Y_t^e denote the pre-crisis expected values of p_t and Y_t. For Korea, we set p_t^e equal to a log-linear trend fit to p_t over the period 1980–1997, and projected forward to 2002. To calculate Y_t^e we take the 1997 level of real GDP as given, and assume a subsequent real growth of 7.2 percent per annum. This value corresponds to the average real growth rate between 1993 and 1997. Figure 3 illustrates these projections.

We define the total change in tax revenue as:

$$\Delta(T) = \sum_{t=t_a+1}^{T_a} (1+r)^{-(t-t_a)}(T_t - T_t^e).$$

Here, T_a denotes 2002.

Next, we decompose $\Delta(T)$ into three components: an output effect, a relative price effect, and a residual effect that we ascribe to explicit fiscal reform. We define the change in tax revenue due to changes in output as:

$$\Delta(T, Y) = \sum_{t=t_a+1}^{T_a} (1+r)^{-(t-t_a)}\tau p_t^e(Y_t - Y_t^e).$$

We note that in this expression, changes in tax revenue are due solely to the effect of the crisis on output. We define the change in tax revenue due to changes in relative prices as:

$$\Delta(T, p) = \sum_{t=t_a+1}^{T_a} (1+r)^{-(t-t_a)}\tau(p_t - p_t^e)Y_t.$$

This expression isolates the impact on tax revenue of changes in p_t associated with the crisis. The residual component, or explicit fiscal reform, is given by:

$$\Delta(T, e) = \Delta(T) - \Delta(T, Y) - \Delta(T, p).$$

Figure 4(a) illustrates the actual path of government revenue in Korea along with the projected path implied by our calculations. Consistent with conventional wisdom, we find that the crisis led to a large decline in the dollar value of tax revenues, both because of the output effect and the relative price effect. We estimate that through 2002, Korean tax revenues fell by 254.3 billion dollars as a result of the crisis. Of this total, 64.1 billion dollars were due to output losses and 227.1 billion dollars were due to the change in relative prices. These two effects were offset by explicit revenue increases amounting to 36.9 billion dollars.

Changes in Primary Expenditure

Government Purchases of Goods and Services

Let G_t denote the dollar value of the actual flow of government purchases of goods and services. We assume that in the absence of the crisis, the dollar value of the flow of government purchases would have been $G_t^e \equiv g p_t^e Y_t^e$. Here, g represents a trend share of government purchases to GDP. The change in the value of government purchases of goods and services due to the crisis is:

$$\Delta(G) = \sum_{t=t_a+1}^{T_a} (1+r)^{-(t-t_a)} (G_t - G_t^e).$$

For Korea, we set $g = 0.154$, which corresponds to the average ratio of government purchases to GDP for 1993–97.

We decompose the change in government purchases into two components: a relative price effect, and a residual effect that we ascribe to explicit fiscal reform. The change in government purchases due to changes in relative prices is given by:

$$\Delta(G, p) = \sum_{t=t_a+1}^{T_a} (1+r)^{-(t-t_a)} g(p_t^G - p_t^e)\bar{Y}_t. \tag{5.2}$$

Here, $p_t^G = P_t^G / S_t$ and P_t^G is the deflator for government purchases from the national income accounts. We rescale P_t^G so that it is equal to P_t in the year prior to the crisis. Expression (5.2) isolates the changes in government purchases that are due to movements in relative prices.

The residual component, or explicit change in government purchases, is:

$$\Delta(G, e) = \Delta(G) - \Delta(G, p).$$

Transfers

Let v_t be actual spending on transfers measured in dollar terms. Recall that in the benchmark model we assume that some transfers are explicitly denominated in dollars but others are explicitly indexed to the local price level. Here, we assume that total transfer spending (measured in dollar terms) is given by:

$$v_t = \left(\bar{\psi}\bar{p}_t + \psi p_t\right)\bar{Y}_t + \bar{p}_t\bar{Y}_t\epsilon_t^v = \left(\bar{\psi} + \psi\frac{p_t}{\bar{p}_t} + \epsilon_t^v\right)\bar{p}_t\bar{Y}_t,$$

where p_t, $\bar{p}_t$ and $\bar{Y}_t$ are defined as above.

We assume that one component of v_t, $\bar{\psi}\bar{p}_t\bar{Y}_t$, is proportional to trend real GDP to capture the fact that transfers are not very sensitive to the business cycle in industrializing countries. Our specification also captures a key feature of our theoretical model: some transfers are sensitive to changes in relative prices, and others are not. Since we do not have any data that distinguishes between these two types of transfers, we use the following procedure to estimate ψ and $\bar{\psi}$. We assume that ϵ_t^v is uncorrelated with $p_t/\bar{p}_t$ and estimate $\bar{\psi}$ and ψ by regressing $v_t/(\bar{p}_t\bar{Y}_t)$ on a constant and $p_t/\bar{p}_t$. Using Korean data for 1990–2002 we obtain $\psi = 0.027$ and $\bar{\psi} = 0.014$. We do not use data prior to 1990 to estimate the parameters, as there was a significant and sharp increase in the scale of transfers in the late 1980s. The fact that our estimate of ψ equals 0.027 also serves as our motivation for the parameterization of CPI-indexed transfers in section 4.

We assume that in the absence of the crisis, expected total transfers (measured in dollars) are $v_t^e = (\bar{\psi} + \psi)p_t^e Y_t^e$. The total change in transfer spending due to the crisis is:

$$\Delta(v) = \sum_{t=t_a+1}^{T_a} (1+r)^{-(t-t_a)}(v_t - v_t^e).$$

We decompose $\Delta(v)$ into two components: a relative price effect, and a residual effect that we ascribe to explicit fiscal reform. We define the change in transfers due to changes in relative prices as:

$$\Delta(v,p) = \sum_{t=t_a+1}^{T_a} (1+r)^{-(t-t_a)}\psi(p_t - p_t^e)Y_t^e.$$

Here, p_t^e and Y_t^e are defined exactly as they were for tax revenue.

The residual component, or explicit change in transfers, is:

$$\Delta(v,e) = \Delta(v) - \Delta(v,p).$$

Overall Change in Primary Expenditure

Figure 4(c) illustrates the actual path of primary expenditure in Korea and the projected path implied by our calculations. We estimate that through 2002 the Korean government saved 301.2 billion dollars on its primary spending as a result of the crisis. Of this total, 254.1 billion dollars were due to the change in relative prices, and 47.1 billion dollars were due to explicit spending cuts.

These calculations demonstrate the quantitative importance of the fall in the relative price of nontradables on the government's fiscal position. In the Korean case, this effect more than offsets the impact of the crisis on tax revenues emphasized in the literature. Focusing on the tax effects while ignoring the expenditure effects greatly overstates the adverse effect of the crisis on the government's fiscal position.

Korea Case Study: Summary In summary, our results for Korea are as follows. The fiscal cost of the banking sector bailout was approximately 114.4 billion dollars or 24 percent of Korea's GDP in 1997. Lost revenue due to the post-crisis recession was roughly 64.1 billion dollars or 13.4 percent of GDP. Explicit fiscal reforms amounted to 84.0 billion dollars or 17.6 percent of GDP. Taken together, these results imply that the Korean government had to raise 94.5 billion dollars, or 19.8 percent of GDP, to pay for the remaining fiscal costs.

Table 7 summarizes our estimate of how much had been financed through 2002. To date, the government has raised 48.7 billion dollars (10.2 percent of GDP) of the costs associated with the crisis. Most of these resources were raised through a substantial decline in the dollar value of transfers amounting to 8.9 percent of GDP. Offsetting this decline was the fall in government revenue net of government purchases of goods and services, which amounted to -3.2 percent of GDP. Because the Korean government had only modest amounts of won-denominated debt, only 3.5 percent of GDP was raised by deflating its dollar value. Additional seignorage contributed only 1.1 percent of GDP in new revenue. So total depreciation-related revenue so far adds up to about 10.2 percent of GDP.

