The Optimal Monetary Response to a Financial Crisis

PRELIMINARY AND INCOMPLETE

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Abstract

We describe a model in which the optimal monetary policy response to a financial crisis is to raise the interest rate immediately, and then reduce it sharply. This pattern is consistent with what actually happened in the Asian crisis episodes.

1 Introduction

The Asian financial crises of 1997-98 triggered a sharp debate over the appropriate response of policy to a financial crises. The hallmark of the crises was a “sudden stop” (Calvo, 1998): capital inflows turned into outflows and output suddenly collapsed. Some argued that the monetary authorities should raise interest rates, to help reverse the outflow of capital. Others argued interest rates should be cut to stimulate output. Interestingly, a look at the data indicates that both pieces of advice were followed in practice. Figure 1 shows what happened to short term interest rates in each of four Asian crisis countries. Initially they rose sharply. Within six months or so, the policy was reversed and interest rates were ultimately driven to below their pre-crisis levels. A casual observer may infer that policy was simply erratic, with policymakers trying out different advice at different times.

In this paper, we argue that the observed policy may have served a single coherent purpose. We describe a model in which the optimal response to a financial crisis is an initial sharp rise in the interest rate, followed by a fall to below pre-crisis levels.

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Our finding builds on the analysis of Christiano, Gust and Roldos (2004) (CGR). CGR study the conditions under which an interest rate cut would stimulate output, employment and raise welfare in the midst of a financial crisis of this kind. In their model, firms require domestic currency working capital to hire labor and foreign currency working capital to finance an imported intermediate input. They adopt the asset market frictions formalized in the limited participation models (Lucas 1990, Fuerst 1992, Christiano and Eichenbaum, 1992, 1995), and model a financial crisis as a time in which collateral constraints are suddenly tightened. The authors show that when these financial frictions are combined with real frictions in the reallocation of labor across sectors, a cut in interest rates is most likely to result in a welfare-reducing fall in output and employment. When these real frictions are absent, a cut in interest rates improves asset values and promotes a welfare-improving economic expansion.

In this paper we extend the work in CGR in three dimensions. First, we provide empirical evidence to support the main assumptions of the model, namely, the role of collateral constraints and imported inputs in the collapse in output and as constraints to the conduct of monetary policy during this kind of financial crisis. Second, we combine the production technology in the two examples of CGR into a unified technology where labor is immobile in the short-run but can be reallocated across sectors in the medium run.1 Third, we study what the optimal monetary policy would be in such an environment.2 Fourth, we present a simple example that sheds light on a core feature of our dynamic model that may at first seem highly counterintuitive: the fact that an interest rate rise raises employment and utility. In the dynamic model, an increase in the interest rate introduces a distortion in the labor market. Normally, this can be expected to reduce employment and utility. Our simple example is non-monetary and there is only one period. The effects of the interest rate in the dynamic model are captured with a straight tax on labor.

1 A similar friction is used by Fernandez de Cordoba and Kehoe (2001) to study the role of capital flows following Spain’s entry to the European Community.

2 Other studies have examined the relationship between optimal interest rates and financial crises. Aghion, Bacchetta and Banerjee (2000) present a model with multiple equilibria, in which a currency crisis is the bad equilibrium. The possibility of the bad equilibrium is due to the interplay between the credit constraints on private firms and the existence of nominal price rigidities. The authors show that the monetary authority should tighten monetary policy after any shock that results in the possibility of the currency crisis equilibrium. Our analysis differs from this analysis in three ways. First, equilibrium multiplicity does not play a role in our analysis. Second, our model emphasizes a different set of rigidities. Third, Aghion, Bacchetta and Banerjee focus on the prevention of crises, while we focus on their management after they occur. Similarly, Caballero and Krishnamurthy (2002) show that when the economy faces a binding international collateral constraint, a monetary expansion that would redistribute funds from consumers to distressed firms has no real effects. Given this lack of effectiveness, a monetary authority that trades-off output and an inflation target focuses on the latter and tightens monetary policy to achieve the inflation objective.
Although a rise in the tax rate distorts the labor market, the overall effects are welfare improving because the collateral constraint on international loans becomes less binding.

The paper is organized as follows. In the first section we provide empirical evidence on the role of collateral constraints and imported intermediate inputs and describe the objectives, constraints and outcomes of monetary policy in the Asian crises countries. The second section presents the simple example. The third section presents our dynamic, monetary model and we highlight its primary financial and real frictions. Section 4 discusses model calibration and section 5 we present the main results. There is a final, concluding section.

2 Collateral Constraints and Monetary Policy

In this section, we provide empirical evidence that motivates and supports some of the key assumptions in our model, as well as the objective, constraints and final outcomes of monetary policy in recent emerging market crises.

The assumption that the land and capital of the firm is collateral for international loans plays an important role in our analysis. We recognize the enforcement problems and other financial market imperfections that are pervasive in emerging markets hence do not restrict ourselves to a narrow (legal or contractual) view of collateral. Rather, we see collateral constraints as capturing the tightening of credit conditions and associated balance sheet problems seen in the aftermath of a financial crisis. They do not just reflect the insistence by creditors that collateral be written explicitly into loan contracts, but also the possibility that regulators induce banks to invest only in ‘secure’ loans, loans to companies that have ample assets in the event that things go wrong. We now briefly provide some empirical evidence on the use of collateral in loan markets.

The use of collateral in loan markets is widespread. Berger and Udell (1990) document that around 70 percent of commercial and industrial loans in the US are secured and Black, De Meza and Jeffreys report similar evidence for the UK. In emerging markets, Gelos and Werner (1999) report that around 60 percent of loans are collateralized in Mexico, while survey evidence from the Bank of Thailand put the figure at more than 80 percent for that country. A review of financial conditions of the Asian crises countries (IMF
notes that lending against collateral was a widespread practice also in these countries.

There is also ample evidence that collateral practices are procyclical. Asea and Blomberg (1998) provide evidence that bank lending standards vary over the US business cycle: in an average contraction, the degree of loan collateralization and spreads charged over Treasuries increase over the year before the trough. In an interesting paper on the recent emerging market crises, Edison, Luangaram and Miller (2000) report that Thai banks that used to lend up to 70-80 percent of the value of pledged collateral before the crisis, moved to lend up to just 50-60 percent after the crisis. More important for our paper, the fraction of syndicated loans in international markets that is collateralized reached a peak (at 42 percent of the total; see Table 1) in the year of the Asian crises. This is reinforced by the fact that the level of syndicated loans also peaked in 1997, in line with the finding in Chadha and Folkerts-Landau (2000) that suggests that commercial banks appear to be lenders of “second-to-last resort” in international credit markets.

There is, however, substantial debate on what constitutes international collateral. In a recent paper, Caballero and Krishnamurthy (2000) assume (with some caveats) that only a fraction of the assets used in the tradable sector would be accepted as collateral by foreign creditors, whereas the totality of domestic assets would be accepted as domestic collateral. Inadequate amounts of international collateral and imperfect aggregation of domestic collateral are shown to lead to fire sales of domestic assets and financial crises.

In recognition of the difficulties defining what constitutes international collateral and the different institutional arrangements and credit market imperfections that characterize emerging markets, we consider the following simplified collateral constraint expressed in units of the foreign currency:

\[
\frac{Q}{S} K \geq R^* z + B.
\]

\(B\) indicates the stock of long-term external debt; \(z\) represents short-term external borrowing to finance a foreign intermediate input; \(R^*\) corresponds to the associated interest rate; \(K\) stands for domestic physical assets like land and capital; \(Q\) is the value (in domestic currency units) of a unit of \(K\); and \(S\) is the nominal exchange rate. We assume that under regular conditions, the collateral constraint is not binding, while it suddenly binds with the onset of a crisis. This may be because in normal times, output in addition to land and capital is acceptable as collateral. We suppose that a crisis is a time when international loans must be
collateralized by physical assets such as land and capital, and that this restriction is binding. Alternatively, in a crisis the fraction of domestic assets accepted as collateral by foreigners suddenly falls. In any case, in our analysis we model the imposition of a binding collateral constraint as an exogenous, unforeseen event.

