

Optimal Monetary Policy in a ‘Sudden Stop’

Fabio Braggion ^{*} Lawrence J. Christiano[†] Jorge Roldos[‡]

June 8, 2005[§]

Abstract

During the Asian financial crises, interest rates were raised immediately, and then reduced sharply. We describe an environment in which this is the optimal monetary policy.

^{*}Northwestern University and Tilburg University.

[†]Northwestern University, and NBER.

[‡]International Monetary Fund.

[§]Braggion thanks the European Central Bank-Research Department for its hospitality. Christiano is grateful for the financial support of a National Science Foundation grant to the National Bureau of Economic Research. The authors are grateful for the advice and comments of Klaus Adam, Narayana Kocherlakota, Andrew Scott, Jaume Ventura and Michael Woodford. The results reported in this paper do not necessarily reflect the opinion of the International Monetary Fund.

1. Introduction

The Asian financial crises of 1997-98 triggered a sharp debate over the appropriate response of policy to a financial crisis. The hallmark of the crises was a “sudden stop” (Calvo, 1998): capital inflows turned into outflows and output suddenly collapsed. Some argued, appealing to the traditional monetary transmission mechanism, that a cut in the interest rate was required to slow or reverse the drop in output. Others argued that because of currency mismatches in balance sheets, the exchange rate depreciation associated with a cut in interest rates might exacerbate the crisis. They argued for an increase in interest rates. 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 might 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.

In our model, because of the presence of real frictions, resources are slow to respond in the immediate aftermath of a shock. Over time, resource allocation becomes more flexible.¹ We characterize a financial crisis as a shock in which collateral constraints unexpectedly bind and are expected to remain in place permanently. Our model has the property that when there is a binding collateral constraint and real frictions hinder resource allocation, then the monetary transmission mechanism is the reverse of what it would otherwise be. In particular, a rise in the interest rate increases economic activity and utility. Over time, as the real frictions wear off, the monetary transmission mechanism corresponds to the traditional one in which low interest rates stimulate output and raise welfare.

We now briefly explain the real and financial frictions in the model, and describe how they shape optimal policy after a financial shock. We adopt a small, tradable/non-tradable goods open economy model. The real friction is that labor in the tradeable sector is chosen prior to the realization of the current period shock.² Thus, when the financial shock occurs, the allocation of labor to the tradeable sector cannot respond in the current period, although it can respond in subsequent periods.

We adopt two forms of financial friction.³ First, to capture the non-neutrality of money our

¹In effect, we combine into one model, the two studied in Christiano, Gust and Roldos (2004). In one model of that paper, labor in the traded good sector was fixed in each period. In another model, labor was completely flexible.

²A 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.

³Other studies have examined the relationship between optimal interest rates and financial crises. Aghion,

model incorporates the portfolio allocation friction in the limited participation model.⁴ In the absence of collateral constraints, our model reproduces the traditional monetary transmission mechanism: when the domestic monetary authority expands the money supply, the liquidity of the banking system increases and interest rates fall, leading to an expansion in output and a depreciation of the exchange rate. Second, our model assumes firms make use of labor and a foreign intermediate input, and that these must be financed in advance. The collateral constraint that is imposed during the crisis applies to these loans.⁵

The surprising feature of optimal policy in our model is that the nominal interest rate rises sharply in the period of the collateral shock. That this is optimal is a consequence of the interaction of the financial and real frictions. When the interest rate is increased, this acts like a tax on the employment of labor in the nontraded good sector, and raises the marginal cost of production in that sector. Because the employment of labor by firms in the traded sector is predetermined in the period of the shock, the interest rate rise does not increase the marginal cost of production in that sector. With the marginal cost of non-traded goods rising relative to the marginal cost of traded goods, the relative price of nontraded goods goes up. Other things the same, this increases the traded-good value of the physical capital stock in the non-traded sector. Because this capital is used as collateral in the import of intermediate goods, the collateral constraint is relaxed. This permits expanding imports of intermediate goods and the production of tradeable goods. Because tradeable and non-tradeable goods are complements in domestic production, this leads to an expansion in the demand for non-tradables and an expansion in overall economic activity. Welfare is increased by this policy, even though it has the effect of introducing a distortionary wedge in the labor market. The reason welfare increases is that the policy has the effect of sharply reducing another wedge, one that is associated with the collateral constraint.

The mechanism by which the higher interest rate produces higher output is novel, and so

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.

⁴For closed economy analyses of this model, see Lucas 1990, Fuerst 1992, Christiano 1991, Christiano and Eichenbaum, 1992, 1995. For open economy applications, see Schlagenhauf and Wrase and Grilli-Roubini (?)

⁵For other papers that study the role of credit constraints in the context of the Asian crisis, see Krugman (1999), Aghion, Bacchetta and Banerjee (2000), Caballero and Krishnamurthy (2000, 2002), Cespedes, Chang and Velasco (2000), Mendoza and Smith (2002), and the references therein.

to further highlight its workings, we construct and analyze a simple example.⁶ The example represents a dramatic simplification of our dynamic model. There is no money, and there is only one period. In the example, a tax rate on labor plays the role of the interest rate in our dynamic, monetary model. We are able to prove that whenever the collateral constraint is binding and the equilibrium is unique, a rise in the labor tax rate must stimulate output, consumption, employment and welfare. This result may be of interest beyond the sudden stop episodes that we study here. In particular, it may be useful for shedding light on the empirical literature on the “non-Keynesian effects of fiscal policy” or “Expansionary Fiscal Consolidations”. For example, Giavazzi, Jappelli and Pagano (1998) identify 65 episodes of large and persistent fiscal contractions in a sample of OECD countries. During these two-year episodes – when the fiscal contraction is on average dominated by an increase in taxes - aggregate output growth is on average greater during than before the contraction. Perotti (1999) presents some evidence that large tax increases are more likely to stimulate the economy when levels of debt are high. Based on this, he argues that a model is required in which the response of the economy to tax changes changes depends on the initial conditions, such as the level of debt. Our model is very much in this spirit.