Given our estimates, the government must still pay for 48.4 percent of the fiscal cost, or 9.6 percent of pre-crisis GDP. As we saw in section 4, our model can account for the large depreciation and modest post-crisis inflation rates in Korea under the assumption that about two thirds (6.3 percent of GDP) of the remaining fiscal cost of the crisis will be financed through future explicit fiscal reforms, with most of the remaining third coming from implicit declines in the dollar value of transfers.

We conclude by emphasizing that in both the data and our model, seignorage, the source of financing most emphasized in the literature, plays a relatively minor role. In reality, the two most important sources of financing are large reductions in both the dollar value of government purchases and transfer payments.

5.2. Case study: Mexico

Timing and Interest Rates For Mexico, the month and year in which the crisis occurred, t_m and t_a, are given by November 1994 and 1994, respectively. Therefore we measure seignorage and debt deflation beginning with December 1994, and changes in government revenue, purchases, and transfers beginning in 1995. We set the annual dollar interest rate to $r = 0.109$. This value corresponds to the average EMBI (Mexico) dollar spread plus the US 3-month T-bill rate between December 1994 and January 2003.

Seignorage Revenue We measure actual seignorage revenue $(M_t - M_{t-1})/S_t$ using the same method as in the Korean case. As above, we assume that in the absence of a crisis, the money stock would have been $M_t^e = M_{t_m}(1+\mu_m)^{t-t_m}$ and the exchange rate would have been $S_t^e = S_{t_m}(1+\delta_m)^{t-t_m}$. We set $\mu_m = 0.0114$ and $\delta_m = 0.003$, which are the average monthly rates of money growth and depreciation between June 1991 and June 1994. As for Korea, we set T_m to December 2002.

According to our estimates, the increase in the Mexican government's seignorage revenue between December 1994 ($t_m + 1$) and December 2002 (T_m) was 7.3 billion dollars, or 1.8 percent of Mexico's GDP in 1994.

Debt Deflation Table 6 summarizes our data on the types of bonds outstanding in Mexico (net of central bank holdings) at the end of November 1994 along with information on their maturities. Cetes are peso-denominated bonds similar to T-bills and Ajustabonos are bonds indexed to the CPI. Mexico also issued domestic securities called Tesabonos and Bondes prior to the crisis. However, Tesabonos were indexed to the dollar and Bondes had adjustable interest rates. For this reason we ignore these securities in our calculations.

For each type of bond, we assume that equal quantities of each maturity were outstanding in November 1994. As we did for Korea, within each maturity we assume that there are equal numbers of bonds within 1 month of their maturity date as there are within two months, three months, etc., of their maturity date. We also treat all bonds as if they were zero coupon bonds.

All Cetes and Ajustabonos outstanding at the end of November 1994 would have been paid back by $T_b =$ November 1999. So, for Cetes we measure debt deflation as:

$$\text{Debt deflation} = \sum_{t=t_m+1}^{T_b} (1+r_m)^{-(t-t_m)} B_t^C \left(\frac{1}{S_t^e} - \frac{1}{S_t} \right).$$

Here, B_t^C represents the number of Cetes maturing at date t. For Ajustabonos we measure debt deflation as:

$$\text{Debt deflation} = \sum_{t=t_m+1}^{T_b} (1+r_m)^{-(t-t_m)} \frac{B_t^A}{P_{t_m}} \left(\frac{P_t^e}{S_t^e} - \frac{P_t}{S_t} \right).$$

Here, B_t^A represents the number of Ajustabonos maturing at date t, P_t represents the CPI, and $P_t^e = P_{t_m}(1+\pi_m)^{t-t_m}$ is an estimate of what the CPI would have been had there been no crisis. We set $\pi_m = 0.0086$, the average monthly CPI inflation rate between June 1991 and June 1994.

For Mexico, the total value of all outstanding Cetes and Ajustabonos at the end of November 1994 was roughly 71.7 billion pesos, or 5.1 percent of 1994 GDP. We estimate that revenue from debt deflation was about 6.9 billion dollars, or 1.7 percent of GDP. Figure 5 illustrates the time series of Mexico's revenue from debt deflation from 1994 through 1999. As in the Korean case, much of the revenue from debt deflation accrued in the first six months after the crisis.

Changes in Tax Revenues To measure the change in taxes due to the crisis, we use the same method as in the Korean case. Our Mexican data set spans the period 1980–2002. Over this period, the Mexican economy experienced substantially more volatility than did the Korean economy. For this reason, we use Hodrick-Prescott trends rather than simple linear trends to construct the $\bar{p}_t$ and $\bar{Y}_t$ series used in the estimation of τ^L. Using data for 1980–2002, we estimate $\tau^L = 0.022$. We choose $\tau = 0.209$ so that the implied ratio of taxes to GDP along the trend path would be equal to 0.231, the ratio of taxes to GDP in 1994.[10]

To project tax revenue beyond the crisis we set $T_t^e = (\tau^L + \tau)p_t^e Y_t^e$. We compute the projections p_t^e and Y_t^e by assuming that p_t and Y_t are expected to increase by 6.9 and 3.3 percent per year, respectively, from their 1994 values. These growth rates correspond to the average growth rates of p_t and Y_t for 1991–94. Figure 6 illustrates these projections.

[10] If we estimate τ with the same procedure used to estimate τ^L, we find $\tau = 0.228$. This value of τ, along with our estimate of τ^L, implies a ratio of taxes to GDP along the trend path equal to 0.251. This ratio is considerably higher than the actual ratio of taxes to GDP in the years 1991–94.

Given the values of τ^L and τ and the series T_t, p_t, and Y_t, we compute the change in tax revenue due to the crisis—and its decomposition into output, relative price, and explicit reform components—as we did for Korea.

Figure 7(a) shows the actual path of government revenue in Mexico along with the trend path implied by our calculations. We estimate that through 2002, Mexican tax revenues fell by 263.5 billion dollars as a result of the crisis. Of this total, 29.6 billion dollars were due to output losses and 184.1 billion dollars were due to the change in relative prices. In addition, we estimate that there were explicit tax cuts amounting to about 49.8 billion dollars.

Changes in Primary Expenditure

Government Purchases of Goods and Services

We set the trend share of government purchases to GDP, g, equal to the ratio of government purchases to GDP in 1994, 0.152. We then decompose the change in government purchases into a relative price effect and explicit fiscal reform, using the same method as for Korea.

Transfers

We decompose the change in transfers into a relative price effect and explicit fiscal reform, using the same method as for Korea. Our estimate of $\bar{\psi}$, which we obtain by using data for 1980–2002, is -0.018. We choose the value of ψ so that the trend value of transfers to GDP coincides with the actual value of the ratio of transfers to GDP in 1994 (6.2 percent). This procedure yields a value of ψ equal to 0.08.

Overall Change in Primary Expenditure

Figure 7(c) illustrates the actual path of primary expenditure in Mexico and the projected path implied by our calculations. We estimate that through 2002, as a result of the crisis, the Mexican government saved 248.5 billion dollars on its primary spending. Of this total, 215.3 billion dollars were due to the change in relative prices, and 33.2 billion dollars were due to explicit spending cuts.

Mexico Case Study: Summary In summary, our results for Mexico are as follows. The fiscal cost of the banking sector bailout was approximately 60.1 billion dollars or 15 percent of Mexico's GDP in 1994. Lost revenue due to the post-crisis recession was roughly 29.6 billion dollars or 7.4 percent of GDP. Explicit fiscal reforms amounted to -16.6 billion dollars or -4.1 percent of GDP. Taken together, these results imply that the Mexican government had to raise 106.4 billion dollars, or 26.5 percent of GDP, of depreciation-related revenues.