The collateral constraint in this paper provides a financial friction that captures in a natural way the “balance sheet” effects frequently mentioned in the discussion of recent crises. A number of recent papers (including Krugman (1999), Aghion, Bacchetta and Banerjee (2000), Caballero and Krishnamurthy (2000, 2002), Cespedes, Chang and Velasco (2000), Gertler, Gilchrist and Natalucci (2000), Mendoza and Smith (2002)) introduce credit constraints that capture some aspects of the balance sheet channel. However, while these papers incorporate the adverse effects derived from the existence of foreign currency denominated debts, the credit frictions in those papers constrain borrowing to be a fraction of current income—rather than the current value of physical assets. The mismatch between assets and liabilities that underscored the financial vulnerability of the crises countries is captured in our model by the fact that a large fraction of domestic assets are in the nontraded sector while a relatively large fraction of liabilities are denominated in terms of the traded good. Hence, a large and persistent fall in the relative price of nontraded goods (i.e. a real exchange rate depreciation) results in a fall in the value of assets relative to liabilities that endogenously magnifies the tightening of credit conditions derived from the initial imposition of collateral constraints in the aftermath of the crisis. In other words, our economy is capable of displaying a “sudden stop” in capital inflows (Calvo, 1998, 2002) that is associated with large and persistent falls in output and

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3 The imposition of collateral constraints is also consistent with recent models of financial crises that focus on the role of guarantees and moral hazard as causes of emerging markets crises (such as Krugman, 1999, Corsetti, Pesenti and Roubini, 1998, Dooley, 1998, and Burnside, Eichenbaum and Rebelo, 2000). In fact, we should stress that our model does not attempt to model the causes of the financial crises but its effects on credit conditions. Now after a crisis happens, i.e. after the guarantees are exercised, the only way in which foreigners would extend further credit to a country would be under further guarantees or additional collateral. This additional collateral has been seen in explicit private (syndicated loan) contracts, in the tightening of bank regulations that impose directly or indirectly collateral requirements, and in governments’ intervention and sales of distressed assets.

4 In some respects our framework resembles a reduced form representation of the environment considered in Albuquerque and Hopenhayn (1997) and further developed in Cooley, Marimon and Quadrini (2001) and Monge (2001). There, an investment project requires an initial fixed investment, followed by a sequence of expenditures to make the investment project productive. The papers in this literature derive the optimal dynamic contract between the entrepreneur and a bank, as well as a sequential decentralization. In the latter, the initial fixed investment is financed by long term debt that resembles our $B$, and the sequence of expenditures is financed by working capital loans with the entrepreneur being restricted by a collateral constraint that resembles the one we adopt. This literature suggests a variety of factors that could cause collateral constraints to suddenly become binding. For example, if there is a shock that causes the court system to be overwhelmed by bankruptcy filings and other business in a recession, collateral constraints could suddenly bind because lenders now understand that the default option is more attractive to the marginal entrepreneur who wishes to borrow.

5 A notable exception is Gertler, Gilchrist and Natalucci (2000), but the nature of the credit constraint is different from the one in this paper. Moreover, the current account is always zero in that paper, hence missing the connection between capital flows and asset prices observed in the crises episodes.
external debt. CGR show that the collateral constraint above matches most of the key stylized facts of "sudden stops".

Another key feature of our model is the use of imported intermediate inputs in the production of tradable goods and the need to finance the working capital necessary to purchase these inputs prior to production and export of the final goods. Table 2 shows that intermediate inputs constitute a large fraction of imports for the Asian crises countries, reaching 50 percent of total imports for Korea and 70 percent of the total for Indonesia and Malaysia.

More important, Figure 2 shows the close correlation between the fall in imports of intermediate inputs and GDP in the crises countries. In a survey of 1,200 Thai firms in late 1997 and 1998, Dollar and Hallward-Driemeier (2000) asked them to rank the causes of the output decline and the most important factor cited was the effect of the exchange rate depreciation on imported inputs costs, followed by weak demand, the high cost of capital and lack of access to credit. In terms of the collateral constraint above, the tightening of external credit conditions forces the repayment of $B$ and, combined with the endogenous fall in $Q$, squeezes the amount of external financing available for the purchase of imported inputs $z$. The importance of this mechanism is widely recognized by practitioners that consider trade finance to be the "life-line" for developing countries. Mulder and Sheikh (2003) summarize this mechanism in the following way: "In case of a financial crisis internationally operating banks...step on the brake by either freezing or indicating to cut credit lines or increase costs and refuse to confirm letters of credit...the bank calls for a clear signal from the debtor country in the form of guarantees or a credible plan...[for] economic agents [that] are vulnerable to stress of not been able to import or to acquire sufficient working capital (Mulder and Sheikh, p. 10).

The conduct of monetary policy in a financial crises associated with a sudden reversal in capital inflows, weak banks and corporates and the abandonment of pegged exchange rates, faces a series of difficult trade-offs. As noted by Boorman et al (2000): “Monetary policy in the IMF-supported programs in the Asian crisis countries tried to walk a narrow line, seeking to resist downward pressure on exchange rates while avoiding a crippling effect on the real economy” (p.31). The IMF policy advise under these circumstances, pursued at times hesitantly by the monetary authorities of the affected countries, is best summarized in
Mussa (2000, p2): “Indeed, in January 1998, the currencies of these five countries had lost more than half their values in terms of the US dollar. In this situation, the IMF’s policy advise, in all cases, was that short-term interest rates needed to be raised significantly (and temporarily)...it was recognized, of course, that significant increases in short-term interest rates, even if pursued for relatively brief periods, had negative side effects for economic activity and for the financial conditions of both nonfinancial businesses and financial institutions. This was likely to be especially true in Asian countries where there was a high degree of leverage in the economy. On the other hand, for those countries with substantial net indebtedness in foreign currencies, there were costs and risks of systemic disruption from allowing uncontrolled exchange rate depreciation.” The trade-off between high interest rates and a highly depreciated currency depends critically on the balance sheet exposures of corporates and financial institutions, and accurate estimates of such balance sheet positions are very hard to come by.6

In the event, short-term nominal interest rates were increased substantially in the first half of 1998. Interest rates were around 12 percent in the period before the crises and spiked at level of 25-30 percent in early January 1998.7 Exchange rates peaked at pretty much the same time and then appreciated steady (see Figure 3). Interest rates remained high for a while but started to come down once exchange rates stabilized and other elements of the crisis management packages—including roll-overs and additional external financing—were in place. Interest rates reached pre-crises level by mid-1998 and continued to fall to levels between 2 and 5 percent per year.

Berg et al. (2003) document the fact that monetary policy in countries that experienced currency crises generally went through two phases: an initial chaotic period of crises containment—basically what we just described—and a longer period during which the monetary policy framework and institutions were more fully developed. Before the crises, the Asian countries had followed relatively loose monetary and credit

6 Claessens, Djankov and Ferri (1998) assess the ex-post impact of the currency and interest rate shocks on the solvency of a sample of East Asian firms between early 1997 and 1998. They find that the exchange rate shock alone was sufficient to drive almost two-thirds of Indonesian firms, 20 percent of Korean firms and 10 percent of Thai firms in their sample into insolvency. The effect of interest rate increases was smaller, driving about 2-5 percent of firms in each of the countries into insolvency. This suggests that the trade-off was somewhat tilted towards resisting an "excessive" exchange rate depreciation.  