Table 7 shows that, through 2002, the government raised 42.6 percent (11.3 percent of GDP) of the costs associated with the crisis. Most of these resources were raised through a substantial decline in the dollar value of transfers amounting to 18.4 percent of GDP, but these declines were offset by a substantial fall in the dollar value of government revenue net of government purchases of goods and services: -10.6 percent of GDP. Because the Mexican government had only modest amounts of peso-denominated debt, only 1.7 percent of GDP was raised by deflating its dollar value. Additional seignorage contributed 1.8 percent of GDP in new revenue. Given our estimates, the government would still need to pay for the remaining 57.4 percent of the fiscal costs (15.2 percent of pre-crisis GDP).

Absent any indication of large impending fiscal reforms, it seems reasonable to suppose that much of the remainder of the fiscal costs will be paid for with seignorage revenues. We estimate that if, from December 2002 on, the monetary base grew at the same monthly rate as under the counterfactual, $\mu_m = 0.0114$, and the peso depreciated at the same rate as under the counterfactual, the government would raise 21.7 percent of pre-crisis GDP from additional seignorage. Under this scenario the government would raise more revenue than it would need to fully finance the remaining costs associated with the crisis. Of course, if Mexico prints money more quickly or the peso depreciates less slowly than under our assumptions, then the government will be able to cover the fiscal costs of the crisis faster.

The key point is that absent any sign of explicit fiscal reforms, it seems quite likely that the bulk of the costs will be covered via explicit seignorage revenues. Our model would predict that with this much financing coming from seignorage, the rate of inflation in Mexico would be considerably higher than it would have been had the implicit fiscal reforms or the initial domestic debt been larger.

5.3. Case Study: Turkey

Timing and Interest Rates For Turkey, the month and year prior to the occurrence of the crisis, t_m and t_a, are given by January 2001 and 2000, respectively. Therefore we measure seignorage and debt deflation beginning with February 2001 and changes in government revenue, purchases, and transfers beginning in 2001. We set the annual dollar interest rate to $r = 0.1066$. This value corresponds to the average EMBI+ (Turkey) dollar spread plus the US 3-month T-bill rate between February 2001 and January 2003. Between the inception of the EMBI+ for Turkey in August 1999 and the end of January 2001, this rate averaged 10.63 percent.

Seignorage Revenue We measure actual seignorage revenue $(M_t - M_{t-1})/S_t$ using the same method as we did for Korea. As above, we assume that in the absence of a crisis, the money stock would have been $M_t^e = M_{t_m}(1 + \mu_m)^{t-t_m}$ and the exchange rate would have been $S_t^e = S_{t_m}(1 + \delta_m)^{t-t_m}$. We set $\mu_m = 0.0238$ and $\delta_m = 0.0175$, which are the average monthly rates of money growth and depreciation between January 2000 and January 2001. We set T_m equal to December 2002.

According to our estimates, the increase in the Turkish government's seignorage revenue between February 2001 $(t_m + 1)$ and December 2002 (T_m) was 3.3 billion dollars, or 1.7 percent of Turkey's GDP in 2000.

Debt Deflation Table 6 summarizes our data on Turkey's outstanding securitized domestic debt. This table indicates the quantities and maturities of different types of bonds outstanding at the end of January 2001. Turkey had small amounts of indexed domestic debt, from which we abstract.

We assume that for each type of bond, there were equal quantities outstanding in each month beginning in February 2001 and ending at the month corresponding to twice the average maturity date given in Table 6. We treat all bonds as if they were zero coupon bonds.

We use the same expression for debt deflation that we used for Korea. For Turkey, all government debt outstanding at the end of January 2001 should be paid back by $T_b =$ April 2009. We set T_s equal to December 2002.

For Turkey, the total value of all domestic debt not held by the public sector at the end of January 2001 was roughly 35.5 quadrillion Turkish lire, or 28.5 percent of 2000 GDP. We estimate that revenue from debt deflation was about 12.5 billion dollars or 6.3 percent of GDP.

Figure 8 illustrates the time series of Turkey's revenue from debt deflation from 2001 projected out to 2009. As in the Korean and Mexican cases, much of the revenue from debt deflation accrued in the first year after the crisis. However, the amount of revenue raised by debt deflation is much larger in the Turkish case.

Changes in Tax Revenues To project tax revenue beyond the crisis we use a simpler model than those used for Korea and Mexico. We set $T_t^e = \tau p_t^e Y_t^e$ and set $\tau = 0.271$, the ratio of taxes to GDP in 2000. Since p_t had been relatively stable in Turkey for many years, we assume that agents expected it to remain constant at its value in 2000. We set the annual growth rate of Y_t^e to 3.7 percent. This value corresponds to the average growth rate of Y_t in the period 1987–2000. Figure 9 illustrates these projections. Given the value of τ and the series T_t, p_t, and Y_t, we compute the change in tax revenue due to the crisis and its decomposition into output, relative price, and explicit components as we did for Korea.

Figure 10(a) shows the actual path of government revenue in Turkey and the trend path implied by our calculations. We estimate that through 2002, Turkish tax revenues fell by 17.9 billion dollars as a result of the crisis. Of this total, 8.4 billion dollars were due to output losses and 12.8 billion dollars were due to the change in relative prices. In addition, we estimate that there were explicit tax increases amounting to about 3.2 billion dollars.

Changes in Primary Expenditure

Government Purchases of Goods and Services

We set the trend share of government purchases to GDP, g, equal to 0.201, which is the ratio of government purchases to GDP in 2000. We then decompose the change in government purchases into a relative price effect and explicit fiscal reform, using the same method as for Korea.

Transfers

We decompose the change in transfers into a relative price effect and explicit fiscal reform, using the same method as for Korea. We set $\bar{\psi} = 0$ and $\psi = 0.074$ so that the trend value of transfers to GDP coincides with the actual value of the ratio of transfers to GDP in 2000 (7.4 percent).

Overall Change in Primary Expenditure

Figure 10(c) illustrates the actual path of primary expenditure in Turkey and the projected path implied by our calculations. We estimate that through 2002 the Turkish government saved 21.1 billion dollars on its primary expenditure as a result of the crisis. Of this total, 10.5 billion dollars were due to the change in relative prices, and 10.6 billion dollars were due to explicit cuts in spending.

Turkey Case Study: Summary In summary, our results for Turkey are as follows. The fiscal cost of the banking sector bailout was approximately 36.2 billion dollars or 18.2 percent of Turkey's GDP in 2000. Lost revenue due to the post-crisis recession was roughly 8.4 billion dollars or 4.2 percent of GDP. Explicit fiscal reforms amounted to 13.8 billion dollars or 6.9 percent of GDP. Taken together, these results imply that the Turkish government had to raise 30.8 billion dollars, or 15.4 percent of GDP, of depreciation-related revenues.

Through 2002, we estimate that the government raised 44.3 percent (6.8 percent of GDP) of the costs associated with the crisis. We summarize these costs in Table 7. Most of these resources were raised through a substantial decline in the dollar value of Turkey's domestic debt amounting to 6.3 percent of GDP, and through increased seignorage revenues (1.7 percent of GDP). The dollar value of transfers declined by 1.9 percent of GDP, but these were offset by a decline in the dollar value of government revenue net of government purchases of goods and services of -3.1 percent of GDP.

Based on this evidence, we conclude that the Turkish case is quite different from the Korean and Mexican cases. First, while all three countries have so far financed about 50 percent of the net fiscal costs associated with their crises, Turkey has done so much more quickly (2 years for Turkey versus 5 and 8, respectively, for Korea and Mexico). Second, the Turkish government has relied much more on seignorage and debt deflation, but the Korean and Mexican governments have relied more on implicit fiscal reform.

6. Conclusion

In this paper we explore the implications of different strategies for financing the fiscal costs associated with a currency crisis for inflation and depreciation rates. We argue that models based on the assumption that seignorage is the only depreciation-related source of revenue lead to misleading predictions about post-crisis rates of inflation and depreciation.

We then show that models that incorporate an empirically plausible menu of depreciation-related revenues can account for the high depreciation rates and low inflation rates that are often observed in the aftermath of currency crises.

Our case studies indicate that different governments pursue different financing strategies. For example, debt deflation played a more important role in Turkey than in Korea or Mexico. In contrast, the reduction in the dollar value transfers played a very large role in Mexico.

We are silent on why these governments chose different strategies. In our view, understanding the political economy considerations that underlie these choices is an important topic for future research.

TABLE 1

SEIGNORAGE

(Average of 2 Years Before and After Each Country's Crisis, % of GDP)

Country	Before Crisis	After Crisis
Korea	0.1	0.6
Thailand	1.5	2.7
Philippines	2.7	2.1
Mexico	0.4	0.9
Brazil	0.6	0.7
Turkey	3.5	2.8

TABLE 2

INFLATION AND DEPRECIATION RATES

(percent)

Country		Cumulative Exchange Rate Depreciation	Cumulative CPI Inflation
Korea	Sep. 97—Sep. 98	50.9	6.9
	—Sep. 99	31.8	7.7
Thailand	June 97—June 98	67.1	15.5
	—June 99	45.4	14.2
Philippines	June 97—June 98	54.2	17.0
	—June 99	44.7	23.7
Mexico	Nov. 94—Nov. 95	94.8	47.2
	—Nov. 96	101.5	88.0
Brazil	Dec. 98—Dec. 99	52.9	8.9
	—Dec. 00	62.9	15.5
Turkey	Jan. 01—Jan. 02	103.2	73.2
	—Jan. 03	146.8	125.5

Notes: We calculate the rate of depreciation as $100(S_{t+j}/S_t - 1)$, where S_t is the monthly average exchange rate.

TABLE 3

CHANGE IN THE RELATIVE PRICE OF NONTRADABLES

(percent)

Country		Change in Dollar Price of Nontradables
Korea	Sep. 97—Sep. 98	−30.3
Thailand	June 97—June 98	−33.2
Philippines	June 97—June 98	−27.7
Mexico	Nov. 94—Nov. 95	−38.4
Brazil	Dec. 98—Dec. 99	−30.0
Turkey	Jan. 01—Jan. 02	−18.9

TABLE 4

MODEL PARAMETERS

(a) Benchmark case	
$\sigma = 1$	inverse of elasticity of intertemporal substitution
$\omega = 0.5$	share of tradables in CPI
$r = 0.055$	real interest rate
$S = 1$	initial exchange rate
$y^T = 1$	output of tradables
$y^N = 1$	output of nontradables
$p^N = 1.79$	initial relative price of nontradables
$y = y^T + p^N y^N = 2.79$	initial GDP (in dollars)
$g = 0.153y$	initial government purchases (in dollars)
$g^T = 0.132g$	initial government purchases of tradables
$g^N = (g - g^T)/p^N$	initial government purchases of nontradables
$v = 0.043y$	initial total transfers (in dollars)
$P\hat{v}/S = 0.027y$	initial CPI-indexed transfers (in dollars)
$(M/S)/y = 0.067$	initial ratio of base money to GDP
$\tau^T = \tau^N = 0.216$	tax rates on tradable and nontradable goods
$b_0 = -0.057y$	initial government dollar debt level
$B = 0.075y$	government nominal debt
$\phi = 0.135$	amount financed by devaluation-based revenues
$t^* = 0.33$	time of the speculative attack
$T = 0.5$	time of switch to new monetary policy
$M_T/M = 1.12$	ratio of base money at time T to initial base money
$\delta = 0.5$	distribution cost of tradables

(b) Without nominal debt: same as (a) except $B = 0$

(c) Without CPI-indexed transfers: same as (a) except $\hat{v} = 0$

(d) Without nominal debt and CPI-indexed transfers: same as (a) except $B = \hat{v} = 0$

(e) Basic textbook model: same as (a) except $\omega = 1$, $y^N = g^N = \hat{v} = B = \delta = 0$, $y = y^T$, $g^T = g$, p^N and τ^N undefined.

(f) ... adding nominal debt: same as (e) except $B = 0.075y$

(g) ... adding nontraded goods with sticky prices: same as (a) except $\delta = 0$ and $\hat{v} = 0$

(h) ... adding CPI-indexed transfers: same as (a) except $\delta = 0$

(i) Same as (a) except r_t rises by 3.2 percentage points for $t^* \leq T$

Note: The alternative models are described in the text. The letters and cases correspond to those in Table 5.

TABLE 5

KOREA CALIBRATION, NUMERICAL RESULTS

	Inflation		Deprec.	Financing (percent of GDP)			
	Yr 1	Long-run	Yr 1	Seig.	Nominal Debt Deflation	Implicit Fiscal Reforms: $g-\tau$	Implicit Fiscal Reforms: Transfers
a) Benchmark model	12.5	1.9	45.6	1.8	3.5	−2.7	10.9
Alternative Financing Scenarios							
b) Benchmark without nominal debt	16.1	5.7	50.6	5.2	0	−2.7	11.0
c) Benchmark without CPI-indexed transfers	22.0	12.1	58.8	10.6	5.7	−2.7	0
d) Benchmark without both	28.6	19.4	68.2	16.3	0	−2.8	0
Deconstructing the Model							
e) Simple textbook model	22.7	11.4	22.7	13.5	0	0	0
f) Textbook model adding nominal debt	18.8	7.3	18.8	9.1	4.4	0	0
g) Case (f) adding nontraded goods with sticky prices	20.1	9.4	34.0	10.2	5.1	−1.8	0
h) Case (g) adding CPI-indexed transfers	16.2	5.3	29.5	6.1	4.3	−1.7	4.9
i) Experiment with time-varying r_t	13.5	1.9	49.7	1.5	3.7	−5.5	13.8
Empirical Estimates	7.2*	2.5†	45.0*	1.1‡	3.5‡	−3.2‡	8.9‡

*Oct. 1997—Oct. 1998.

†Average rate between Oct. 1998 and Dec. 2002.

‡We measure seignorage at a monthly frequency through Dec. 2002. Debt deflation is also measured monthly through Dec. 2002, and includes an estimate of future debt deflation. We measure implicit fiscal reforms at an annual frequency through 2002.

TABLE 6

OUTSTANDING DOMESTIC DEBT

	Value Outstanding	Maturities	Average Mos. to Maturity
(a) Korea, End of Oct. 1997	(trillion won)		
Grain securities	4.9	1, 3 and 5 yrs.	n.a.
Subway construction bond	3.0	3 yrs.	n.a.
National housing bond	12.7	5–10 yrs.	n.a.
FX stabilization fund bonds	4.0	1–5 yrs.	n.a.
Treasury bonds	5.8	1–10 yrs.	n.a.
Monetary stabilization bonds	26.4	0.5, 1, 2, 3, 4.5, 6, 12, 18 mos.	n.a.
Industrial finance debentures	17.1	1–10 yrs.	n.a.
(b) Mexico, End of Sep. 1994	(billion pesos)		
Cetes	42.2	1, 3, 6 and 12 mos.	n.a.
Ajustabonos	29.5	3 and 5 yrs.	n.a.
(c) Turkey, End of Jan. 2001	(quadrillion TL)		
Government Bonds (cash)	0.7	1 Yr.	5.9
	14.7	Irregular 1—2 Yrs	7.0
	2.9	2 Yrs.	11.7
	2.0	Irregular 2—3 Yrs.	18.3
	1.1	3 Yrs.	18.3
Government Bonds (noncash)	11.4		50.0
Treasury Bills (cash)	0.8	3 Mos.	1.6
	0.1	Irregular 3—6 Mos.	3.7
	0.9	6 Months	5.4
	0.1	Irregular 6—9 Mos.	5.6
	0.9	Irregular 9—12 Mos.	4.9
Treasury Bills (noncash)	0.0		1.0

Sources: See Data Appendix.