7 Malaysia’s short-term interest rates were increased less than in the other countries—but overnight rates rose from 6 percent in June 1997 to 35 percent in July 1997. Analysts attribute this difference to the lower exposure to exchange rate risks and relatively higher domestic leverage of Malaysian corporates and financial institutions. Also, the authorities tightened monetary conditions through various direct instruments such as credit plans for financial institutions and a ban on new lending to the property sector (see Boorman et al, 2000).
policies. Following the initial increase in interest rates aimed at stabilizing exchange rates, most countries moved to avoid an inflation/depreciation spiral and continued to float while improving monetary control.\(^8\) Indeed, the authors show that the countries that most quickly regained monetary control tended to have the smallest output declines and have brought inflation down relatively fast.\(^9\)

3 Example

A basic result in the dynamic simulations reported later on is that a rise in the domestic interest rate can produce a rise in equilibrium employment when there is a binding collateral constraint. At first glance this result may seem puzzling since in effect the rise in the interest rate introduces a distortion in the labor market. Partial equilibrium reasoning suggests this distortion should lead to a decrease in employment, not an increase. In fact, the partial equilibrium effect may be overwhelmed by a particular general equilibrium effect when there is a binding collateral constraint. We illustrate this point with sharply simplified version of our dynamic monetary model.

Our example has one period only. The economy has a traded good sector and a non-traded good sector. The non-traded good sector uses labor and no imported intermediate inputs, while the traded sector uses no labor and an imported intermediate input. Financing for the imported intermediate input must be obtained at the beginning of the period, subject to a binding collateral constraint. International loans are paid off at the end of the period. The collateral used in the international loans are productive in the nontraded good sector. When the labor tax rate is increased, this raises the marginal cost of non-traded goods and leads to a rise in their relative price. This rise in price increases the value of the collateral in the non-traded good sector and permits an expansion in imports of the intermediate good. The increased imports leads to an increased demand for the non-traded good, because traded and non-traded goods are complementary in the production of a final good. Through this sequence of events, the net effect of the rise in the labor tax rate is to increase employment and utility. In effect, the binding collateral constraint represents an

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\(^8\)Berg et al. (2003) note that two pre-requisites are necessary to regain monetary stability: the first is the elimination of dollar shortages and the second the resolution of banking sector problems. The first phase was longer in Indonesia—because of the longer period involved in resolving banking problems—and in Mexico—because of doubts about the resolution of the dollar liquidity and banking problems.

\(^9\)In the case of Korea, inflation was very low—under 1 percent in the year after the crisis—despite a large nominal depreciation of the won. Burnstein, Eichenbaum, and Rebelo (2002) explain this in terms of relatively large component of nontradable distribution costs in the final consumption of tradable goods.
inefficiency wedge for the economy. By introducing an inefficiency wedge in the labor market, the labor tax rate helps mitigate the effects of the inefficiency wedge associated with the collateral constraint. The overall effect is welfare-improving.

3.1 Model

A representative household has preferences over consumption and labor, $c$ and $L$, as follows:

$$u(c, L) = c - \frac{\psi_0}{1 + \psi}L^{1+\psi}. \quad (1)$$

The non-tradeable consumption good is produced using traded and non-traded intermediate goods using the following Leontief technology:

$$c = \min \{(1 - \gamma)c^T, \gamma c^N\}. \quad (2)$$

Traded and non-traded intermediate goods are produced, respectively, using the following two technologies:

$$y^T = Az^\theta, \quad y^N = K^\alpha L^{1-\alpha}. \quad (3)$$

Here, $z$ is a good which is imported from abroad, and $y^T$ is the gross amount of traded goods produced. Traded goods are used in domestic production, and for paying international debt as follows:

$$y^T = c^T + R^*z, \quad (4)$$

where $R^*$ is the gross rate of interest, in traded good terms. In (4), $z$ is the amount borrowed from abroad to finance the purchase of $z$ for use in (3), so that $R^*z$ is the total quantity of traded goods owed to foreign creditors at the end of the period. Equation (4) is the market clearing condition in the market for traded goods. Non-traded goods can only be used as intermediate goods in production of $c$, so that:

$$y^N = c^N.$$

We consider a competitive market environment. The representative household maximizes utility, (1), subject to the budget constraint,

$$pc \leq wL + \pi + T.$$
Here, $p$ denotes the price of the consumption good, $w$ denotes the wage rate, $\pi$ denotes profits, and $T$ is a lump-sum transfer payment from the government. All these quantities are measured in units of the traded good.

The consumption good, $c$, is produced by a representative firm using the technology, (2). This firm takes as given the price, $p$, of its output as well as the price of nontraded goods, $p^N$. The traded intermediate good is the numeraire, and its price is taken to be unity.

A representative intermediate good firm operates the two technologies, (3), and seeks to maximize profits,

$$\pi = p^N y^N + y^T - q(K - K_0) - w(1 + \tau)L - R^* z.$$  

It is convenient express the firm’s profits in non-traded goods units:

$$\frac{\pi}{p^N} = y^N + \frac{1}{p^N}[y^T - R^* z] - \frac{q}{p^N}(K - K_0) - \frac{w}{p^N}(1 + \tau)L$$  \hspace{1cm} (5)

In (5), $\tau$ denotes a tax on labor. This tax is rebated in lump sum form to households via $T$ in their budget constraint. In addition, $K_0$ is the initial endowment of capital of the firm, $q$ is the price of capital, and $K$ is the actual capital used in production. Foreign creditors impose a borrowing constraint which stipulates that a fraction, $\tau^N$, of the value of capital, $qK$, must be no less than the firm’s end-of-period international obligations:

$$\tau^N qK \geq R^* z.$$  \hspace{1cm} (6)

The timing of the intermediate good firm’s decisions are as follows. First, the tax rate, $\tau$, becomes known. Then, a market opens in which intermediate good firms trades capital among themselves at a price, $q$. Then $z$, $L$, $c$, $y^N$ and $y^T$ are determined and production occurs. At this point, the intermediate good firm decides whether to default on its international loans. If it does, then the creditors can seize from the firm an amount of output equal to the firm’s obligations. Although the firm’s physical capital is worthless at this point in time, the firm does have at least $\tau^N qK$ goods on hand. To see this, note from (4) and (3) that\(^\text{10}\):

$$Az^\theta \geq R^* z.$$  

\(^{10}\)Implicitly, we suppose that $z$ has no value to the intermediate good producer other than as an input to production. For example, the producer has no incentive to abscond with $z$ without producing anything.
As a result, the profits of a firm which pays labor in the non-traded good sector, but contemplates not repaying its international debt are:

\[ \alpha p^N y^N + Az^\theta \geq R^* z. \]

A competitive equilibrium is a set of allocations and prices where households and firms solve their problems subject to their constraints and markets clear.

### 3.2 Equilibrium Characterization and Computation

We begin by listing 5 equations that characterize 5 equilibrium variables - \( p^N, q, L, z \) and the Lagrange multiplier on (6) - for our model. Consider the representative final good producer. As long as input prices are strictly positive, the final good producer always sets \( c^T = \left[ \gamma/(1 - \gamma) \right] y^N \). Combining (3) and (4), this implies:

\[ Az^\theta - R^* z = \frac{\gamma}{1 - \gamma} K^\alpha L^{1-\alpha}. \]  

(7)

If the price of, say, \( c^T \), were zero, then the final good producer would be indifferent between purchasing an amount of \( c^T \) consistent with (7), or purchasing more. In such a case, we suppose that the producer resolves the indifference by imposing (7). Competition in final goods leads the firm to equate price to marginal cost:

\[ p = \frac{1}{1 - \gamma} + \frac{1}{\gamma} p^N, \]

(8)

The representative intermediate good firm’s optimal choice of capital leads to the following expression for the price of capital:

\[ q = \frac{\alpha p^N K^{\alpha - 1} L^{1-\alpha}}{1 - \lambda \tau^N}. \]

(9)

This is the first order necessary condition for optimization in the Lagrangian representation of the intermediate good firm’s optimization problem, in which \( \lambda \geq 0 \) is the multiplier on (6). The labor demand choice by the intermediate good firm leads it to equate the marginal cost, \((1 + \tau)w\), and value marginal product of labor in the production of non-traded goods to obtain (after making use of (8)),

\[ \frac{1 - \alpha}{\left( \frac{1}{1 - \gamma} \frac{1}{p^N} + \frac{1}{\gamma} \right)} K^\alpha L^{-\alpha} = \frac{1}{p} \]

(10)
Optimization in the choice of $z$ leads to the following first order condition:

$$\frac{1}{p^N} [\theta A z^{\theta-1} - R^*(1 + \lambda)] = 0. \quad (11)$$

Evidently, for $p^N < \infty$, (11) corresponds to setting the expression in square brackets to zero. However, we will also allow $p^N = \infty$ (this corresponds to a zero price on $c^T$), in which case (11) does not require the numerator to be zero. Finally, the complementary slackness condition on $\lambda$ for intermediate good firm optimization is:

$$\lambda \left[ \tau^N q K - R^* z \right] = 0, \; \lambda \geq 0, \; \tau^N q K - R^* z \geq 0. \quad (12)$$

Market clearing requires that prices be strictly positive:

$$q, \; p^N > 0. \quad (13)$$

The latter, in combination with (9) impose an upper bound on $\lambda$, $\lambda \leq 1/\tau^N$.