TABLE 7

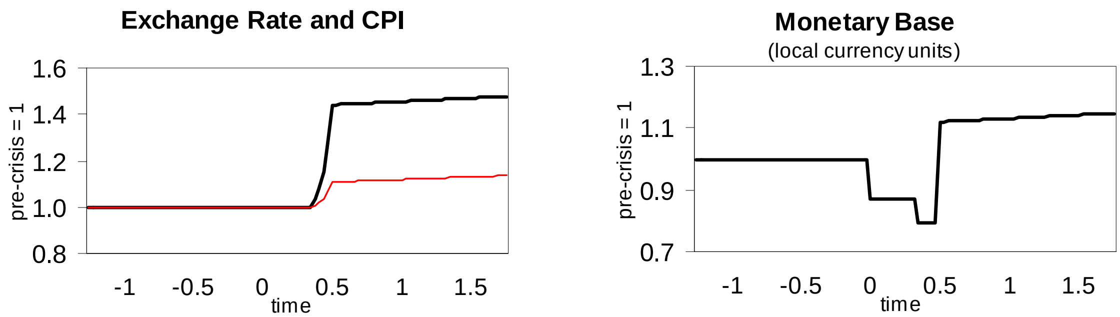
CRISIS-RELATED COSTS AND SOURCES OF NEW FINANCING

	% of GDP	% of Net Cost
(a) Korea		
Cost of bailing out banking system	24.0	
Recession costs	13.4	
Explicit fiscal reform	17.6	
Net cost to be financed	**19.8**	
seignorage	1.1	5.5
Debt deflation	3.5	17.5
Implicit decline in transfers	8.9	44.7
Implicit decline in purchases–taxes	−3.2	−16.2
Total depreciation-related financing through 2002	**10.2**	**51.6**
(b) Mexico		
Cost of bailing out banking system	15.0	
Recession costs	7.4	
Explicit fiscal reform	−4.1	
Net cost to be financed	**26.5**	
Seigniorage	1.8	6.8
Debt deflation	1.7	6.4
Implicit decline in transfers	18.4	69.4
Implicit decline in purchases–taxes	−10.6	−40.0
Total depreciation-related financing through 2002	**11.3**	**42.6**
(c) Turkey		
Cost of bailing out banking system	18.2	
Recession costs	4.2	
Explicit fiscal reform	6.9	
Net cost to be financed	**15.4**	
Seigniorage	1.7	10.8
Debt deflation	6.3	40.8
Implicit decline in transfers	1.9	12.5
Implicit decline in purchases–taxes	−3.1	−19.8
Total depreciation-related financing through 2002	**10.3**	**44.3**

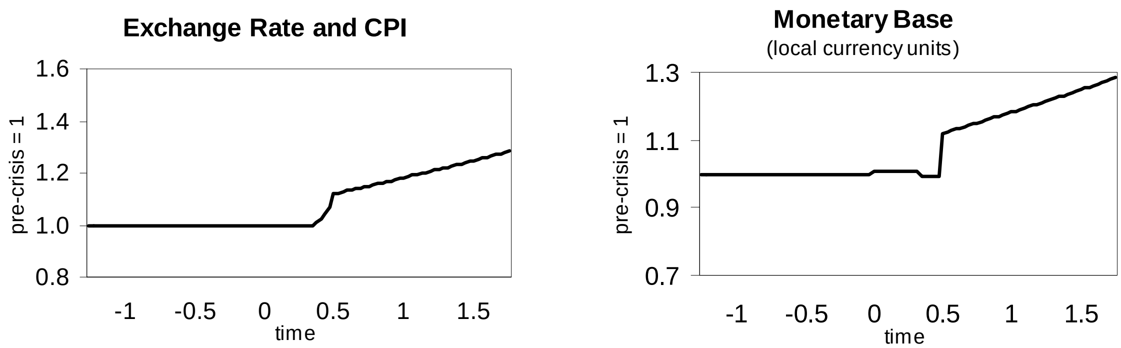
FIGURE 1

EQUILIBRIUM PATHS IMPLIED BY THE MODEL

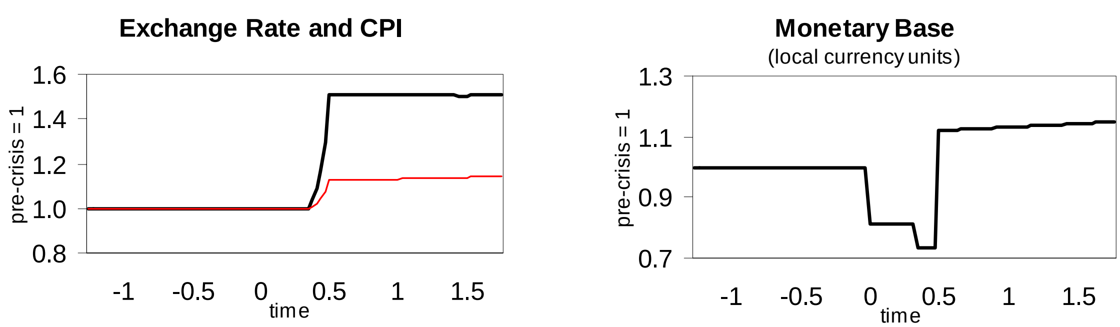
(a) Benchmark Model



(b) Basic Textbook Model



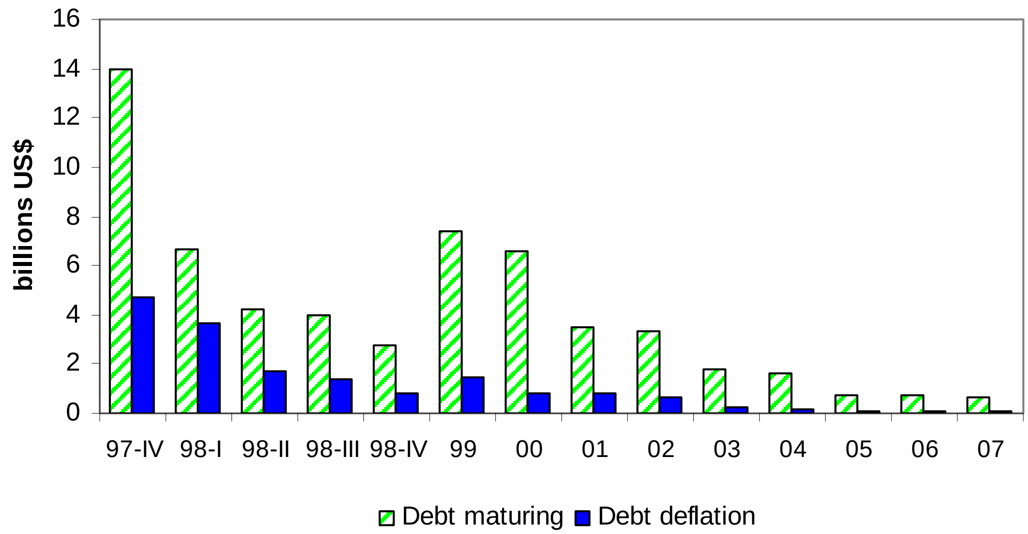
(c) Model with Time-Varying Interest Rates



Note: The benchmark model (a) is our full model with nontradable goods, distribution costs, sticky prices, nominal debt, and CPI-indexed transfers. The basic textbook model (b) has none of these features. The model with time-varying interest rates (c) allows for a rise in interest rates in the wake of the crisis (see the main text for a full description).

FIGURE 2

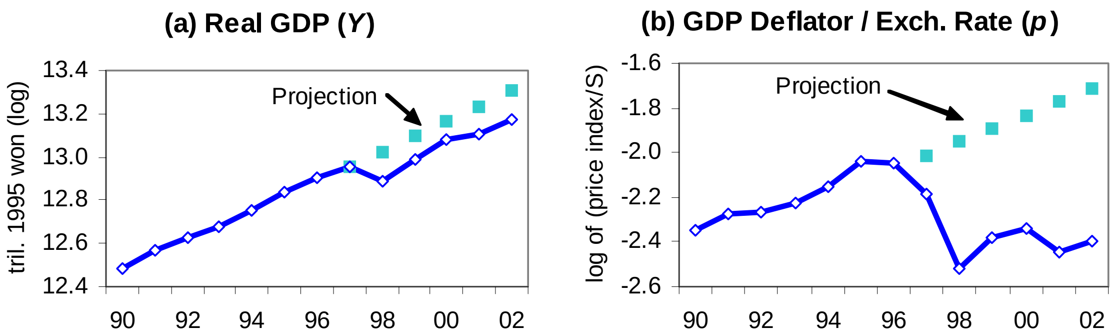
REVENUE FROM DEBT DEFLATION IN KOREA, 1997–2007



Notes: The quantity of debt maturing is sum of the face values (in won) of all debt maturing within each time period divided by the exchange rate (won/dollar). Debt deflation is unanticipated revenue from the decline in the dollar value of domestic debt. See the text for the details of the calculations and data.

FIGURE 3

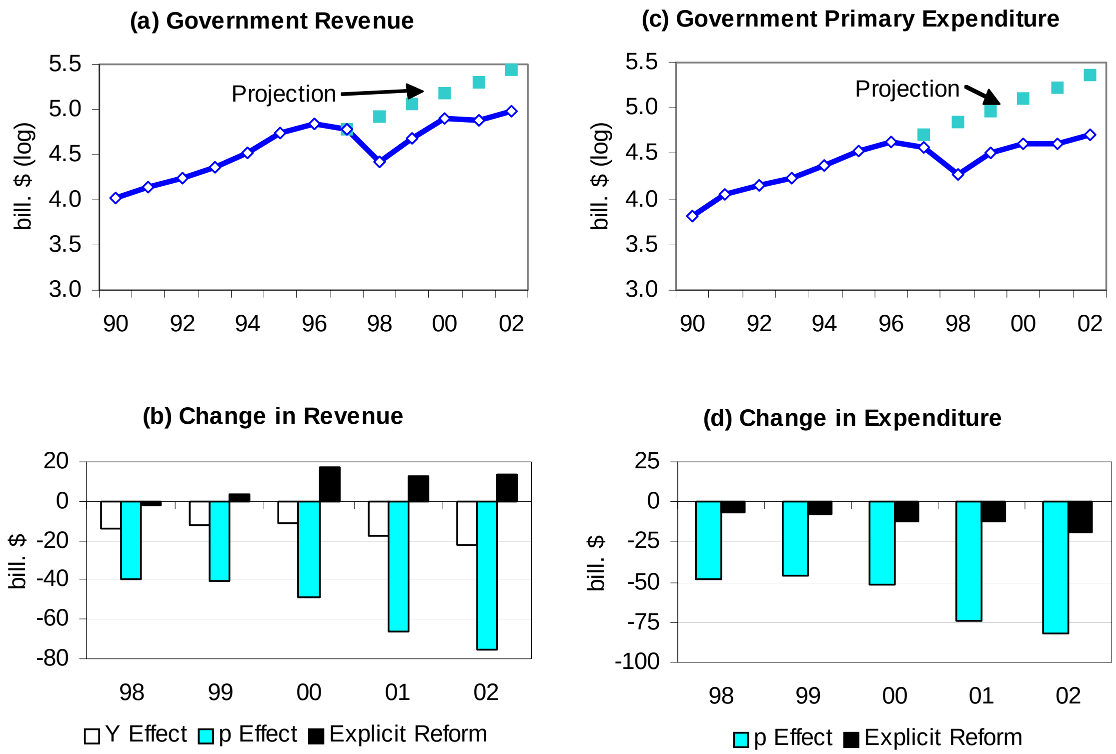
PROJECTED PATHS FOR KOREAN TIME SERIES



Notes: Real GDP is measured in trillions of constant 1995 won, and expressed in logarithms in the chart. The GDP deflator is an index number equal to 100 in 1995. The exchange rate is measured in won per dollar. The ratio of these two series is expressed in logarithms in the chart. The projections were calculated as described in the text.

FIGURE 4

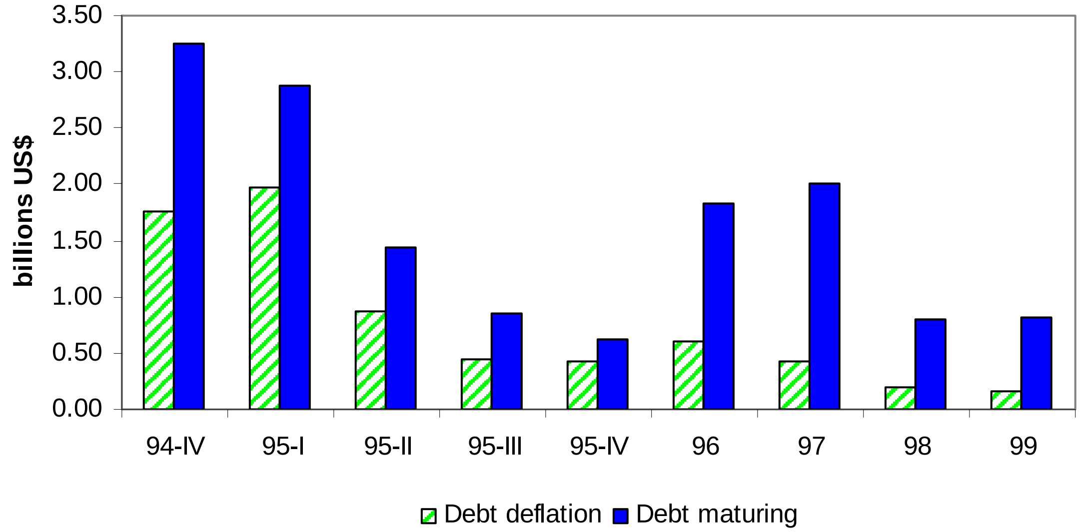
GOVERNMENT SPENDING, REVENUE AND FISCAL REFORMS IN KOREA



Notes: The projections of government revenue and expenditure were estimated as described in the text. The changes in revenue and expenditure are the actual values minus the projected values. Explicit reforms that improve the government's finances are positive in the revenue panel (b), but negative in the expenditure panel (d). Calculations used in defining the time series in (b) and (d) are described in the text.

FIGURE 5

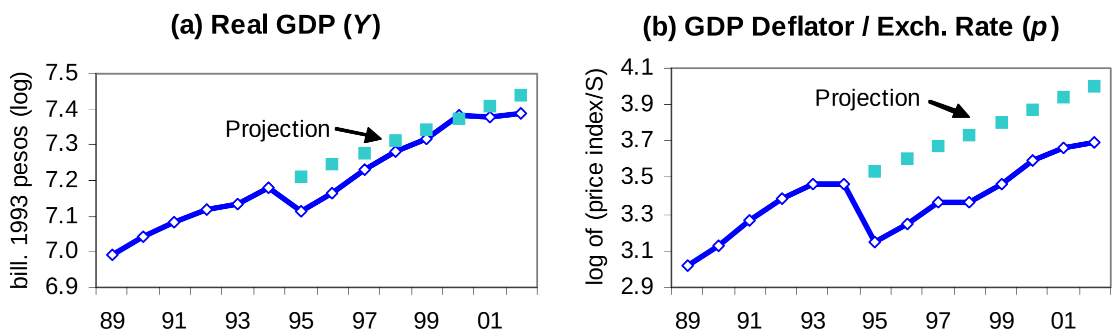
REVENUE FROM DEBT DEFLATION IN MEXICO, 1994–1999



Notes: The quantity of debt maturing is sum of the face values (in pesos) of all debt maturing within each time period divided by the exchange rate (pesos/dollar). Debt deflation is unanticipated revenue from the decline in the dollar value of domestic debt. See the text for the details of the calculations and data.