Household optimization of employment leads to the following labor supply curve:

$$\psi_o L^\psi = \frac{w}{p}. \quad (14)$$

For purposes of the following analysis, it is convenient to substitute out the real wage rate by combining (10) and (14). Solving the resulting expression for $p^N$, we obtain:

$$\frac{1}{p^N} = \frac{1 - \gamma}{\gamma} \left[ \frac{\kappa}{1 + \tau} - 1 \right], \; \kappa = \frac{\gamma (1 - \alpha) K^\alpha}{\psi_o L^{\psi+\alpha}}. \quad (15)$$

In (15), $\kappa$ is of interest because a planner for whom $c^T$ is free would set $L$ so that $\kappa = 1$. We have 5 variables, $p^N, \; q, \; L, \; z, \; \lambda$, whose equilibrium values can be determined by the 5 conditions, (7), (9), (11), (12), (15), as well as the nonnegativity constraints, (13).

These equations suggest a simple strategy for computing an equilibrium. We define a mapping from the space of admissible equilibrium multipliers, $D = [0, 1/\tau^N]$, to candidate equilibrium outcomes that satisfy our 5 equilibrium conditions, minus (12). We then adjust $\lambda \in D$ until (12) is satisfied. When this is so, the candidate equilibrium outcomes constitute an actual equilibrium. The mapping from $\lambda \in D$ to candidate outcomes is as follows. First, conjecture that $p^N$ takes on a positive, finite value. Then, compute the value of $z$ that solves (11). After this, compute the value of $L$ that satisfies (7) and evaluate $\kappa$ in
(15). If $\kappa > (1 + \tau)$, then use (15) to compute $p^N$ (note that the finiteness assumption on $p^N$ is verified). In this case $q$ can be computed from (9). Finally, compute $\tau^N q K - R^* z$, so that (12) can be evaluated.

Now suppose $\kappa \leq (1 + \tau)$. In this case, set $p^N = \infty$ (i.e., $1/p^N = 0$) and $\kappa = 1 + \tau$. The latter expression determines a value for $L$, which replaces the (smaller) value computed above. Solve for the smaller of the two values of $z$ which satisfy (7) with the given $L$. According to (9), $q = \infty$ and therefore $\tau^N q K - R^* z = \infty$ also.

### 3.3 Analysis

The labor demand and supply curves, (10) and (14), are displayed in Figure 4. The figure indicates that a rise in $\tau$, holding $p^N$ fixed, shifts the labor demand curve left, and results in a fall in employment. At the same time, a rise in $p^N$ shifts the labor demand curve to the right. Because the labor supply curve is not a function of $\tau$ or $p^N$, a rise in $p^N$ leads to a rise in employment and output. So, if general equilibrium effects raise $p^N$ by enough after a rise in $\tau$, equilibrium employment could increase.

Could the general equilibrium effects on $p^N$ really be so great as to reverse the negative effects on employment of a tax increase? To see that the answer is yes, suppose that the collateral constraint is not binding, so that $\lambda = 0$. In this case, (11) pins down a unique value of $z$ that is independent of $\tau$. As long as this value of $z$ is not too great, so that $p^N < \infty$, the implied quantity of $e^T$ will be fully utilized in the production of final goods. The Leontief assumption on production, (7), then pins down the equilibrium level of employment, $L$. Thus, both $z$ and $L$ are determined independently of the value of $\tau$. From (15) it is apparent that a rise in $\tau$ must produce a rise in $p^N$ that is large enough to completely undo the effect of any rise in $\tau$. So, it should not be surprising that in a perturbation of our economy in which the collateral constraint is binding, it is possible for a rise in $p^N$ to more than compensate for a rise in $\tau$. To see that this is so, we comput ed a numerical example.

We adopted the following parameter values:

$$A = 2, \ R^* = 1.06, \ \theta = 0.1, \ \gamma = 0.43, \ \alpha = 0.25, \ \tau^N = 0.1, \ \psi_0 = 0.06, \ \psi = 1, \ K = 1.$$  

We computed equilibrium allocations corresponding to $\tau$ in the range, 0.01 to 1.00. By considering a fine grid of $\lambda \in D$, we found that, for each value of $\tau$ considered, the equilibrium is unique. The values of...
utility, $1/p^N, q, \lambda, z, L$ corresponding to each $\tau$ are displayed in Figure 5. Note that for $\tau$ in the range of 0 to 0.4, utility is strictly increasing. In this range, an increase in the tax rate raises $p^N$ and raises $q$ as well. The latter has the effect of relaxing the collateral constraint, which is reflected in the fall in $\lambda$. Note that the initial value of $\lambda$ is extremely high. According to (11), $\lambda$ is equivalent to a tax on the purchase of the foreign intermediate input. When $\tau = 0$ that tax rate is about 175%. By increasing the labor tax rate, the shadow tax rate on foreign borrowing is completely eliminated. This leads to an increase in imports ($z$ rises by a multiple of over 3), which in turn leads to an expansion in $L$. The increase in $L$ and in utility continues until $\lambda$ has been driven to zero. For $\tau$ in the range $0.4 < \tau < 0.72$, utility and employment are invariant to additional increases in $\tau$. This is because in this range, $z$ is in a sense a binding constraint on domestic production. The amount of $z$, which is now pinned down by $A$ and $R^*$ in (11), determines $L$ through (7). Eventually, with additional increases in $\tau$, it is employment that becomes the binding constraint in production. At this point, additional increases $\tau$ result in a reduction in $L$ and ‘excess supply’ of $c^T$. Although the economy can produce the $c^T$ implied by the equation in square brackets in (11) and (4), some of this $c^T$ goes unused. On the margin, $c^T$ is literally free and this is reflected in $p^N = \infty$.\footnote{Technically, in the range where $L$ is constant, $\kappa$ in (15) is constant. As long as $\kappa/(1 + \tau) > 1$, $p^N$ is finite, but $p^N = \infty$ when increases in $\tau$ result in $\kappa = 1 + \tau$.} With additional increases in $\tau$ beyond this point, $L$ falls and utility declines.\footnote{We carried out some experiments to see if the results in this example are robust. For example, we found that the results are robust to increasing $\theta$ to 0.2, although for $\theta$ above 0.2 we found that the model tends to have multiple equilibria. When we reduced $\theta$, we found that eventually the collateral constraint is not binding and so the experiment we do here is not interesting. [Report other robustness exercises here.]} It is of interest that the value of the traded good used in production, $c^T$, relative to the value of non-traded goods, $p^N c^N$, is 0.50 for $\tau = 0$ and falls to 0.13 when the tax rate reaches its optimal value. For higher tax rates, this ratio drops to zero.

4 The Dynamic, Monetary Model

This section describes our dynamic, monetary model. In its basic structure, it is a standard traded good-non traded good small open economy model. The model has households, firms, a financial intermediary, and a domestic monetary authority. For the most part, the model corresponds to the one in CGR, and so the presentation is brief. A key difference between this model and that in CGR is that labor in the traded
good sector cannot be quickly adjusted in response to a shock.

4.1 Households

There is a representative household, which derives utility from consumption, $c_t$, and leisure as follows:

$$\sum_{t=0}^{\infty} \beta^t u(c_t, L_t),$$

(3.1.1)

where $L_t$ denotes labor time spent in the market and $c_t$ denotes consumption. We adopt the following specification of utility:

$$u(c, L) = \frac{c - \psi_0 L^{1+\psi}}{1 - \sigma}.$$  

(3.1.2)

The household begins the period with a stock of liquid assets, $\tilde{M}_t$. Of this, it allocates $Q_t$ to consumption expenditures and the rest, $\tilde{M}_t - Q_t$, is deposited with the financial intermediary. The cash constraint that the household faces on its consumption expenditures is:

$$P_t c_t \leq W_t L_t + Q_t,$$

(17)

where $W_t$ denotes the wage rate and $P_t$ denotes the price level.

The household also faces a flow budget constraint governing the evolution of its assets:

$$\tilde{M}_{t+1} = R_t (\tilde{M}_t - Q_t + X_t) + P_t^T \pi_t + [W_t L_t + Q_t - P_t c_t].$$

(18)

Here, $R_t$ denotes the gross domestic rate of interest, $\pi_t$ is profits which derive from household’s ownership of firms, and $X_t$ is a liquidity injection from the monetary authority. $\pi_t$ is measured in units of traded goods, and $P_t^T$ is the domestic currency price of traded goods. The term on the right of the equality reflects the household’s sources of liquid assets at the beginning of period $t + 1$: interest earnings on deposits and on the liquidity injection, profits and any cash that may be left unspent in the period $t$ goods market.

The household maximizes (3.1.1) subject to (17)-(18), and the several timing constraints. Since the model is deterministic after the first period, timing assumptions then do not matter. They do matter in the first period, since the financial crisis is modeled as unanticipated in that period. So our timing assumptions matter for the first periods. We assume that the employment decision is made at the very beginning of the period, before any shock (e.g., the onset of the financial crisis) is realized. The household deposit decision
is made after the financial crisis occurs, but before the monetary authority’s response is realized. All other household decisions are made after the monetary authority.

4.1.1 Firms

There are two types of representative, competitive, firms. The first produces the final consumption good, \( c \), purchased by households. Final goods production requires intermediate goods which are produced in traded and non-traded good sectors by the second type of representative firm. We now discuss the decisions facing these firms.

4.1.2 Final Good Firms

The production function of the final good firms is:

\[
 c = \min \left\{ (1 - \gamma) c^T, \gamma c^N \right\},
\]

where \( c^T \) and \( c^N \) denote quantities of tradeable and non-tradeable intermediate inputs, respectively. As noted above, the price of \( c \) is denoted by \( P \), while \( P^T \) and \( P^N \) denote the money prices of the traded and nontraded inputs, respectively. The firm takes these prices parametrically.

Zero profits and efficiency imply the following relation between prices:

\[
 p = \frac{1}{1 - \gamma} + \frac{p^N}{\gamma}, \quad p = \frac{P}{P^T}.
\]

The object, \( P \), in the model corresponds to the model’s ‘consumer price index’, denominated in units of the domestic currency. The object, \( p \), is the consumer price index denominated in units of the traded good.

4.1.3 Intermediate Inputs

A single representative firm produces the traded and non-traded intermediate inputs. That firm manages three types of debt, two of which are short-term. The firm borrows at the beginning of the period to finance its wage bill and to purchase a foreign input, and repays these loans at the end of the period. In addition, the firm holds the outstanding stock of external (net) indebtedness, \( B_t \).

The firm’s optimization problem is:

\[
 \max \sum_{t=0}^{\infty} \beta^t \Lambda_{t+1} \pi_t,
\]

15
\[
\pi_t = p_t^N y_t^N + y_t^T - w_t^N R_t L_t^N - w_t^T R_t L_t^T - R^* z_t - r^* B_t + (B_{t+1} - B_t),
\]

(22)
denotes dividends, denominated in units of traded goods. Also, \(B_t\) is the stock of external debt at the beginning of period \(t\), denominated in units of the traded good; \(R^*\) is the gross rate of interest (fixed in units of the traded good) on loans for the purpose of purchasing \(z_t\); and \(r^*\) is the net rate of interest (again, fixed in terms of the traded good) on the outstanding stock of external debt. The price, \(\Lambda_{t+1}\), is taken parametrically by firms. In equilibrium, it is the multiplier on \(\pi_t\) in the (Lagrangian representation of the) household problem:13

\[
\Lambda_{t+1} = \beta \left( \frac{u_{c,t+1} P_t^T}{P_{t+1}} + \Omega_{t+1} P_t^T \right) = \beta \frac{u_{c,t+1} p_t^T}{p_{t+1} P_t^T} \frac{1}{(1 + x_t)},
\]

(23)

where

\[
p_t^T = \frac{P_t^T}{M_t},
\]

\[
q_t = \frac{Q_t}{M_t}.
\]

Here, \(M_t\) is the aggregate stock of money at the beginning of period \(t\), which is assumed to evolve according to:

\[
\frac{M_{t+1}}{M_t} = 1 + x_t.
\]

(24)

Note that under our notational convention, all lower case prices except one, expresses that price in units of the traded good. The exception, \(p_t^T\), is the domestic currency price of traded goods, scaled by the beginning of period stock of money. Alternatively, \(p_t^T\) is the inverse of a measure of real balances.

The firm production functions are:

\[
y^T = \left( \theta |\mu_1 V |^{\frac{\mu_1}{\tau}} + (1 - \theta) |\mu_2 z |^{\frac{\mu_2}{\tau}} \right)^{\frac{\tau}{\mu_t}},
\]

(25)
\[
V = A (K^T)^\nu (L^T)^{1-\nu},
\]
\[
y^N = (K^N)^\alpha (L^N)^{1-\alpha}.
\]

13The intuition underlying (23) is straightforward. The object \(\Lambda_{t+1}\) in (23), is the marginal utility of one unit of dividends, denominated in traded goods, transferred by the firm to the household at the end of period \(t\). This corresponds to \(P_t^T \pi_t\) units of domestic currency. The households can use this currency in period \(t+1\) to purchase \(P_t^T \pi_t/P_{t+1}\) units of the consumption good. The value, in period \(t\), of these units of consumption goods is \(\beta u_{c,t+1} P_t^T \pi_t/P_{t+1}\), or \(\beta u_{c,t+1} P_t^T \pi_t/(p_{t+1} P_{t+1})\), where \(u_{c,t}\) is the marginal utility of consumption. This is the first expression in (23).
where $\xi$ is the elasticity of substitution between value-added in the traded good sector, $V_t$, and the imported intermediate good, $z_t$. In the production functions, $K^T$ and $K^N$ denote capital in the traded and non-traded good sectors, respectively. They are owned by the representative intermediate input firm. We keep the stock of capital fixed throughout the analysis. It does not depreciate and there exists no technology for making it bigger.

Total employment of the firm, $L_t$, is:

$$L_t = L^T_t + L^N_t.$$ 

We impose the following restriction on borrowing:

$$\frac{B_{t+1}}{(1 + r^*)^t} \to 0, \text{ as } t \to \infty. \tag{26}$$

We suppose that international financial markets impose that this limit cannot be positive. That it cannot be negative is an implication of firm optimality.

The firm’s problem at time $t$ is to maximize (21) by choice of $B_{t+j+1}$, $y^N_{t+j}$, $y^T_{t+j}$, $z_{t+j}$, $L^T_{t+j}$, $L^M_{t+j}$ and $L^N_{t+j}$, $j = 0, 1, 2, ...$ and the indicated technology. In addition, the firm takes all prices and rates of return as given and beyond its control. The firm also takes the initial stock of debt, $B_t$, as given. This completes the description of the firm problem in the pre-crisis version of the model, when collateral constraints are ignored.