FIGURE 6

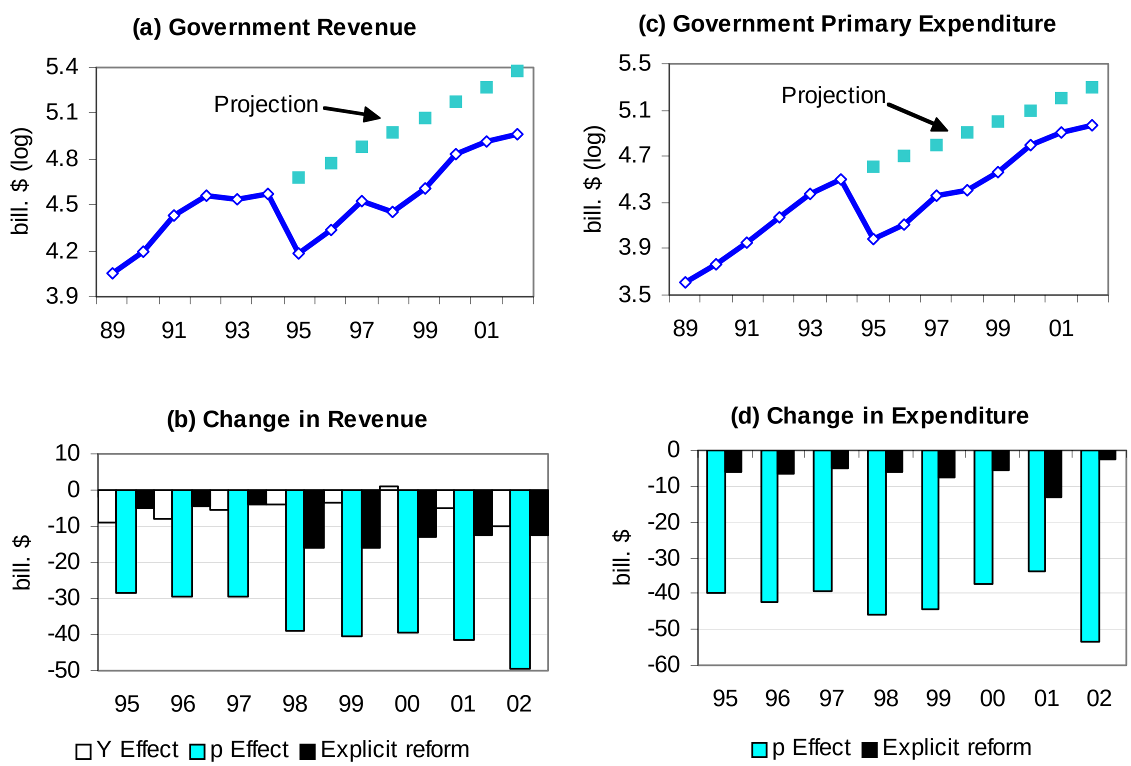
PROJECTED PATHS FOR MEXICAN TIME SERIES



Notes: Real GDP is measured in billions of constant 1993 pesos, and expressed in logarithms in the chart. The GDP deflator is an index number equal to 100 in 1993. The exchange rate is measured in pesos per dollar. The ratio of these two series is expressed in logarithms in the chart. The projections were calculated as described in the text.

FIGURE 7

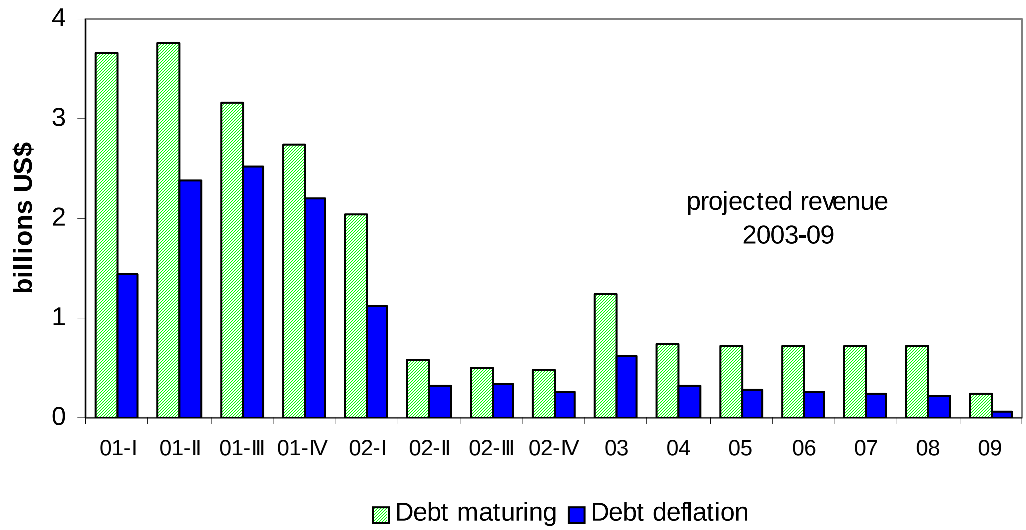
GOVERNMENT REVENUE, EXPENDITURE AND FISCAL REFORMS IN MEXICO



Notes: The projections of government revenue and expenditure were estimated as described in the text. The changes in revenue and expenditure are the actual values minus the projected values. Explicit reforms that improve the government's finances are positive in the revenue panel (b), but negative in the expenditure panel (d). Calculations used in defining the time series in (b) and (d) are described in the text.

FIGURE 8

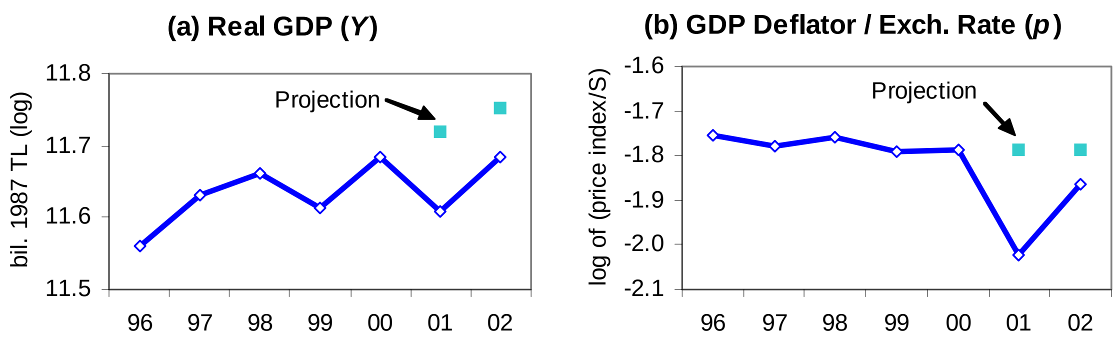
REVENUE FROM DEBT DEFLATION IN TURKEY, 2001-2009



Notes: The quantity of debt maturing is sum of the face values (in TL) of all debt maturing within each time period divided by the exchange rate (TL/dollar). Debt deflation is unanticipated revenue from the decline in the dollar value of domestic debt. See the text for the details of the calculations and data.