The crisis brings on the imposition of the following collateral constraint:

$$\tau^N q^N_i K^N + \tau^T q^T_i K^T \geq R^* z_t + (1 + r^*)B_t + \zeta R_t (W^T_i L^T_i + W^N_i L^N_i) \tag{27}$$

Here, $q^i$, $i = N, T$ denote the value (in units of the traded good) of a unit of capital in the nontraded and traded good sectors, respectively. Also, $\tau^i$ denotes the fraction of these stocks accepted as collateral by international creditors. The left side of (27) is the total value of collateral, and the right side is the payout value of the firm’s external debt; $\zeta$ indicates the fraction of the wage bill that enters into the liabilities side of the collateral constraint, and represents the share of domestic loans that are collateralized and would compete with foreign creditors’ claims on the firm’s assets. Before the crisis, firms ignore (27), and assign
a zero probability that it will be implemented. With the coming of the crisis, firms believe that (27) must be satisfied in every period henceforth, and do not entertain the possibility that it will be removed.

We obtain $q_t^N$ and $q_t^T$ by differentiating the Lagrangian representation of the firm optimization problem with respect to $K^N$ and $K^T$, respectively. The equilibrium value of the asset prices, $q_t^i$, $i = N, T$, is the amount that a potential firm would be willing to pay in period $t$, in units of the traded good, to acquire a unit of capital and start production in period $t$. We let $\lambda_t \geq 0$ denote the multiplier on the collateral constraint ($= 0$ in the pre-crisis period) in firm problem. Then, $q_t^i$ solves

$$q_t^i = \frac{VMP_{k,t}^i + \beta \frac{\Lambda_{t+2}}{\Lambda_{t+1}} q_{t+1}^i}{1 - \lambda_t^i}, \quad i = N, T. \quad (28)$$

Here, $VMP_{k,t}^i$ denotes the period $t$ value (in terms of traded goods) marginal product of capital in sector $i$.

When $\lambda_t = 0$, (28) is just the standard asset pricing equation. It is the present discounted value of the value of the marginal physical product of capital. When the collateral constraint is binding, so that $\lambda_t$ is positive, then $q_t^i$ is greater than this. This reflects that in this case capital is not only useful in production, but also for relieving the collateral constraint. In our model capital is never actually traded since all firms are identical. However, if there were trade, then the price of capital would be $q_t^i$. If a firm were to default on its credit obligations, the notion is that foreign creditors could compel the sale of its physical assets in a domestic market for capital. The price, $q_t^i$, is how much traded goods a domestic resident is willing to pay for a unit of capital. Foreign creditors would receive those goods in the event of a default. We assume that with these consequences for default, default never occurs in equilibrium.

To understand the impact of a binding collateral constraint on firm decisions, it is useful to consider the Euler equations of the firm. Differentiating Lagrangian representation of the firm problem with respect to $B_{t+1}$:

$$1 = \beta \frac{\Lambda_{t+2}}{\Lambda_{t+1}} (1 + r^*) (1 + \lambda_{t+1}), \quad t = 0, 1, 2, \ldots . \quad (29)$$

Following standard practice in the small open economy literature, we assume $\beta (1 + r^*) = 1$, so that$^{14}$

$$\Lambda_{t+1} = \Lambda_{t+2} (1 + \lambda_{t+1}), \quad t = 0, 1, 2, \ldots . \quad (30)$$

$^{14}$See, for example, Obstfeld and Rogoff (1997).
A high value for $\lambda$, which occurs when the collateral constraint is binding, raises the effective rate of interest on debt. The interpretation is that when $\lambda$ is large, then the debt has an additional cost, beyond the direct interest cost. This cost reflects that when the firm raises $B_{t+1}$ in period $t$, it not only incurs an additional interest charge in period $t+1$, but it is also further tightens its collateral constraint in that period. This has a cost because, via the collateral constraint, the extra debt inhibits the firm’s ability to acquire working capital in period $t+1$. Thus, when $\lambda$ is high, there is an additional incentive for firms to reduce $\pi$ and ‘save’ by paying down the external debt. Although the firm’s actual interest rate on external debt taken on in period $t$ is $1 + r^*$, its ‘effective’ interest rate is $(1 + r^*) (1 + \lambda_{t+1})$.

4.2 Financial Intermediary and Monetary Authority

The financial intermediary takes domestic currency deposits, $D_t = M_t - Q_t$, from the household at the beginning of period $t$. In addition, it receives the liquidity transfer, $X_t = x_t M_t$, from the monetary authority.\textsuperscript{15} It then lends all its domestic funds to firms who use it to finance their employment working capital requirements, $WL$. Clearing in the money market requires $M_t = Q_t + X_t = W_t L_t$, or, after scaling by the aggregate money stock,

$$
d_t + x_t = p_t^T \left[ w_t^N L_t^N + w_t^T L_t^T \right],
$$

where $d_t = D_t / M_t$.

The monetary authority in our model simply injects funds into the financial intermediary. Its period $t$ decision is taken after the household has selected a value for $Q_t$, and before all other variables in the economy are determined. This is the standard assumption in the limited participation literature. It is interpreted as reflecting a sluggishness in the response of household portfolio decisions to changes in market variables. With this assumption, a value of $x_t$ that deviates from what households expected at the time $Q_t$ was set produces an immediate reaction by firms and the financial intermediary but not, in the first instance, by households. The name, ‘limited participation’, derives from this feature, namely that not all agents react immediately to (or, ‘participate in’) a monetary shock. As a result of this timing assumption, many models

\textsuperscript{15} In practice, injections of liquidity do not occur in the form of lump sum transfers, as they do here. It is easy to show that our formulation is equivalent to an alternative, in which the injection occurs as a result of an open market purchase of government bonds which are owned by the household, but held by the financial intermediary. We do not adopt this interpretation in our formal model in order to conserve on notation.
exhibit the following behavior in equilibrium. An unexpectedly high value of $x_t$ swells the supply of funds in the financial sector. To get firms to absorb the increase in funds, a fall in the equilibrium rate of interest is required. When that fall does occur, they borrow the increased funds and use them to hire more labor and produce more output.

We abstract from all other aspects of government finance. The only policy variable of the government is $x_t$.

### 4.3 Equilibrium

We consider a perfect foresight, sequence-of-market equilibrium concept. In particular, it is a sequence of prices and quantities having the properties: (i) for each date, the quantities solve the household and firm problems, given the prices, and (ii) the labor, goods and domestic money markets clear.

Clearing in the money market requires that (31) hold and that actual money balances, $M_t$, equal desired money balances, $\tilde{M}_t$. Combining this with the household's cash constraint, (17), we obtain the equilibrium cash constraint:

$$ p_t^T p_t c_t = 1 + x_t. \quad (32) $$

According to this, the total, end of period stock of money must equal the value of final output, $c_t$. Market clearing in the traded good sector requires:

$$ y_t^T - R^* z_t - r^* B_t - c_t^T = - (B_{t+1} - B_t). \quad (33) $$

The left side of this expression is the current account of the balance of payments, i.e., total production of traded goods, net of foreign interest payments, net of domestic consumption. The right side of (33) is the change in net foreign assets. Equation (33) reflects our assumption that external borrowing to finance the intermediate good, $z_t$, is fully paid back at the end of the period. That is, this borrowing resembles short-term trade credit. Note, however, that this is not a binding constraint on the firm, since our setup permits the firm to finance these repayments using long term debt. Market clearing in the nontraded good sector requires:

$$ y_t^N = c_t^N. \quad (34) $$
Our procedure for computing the equilibrium of the model is a generalization on the multiplier-based method used in section 3. It corresponds a variation on the procedure applied in CGR and the details are available from the authors on request.

5 Quantitative Analysis

In this section we begin with a discussion of the parameterization of the model. We then report the results for optimal monetary policy.

5.1 Parameter Values and Steady State

The parameter values are displayed in Table 3. These were chosen to so that the model's steady state in the absence of collateral constraints roughly matches features of Korean and Thai data during the first semester of 1997. The share of tradables in total production for Korea, assuming that tradables correspond to the non-service sectors, was approximately one third before the crisis. Combining this assumption with estimates of labor shares from A. Young (1995), we estimate shares of capital for the tradable and nontradable sector in Korea to be respectively 0.48 and 0.21. Based on figures for Argentina, Uribe (1995) and Rebelo and Vegh (1995) estimate the same shares to be 0.52 and 0.37. We take an intermediate point between these estimates by specifying $\nu = 0.50$ and $\alpha = 0.36$. Reinhart and Vegh (1995) estimate the elasticity of intertemporal substitution in consumption for Argentina to be equal to 0.2. We adopt a somewhat higher elasticity by setting $\sigma = 2$. We take the foreign interest rate to be equal to 6 percent and we assume a rate of money growth of 6 percent to obtain a nominal domestic interest rate of 12.3 percent, roughly in line with the experience of Korea and Thailand in the years before the crises. We set $\psi = 3$, implying a labor supply elasticity of 1/3. This is low by comparison to that used in standard business cycle models. Our choice of a low labor supply elasticity is conservative. We presume that a higher labor supply elasticity would have simply resulted in a smaller recession.

The parameters $\mu_1$ and $\mu_2$, in the production function were chosen to reproduce the ratio of imported intermediate inputs in manufacturing to manufacturing value-added in Korea for the year 1995. In that year the ratio is 0.4, in other words $z/V = 0.4$.

As mentioned above, the share of tradable goods in production is roughly one third, so we calibrate
the remaining parameters of the model to produce a ratio of consumption of nontradables to tradables of approximately 2. In addition, we chose $\tau$ and the stock of debt in the initial steady state equilibrium so that the initial and final debt to output ratio correspond roughly to the experience of Korea and Thailand. Korea’s (Thailand’s) external debt started at 33% of GDP by end-1997 (60.3%) and was around 26.8% of GDP (51% of GDP) and the end of the year 2000. The interest rate in the initial steady state is set to 11 percent, in annual terms. This is very close to the pre-crisis interest rates in Korea and Thailand. The pre-crisis steady state of the model is reported in Table 4.

5.2 Optimal Monetary Policy

We now consider the dynamic effects of the imposition of the collateral constraint—our reduced form, underlying source of the financial crisis—and the implementation of the optimal monetary policy in this context. The timing of the experiment can be seen in Figure 6. Up until period 0, the economy is in a nonstochastic steady state in which the collateral constraint is not binding. At the start of period 0, the household makes its employment decision in the traded sector. After this, the collateral constraint on borrowing is unexpectedly imposed. This constraint is binding. Then, the household makes its deposit decision. In making its deposit decision the household assumes money growth will continue at its previous constant rate. After this, the monetary action occurs. Finally, all activity occurs. The remainder of all time unfolds in a non-stochastic way. The collateral constraint remains in force for ever after.

The results are reported in Figure 7. A period in the model is taken to be 6 months. As a benchmark, we include actual (semi-annual) data for Korea. Note the sharp rise in the current account. Also, the drop in GDP, relative to its pre-crisis trend, is nearly 15 percent. The drop in employment is less, though it takes longer to recover. Interestingly, this represents a substantial drop in labor productivity. The drop in consumption is a little larger and more persistent than the drop in output. Share prices fall and then recover. The interest rate rises sharply (as noted in Figure 1), and then falls substantially below its pre-crisis level. The exchange rate initially depreciates by about 50 percent, although the depreciation is ultimately smaller. Finally, inflation jumps from about 5 percent initially to about 12 percent, before stabilizing at a lower level.
Now consider the response of the model under the optimal monetary policy. Note that the current account in the model increases, though not as much as in the Korean data. We suspect that the absence of investment in our model is part of the reason for this. With domestic investment there is an additional margin that can be used to cut back domestic absorption and increase the current account. We expect that in a version of our model with investment, agents would exploit this margin given the very high value of the multiplier on the collateral constraint. The drop in domestic output is of a similar order of magnitude as the drop in output in Korea, though somewhat smaller. In the case of employment, the model substantially overstates the drop. This is an interesting miss. In effect, the model cannot explain the substantial drop in labor productivity observed in the wake of the Korean financial crisis. The model matches the behavior of asset prices and the nominal exchange rate quite well. However, the model substantially overstates the nominal interest rate and the rate of inflation in the wake of the Korean crisis.

Overall, we believe that the model captures reasonably well the behavior of the Korean data during the currency crisis. Figure 8 helps to assess the optimal monetary policy by comparing it with a particular benchmark. In the benchmark, money growth is held fixed at its pre-shock level. Note that relative to this benchmark, the optimal monetary policy stimulates aggregate output, consumption, employment and imports. It does so by raising the nominal interest rate substantially.

The economic intuition underlying these results can be found in contemplating the collateral constraint. The rise of the interest rate in period 0 slows the exchange rate depreciation and this contributes to a smaller reduction in asset prices. This relative improvement on the asset side of the collateral constraint allows for a smaller drop in imports of intermediate inputs, and a smaller reduction in real GDP, employment and consumption. Once the initial increase in interest rates and exchange rate depreciation set in motion the external adjustment process, labor is reallocated to the traded sector. From that moment onwards, the optimal monetary policy consists of reducing interest rate to values very close to the arrival steady state level of 2%. It is worth noting that during this transition period, and in consonance with the evidence on the crises countries, interest rate cuts are associated with nominal (and real) exchange rate depreciations (Mussa, 2000).
6 Conclusions

In this paper we studied the optimal monetary policy response to a financial crisis of the kind experienced by the Asian economies in 1997-98. These crises, as many other emerging market crises, were characterized by a sudden reversals in capital inflows. Using a fairly general open economy model with collateral constraints, we found that the optimal monetary response to such crises involves and initial increase in interest rates, followed by a relatively sharp and rapid reduction in rates in the aftermath of the crisis. The optimal monetary policy does not avoid the recessionary effects of the sudden stop, but it attenuates the fall in asset prices, output and employment, and allows for better consumption smoothing opportunities.

The collateral constraint captures the balance sheet constraints discussed by policymakers as constraints on credit conditions and on the conduct of monetary policy. The optimal monetary policy in such crises, and its implications for other macro variables as predicted by the model, are similar to the evolution of actual variables in the cases of Korea and Thailand.
References


[27] Mussa, Michael, 2000, “Using Monetary Policy to Resist Exchange Rate Depreciation”, mimeo, IMF.


Table 1: Syndicated Loans to Emerging Markets  
(in billions of U.S. dollars)  
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Source: Capital Data, Loanware

Table 2: Intermediate Imports and Total Imports  
Panel A: Thailand  
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<tr>
<td>2001</td>
<td>61,847</td>
<td>22,978</td>
<td>37%</td>
</tr>
<tr>
<td>2002</td>
<td>64,317</td>
<td>24,461</td>
<td>38%</td>
</tr>
</tbody>
</table>

Panel B: Korea  
<table>
<thead>
<tr>
<th>Total</th>
<th>Intermediate</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>83,800</td>
<td>43,987</td>
<td>52%</td>
</tr>
<tr>
<td>102,348</td>
<td>50,158</td>
<td>49%</td>
</tr>
<tr>
<td>135,119</td>
<td>64,611</td>
<td>48%</td>
</tr>
<tr>
<td>150,339</td>
<td>68,556</td>
<td>46%</td>
</tr>
<tr>
<td>144,616</td>
<td>69,361</td>
<td>48%</td>
</tr>
<tr>
<td>93,282</td>
<td>45,593</td>
<td>49%</td>
</tr>
<tr>
<td>119,752</td>
<td>57,253</td>
<td>48%</td>
</tr>
<tr>
<td>160,481</td>
<td>78,975</td>
<td>49%</td>
</tr>
<tr>
<td>141,098</td>
<td>71,929</td>
<td>51%</td>
</tr>
<tr>
<td>152,126</td>
<td>73,891</td>
<td>49%</td>
</tr>
</tbody>
</table>
Panel C: Malaysia