FIGURE 9

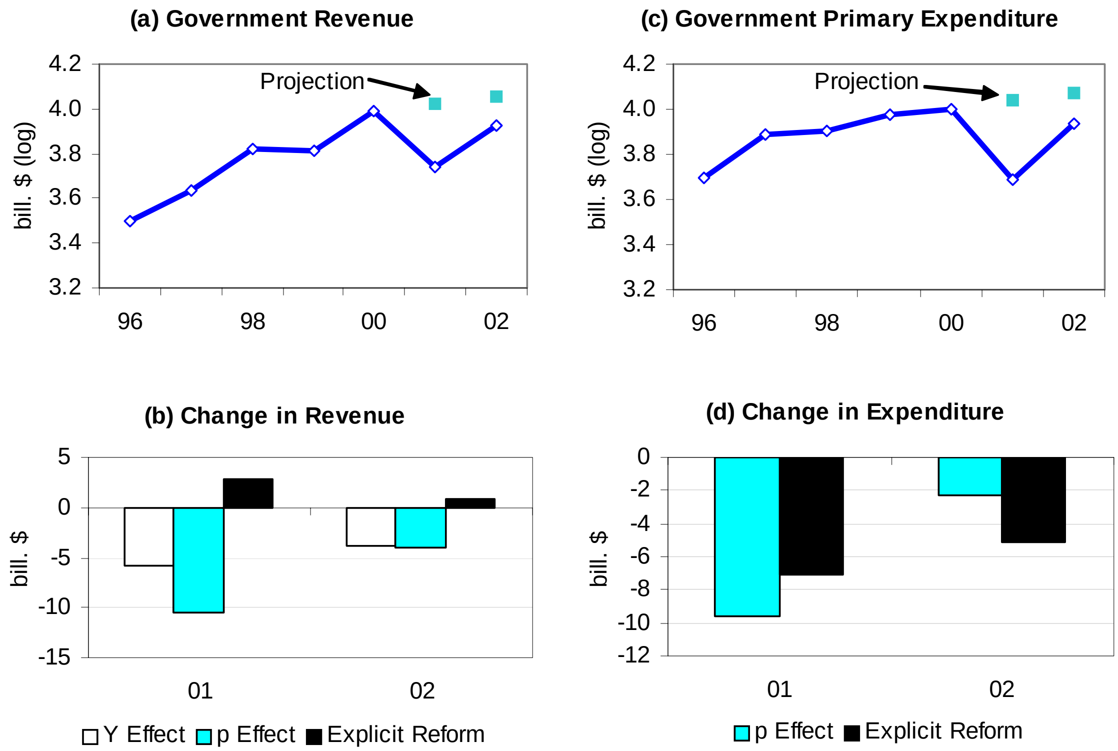
PROJECTED PATHS FOR TURKISH TIME SERIES



Notes: Real GDP is measured in billions of constant 1987 TL, and expressed in logarithms in the chart. The GDP deflator is an index number equal to 100 in 1987. The exchange rate is measured in TL per dollar. The ratio of these two series is expressed in logarithms in the chart. The projections were calculated as described in the text.

FIGURE 10

GOVERNMENT SPENDING, REVENUE AND FISCAL REFORMS IN TURKEY



Notes: The projections of government revenue and expenditure were estimated as described in the text. The changes in revenue and expenditure are the actual values minus the projected values. Explicit reforms that improve the government's finances are positive in the revenue panel (b), but negative in the expenditure panel (d). Calculations used in defining the time series in (b) and (d) are described in the text.

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Data Sources

Exchange Rates For monthly and annual data we use the International Monetary Fund's International Financial Statistics (IFS) series AE...ZF (end-of-period) and AF...ZF (period-average) which we measure in local currency units per U.S. dollar. We use end-of-period figures when converting end-of-period stocks measure in units of local currency to dollar measures. We use period-average figures when converting local currency flows to dollars.

CPI For monthly data we use the IFS series 64...ZF.

Monetary Base For monthly end-of-period data we use the IFS data series *reserve money*, 14...ZF.

Interest Rates For Korea we use data from the IFS on the money market interest rate (60B..ZF), time deposits at deposit money banks (60L..ZF), lending rates of deposit money banks (60P..ZF), and yields on national housing bonds (61...ZF). These data all pertain to won-denominated assets. We compute equivalent dollar returns using our exchange rate data for Korea.

For Mexico and Turkey we use data on Emerging Market Bond Index (EMBI) and EMBI+ spreads. We use the EMBI spread for Mexico and the EMBI+ spread for Turkey (there is no EMBI spread for Turkey). Our source for these data is Bloomberg. The data pertain to the spreads over U.S. interest rates on dollar-denominated assets. To generate dollar interest rates, we combine the spread information with information on 3-month U.S. Treasury Bill rates from the Board of Governors of the Federal Reserve System Release H.15 (http://www.federalreserve.gov/ releases/).

Cost of the Banking Sector Bailout For Korea, we use the estimate provide by Standard and Poor's (2000). As of December 1999, Standard and Poor's estimated that the fiscal cost of the banking crisis would be roughly 24 percent of 1997 GDP, or 114.4 billion dollars.

Lindgren, Garcia, and Saal (1996) estimate the fiscal cost of the Mexican 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.

For Turkey we use the estimate provide by Burnside (2002), 36.2 billion dollars, which is he bases on a detailed analysis of the changes in Turkey's "noncash" domestic debt stock between January and December 2001.

National Income Accounts Data We use national income accounts data to get measures of real and nominal GDP, their expenditure and production components, and the relevant deflators. We obtain our data for Korea from the Statistics Database available on the Bank of Korea's website, http://www.bok.or.kr, with 1995 as the base year. Our data for Mexico come from the website of Instituto Nacional de Estadística, Geografía e Informática (INEGI), http://www.inegi.gob.mx, and have a base year of 1993. For Turkey we obtain data, which have a base year of 1987, from the Bank of Turkey's Electronic Data Delivery System (EDDS) website, http://tcmbf40.tcmb.gov.tr/cbt.html.

Fiscal Data For Korea we measure government purchases as the sum of the government consumption and government capital formation series in the national income accounts (described above). For revenue, we use "current receipts" from the "Income transactions of the sub-sectors of general government" table in the national income accounts, supporting tables, also available from the Bank of Korea. For transfer spending, we use the sum of the series "subsidies," "social security benefits," "social assistance benefits," and "current transfers N.E.C." from the same table.

For Mexico we combine data from the national accounts (described above) and data provided by Banco de Mexico at its website: http://www.banxico.org.mx/ under "Public Finances" that pertain to the central government budget. We measure government purchases as the average of two series: (i) the sum of the government consumption expenditure and government investment expenditure series in the national income accounts and (ii) (from the public finance dataset) capital expenditure plus current expenditure (excluding transfers and interest) plus a share of "revenue sharing to state and local governments" corresponding to the share of non-transfer spending in federal current non-interest expenditure. For transfers we use (from the public finance dataset) "net transfers" plus a fraction of "revenue sharing to state and local governments" corresponding to the share of federal transfer spending in federal non-interest spending other than transfers to state and local governments. For revenue, we use "consolidated budgetary revenues" from the same website.

For Turkey we measure government purchases as the sum of government consumption expenditure and public sector investment expenditure as define in the national income accounts (described above). For revenue we use the series "revenues" from the page "Consolidated Budget (Treasury)" at the Bank of Turkey EDDS website (described above). For transfers we use the series "other transfers" from the same page.

Data on Nominal Debt We obtain our data on Korea's stocks of different domestic debt instruments from the National Statistics Office website, http://www.stat.go.kr/cgi-bin/bbs/imain.cgi. The data were originally sourced from the Bank of Korea and the Ministry of Finance and Economy.

Our data for Mexico's stocks of different domestic debt instruments are from the Ministry of Finance and Public Credit (SHCP): http://www.shcp.gob.mx/english/eofp/cuadros/E01I1994.html.

Our data for Turkey's stocks of different domestic debt instruments at the end of January 2001 come from the Turkish Treasury website, http://www.treasury.gov.tr/english/debtstat.htm, 2001 spreadsheet, Table 4: Maturity Composition of Outstanding Debt.