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Intermediate</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>77,601</td>
<td>50,447</td>
<td>65%</td>
</tr>
<tr>
<td>1994</td>
<td>78,426</td>
<td>52,201</td>
<td>67%</td>
</tr>
<tr>
<td>1995</td>
<td>79,036</td>
<td>51,922</td>
<td>66%</td>
</tr>
<tr>
<td>1996</td>
<td>58,293</td>
<td>40,901</td>
<td>70%</td>
</tr>
<tr>
<td>1997</td>
<td>65,389</td>
<td>48,321</td>
<td>74%</td>
</tr>
<tr>
<td>1998</td>
<td>81,963</td>
<td>61,233</td>
<td>75%</td>
</tr>
<tr>
<td>2000</td>
<td>73,856</td>
<td>53,271</td>
<td>72%</td>
</tr>
<tr>
<td>2001</td>
<td>79,881</td>
<td>56,939</td>
<td>71%</td>
</tr>
</tbody>
</table>

Source: CEIC

Panel D: Indonesia

<table>
<thead>
<tr>
<th>Total</th>
<th>Intermediate</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>28,376</td>
<td>20,035</td>
<td>71%</td>
</tr>
<tr>
<td>32,222</td>
<td>23,146</td>
<td>72%</td>
</tr>
<tr>
<td>40,921</td>
<td>29,610</td>
<td>72%</td>
</tr>
<tr>
<td>44,240</td>
<td>30,470</td>
<td>69%</td>
</tr>
<tr>
<td>46,223</td>
<td>30,230</td>
<td>65%</td>
</tr>
<tr>
<td>31,942</td>
<td>19,612</td>
<td>61%</td>
</tr>
<tr>
<td>30,600</td>
<td>18,475</td>
<td>60%</td>
</tr>
<tr>
<td>40,367</td>
<td>26,073</td>
<td>65%</td>
</tr>
<tr>
<td>34,669</td>
<td>23,879</td>
<td>69%</td>
</tr>
<tr>
<td>24,118</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Panel E: Philippines

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Intermediate</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>17,597</td>
<td>7,855</td>
<td>45%</td>
</tr>
<tr>
<td>1994</td>
<td>21,333</td>
<td>9,559</td>
<td>45%</td>
</tr>
<tr>
<td>1995</td>
<td>26,538</td>
<td>12,174</td>
<td>46%</td>
</tr>
<tr>
<td>1996</td>
<td>32,427</td>
<td>14,015</td>
<td>43%</td>
</tr>
<tr>
<td>1997</td>
<td>35,933</td>
<td>14,663</td>
<td>41%</td>
</tr>
<tr>
<td>1998</td>
<td>29,660</td>
<td>11,586</td>
<td>39%</td>
</tr>
<tr>
<td>1999</td>
<td>30,726</td>
<td>12,596</td>
<td>41%</td>
</tr>
<tr>
<td>2000</td>
<td>34,491</td>
<td>16,747</td>
<td>49%</td>
</tr>
<tr>
<td>2001</td>
<td>33,058</td>
<td>15,121</td>
<td>46%</td>
</tr>
<tr>
<td>2002</td>
<td>35,427</td>
<td>14,791</td>
<td>42%</td>
</tr>
</tbody>
</table>

Source: CEIC
Table 3: Parameters Values of the Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.943</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.3</td>
</tr>
<tr>
<td>$\psi$</td>
<td>3.00</td>
</tr>
<tr>
<td>$R$</td>
<td>1.11</td>
</tr>
<tr>
<td>$R^*$</td>
<td>1.06</td>
</tr>
<tr>
<td>$r^*$</td>
<td>0.06</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.36</td>
</tr>
<tr>
<td>$\nu$</td>
<td>0.5</td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>1</td>
</tr>
<tr>
<td>$\mu_2$</td>
<td>3.5</td>
</tr>
<tr>
<td>$\tau$</td>
<td>0.08</td>
</tr>
<tr>
<td>$\psi_0$</td>
<td>0.0036</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>2</td>
</tr>
<tr>
<td>$A$</td>
<td>1.5</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.1</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Note: Here, $\beta$, $R$ and $R^*$ are expressed in annualized terms.

Table 4: Steady State Ignoring Collateral Constraint

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L$</td>
<td>30</td>
</tr>
<tr>
<td>$z$</td>
<td>2.67</td>
</tr>
<tr>
<td>$L^T$</td>
<td>7.75</td>
</tr>
<tr>
<td>$L^N$</td>
<td>22.25</td>
</tr>
<tr>
<td>$c^T$</td>
<td>6.17</td>
</tr>
<tr>
<td>$c^N$</td>
<td>16.68</td>
</tr>
<tr>
<td>$w$</td>
<td>0.3824</td>
</tr>
<tr>
<td>$V$</td>
<td>9.33</td>
</tr>
<tr>
<td>$\tilde{p}^N$</td>
<td>2.39</td>
</tr>
<tr>
<td>$p^T$</td>
<td>9.34</td>
</tr>
<tr>
<td>$\tilde{p}^N$</td>
<td>0.8861</td>
</tr>
<tr>
<td>$p^T$</td>
<td>0.0515</td>
</tr>
<tr>
<td>$q^T$</td>
<td>22.95</td>
</tr>
<tr>
<td>$q^N$</td>
<td>18.54</td>
</tr>
<tr>
<td>$B$</td>
<td>14.2</td>
</tr>
<tr>
<td>$\frac{B}{p^N c^N + y^T - R^* z}$</td>
<td>0.6644</td>
</tr>
</tbody>
</table>

Table 5: Arrival Steady State with Monetary Experiment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L$</td>
<td>30.69</td>
</tr>
<tr>
<td>$z$</td>
<td>2.703</td>
</tr>
<tr>
<td>$L^T$</td>
<td>7.911</td>
</tr>
<tr>
<td>$L^N$</td>
<td>22.78</td>
</tr>
<tr>
<td>$c^T$</td>
<td>6.264</td>
</tr>
<tr>
<td>$c^N$</td>
<td>16.94</td>
</tr>
<tr>
<td>$w$</td>
<td>0.4088</td>
</tr>
<tr>
<td>$V$</td>
<td>9.4341</td>
</tr>
<tr>
<td>$\tilde{p}^N$</td>
<td>2.3912</td>
</tr>
<tr>
<td>$y^T$</td>
<td>9.44</td>
</tr>
<tr>
<td>$\tilde{p}^N$</td>
<td>0.8844</td>
</tr>
<tr>
<td>$p^T$</td>
<td>0.047</td>
</tr>
<tr>
<td>$q^T$</td>
<td>23.19</td>
</tr>
<tr>
<td>$q^N$</td>
<td>18.78</td>
</tr>
<tr>
<td>$B$</td>
<td>13.37</td>
</tr>
<tr>
<td>$\frac{B}{p^N c^N + y^T - R^* z}$</td>
<td>0.618</td>
</tr>
</tbody>
</table>
Intermediate Goods Import vs. GDP
(Index 1995 = 100)

Sources: CEIC; and WEO.

Figure 2
Figure 4: Labor Market Equilibrium

Labor Demand \((p^N, \tau)\)

Labor supply
Figure 5: Equilibrium Associated With Various Tax Rates
Figure 6: Timing

- Collateral Shock
- Monetary Action

0

Household Decides Employment in Traded Sector

Household Deposit Decision

1

Production, Consumption Occur

2
Figure 8: Optimal and Constant Money Growth

- Current Account
- Real GDP
- Employment
- Consumption
- Imports
- Asset Prices
- Nominal Interest Rate
- Nominal Exchange Rate (Price of Traded)
- Inflation

Legend:
- Blue: Optimal Money Growth
- Green: Constant Money Growth