We now briefly discuss the interaction of monetary policy and sudden stop in our model. The sudden stop is triggered by a tightening of collateral constraints. The effect of the collateral shock is to increase the shadow cost of foreign borrowing, since international debt limits - via the collateral constraint - the ability of firms to purchase foreign intermediate inputs. As a result, imports of intermediate inputs drop and, because they are crucial for domestic production, the latter falls. In addition, the sharp rise in the shadow cost of debt induces agents to pay down that debt by running a current account surplus. This process continues until the debt falls to the point where the collateral constraint is marginally non-binding, and now the economy is in a new steady state. Monetary policy has no impact on the presence of the collateral constraint,

⁶There exist other examples in the literature of how financial frictions may have the consequence that a high interest rate is desirable. For example, Kocherlakota (2002, 2003) shows that a high interest rate may be part of a socially efficient mechanism to help individuals smooth consumption intertemporally, in the face of binding borrowing constraints. In private communication, Kocherlakota has provided us with a very simple example that illustrates the point. Consider a two period economy, in which 1/2 the population (‘borrowers’) has a sequence of endowments, y^L in the first period and y^H in the second period, where $y^L < y^H$. Suppose the other half of the population (‘lenders’) has the opposite lifetime sequence of endowments, y^H, y^L . Suppose everyone has the same utility function, $u(c_1) + u(c_2)$, where u is strictly concave and c_1 and c_2 are periods 1 and 2 consumption, respectively. Suppose also that borrowing is not permitted. Then the unique equilibrium is that everyone consumes their endowment. The borrowers are forced to do so by the non-negativity constraint on private bonds, and the lenders are prevented from lending by a very low interest rate, $R = u'(y^H)/u'(y^L)$. An optimal policy is for the government to issue bonds in the first period, and redistribute the proceeds to everyone (suppose the government cannot see who is constrained and who is not) in lump sum form. In the second period, the government taxes everyone in order to pay back the bonds. This policy in effect allows borrowers and lenders to exchange amongst themselves. A side effect of this policy is that the interest rate is lower. Although this example has some of the flavor of our analysis (optimal policy under binding financial constraints is associated with a high interest rate), in its details it is very different.

nor does it have an important impact on real variables in the new steady state. Monetary policy affects real variables and welfare primarily by its impact on the nature of the transition from the old to the new steady state. As discussed above, optimal monetary policy initially raises the domestic interest rate sharply and cuts it thereafter. That optimal policy cuts the interest rate eventually is no surprise. Eventually, the collateral constraint ceases to bind and resources are allocated flexibly. At this point, a Friedman deflation is optimal. As discussed above, in the period of the shock it is optimal to sharply raise the interest rate. This has the effect of resisting (not reversing) the fall in output, employment, consumption, and real and nominal exchange rates.

We compare the dynamic behavior of the variables in the model with data drawn from the Asian crisis economies. Qualitatively, the model reproduces the behavior of data for these economies reasonably well. In particular, the model reproduces the observed transitory rise in the current account, and fall of real quantities such as employment, consumption and output. The model also captures the evolution of asset prices, the real and nominal exchange rate and the behavior of the interest rate. Taken together, this evidence suggests that our model may provide a useful interpretation of the apparently erratic behavior of monetary policy exhibited in Figure 1.

The model does have quantitative empirical shortcomings. Although it captures the direction of movement in the current account, it understates the magnitude. We suspect that this reflects the absence of physical investment in the model. A reduction in investment provides agents with another margin from which to draw resources that can be used to pay off the international debt. The presence of investment may also help the model with persistence, which is another dimension on which there is some weakness. Finally, although the inflation response of the model to the financial shock matches qualitatively, it misses on magnitude.

The paper is organized as follows. First, we provide empirical evidence to support the main assumptions of the model. In particular, we show that collateral constraints were increased during the Asian financial crisis. We also show that imported intermediate inputs are a large fraction of imports, and that they fell sharply during the crisis. Second, we present the simplified example discussed above. The third section presents our dynamic, monetary model. Section 4 discusses model calibration and section 5 present our simulation results. Section 6 concludes.

2. Collateral Constraints, Intermediate Inputs and Exchange Rates

We first show that the use of collateral in emerging markets is widespread, and that collateralization increased in the wake of financial crises. Table 1 reports evidence on syndicated loans to emerging markets. Up until 1996, approximately 20 percent of these loans were secured by collateral. At the onset of the financial crises of 1997, this fraction doubled to over 40 percent.

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 1999) notes that lending against collateral was a widespread practice also in these countries. Finally, 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.

In our reduced form crisis model, the tightening of the collateral constraint forces a cutback in imports, and this is the proximate cause of the fall in output. In the model, the fall in imports produces a fall in output because imports constitute crucial intermediate inputs. For evidence that intermediate goods are an important component of imports, see Table 2. According to Table 2, intermediate good imports are 50 percent of total imports for Korea and 70 percent of total imports for Indonesia and Malaysia. Figure 2 shows real GDP and intermediate good imports and shows the close correlation between the two.

In our model, the cutback in imports leads to a fall in the production of tradable goods. Output in the economy falls because of limited substitutability between these goods and non-traded goods in the production of final goods. This limited substitutability implies that the price of non-traded goods, relative to that of traded goods should fall sharply. For evidence on this, consider the data on exchange rates in Figure 3. Note that in each of the Asian crisis countries considered there is a dramatic depreciation in the aftermath of the crisis. The smallest depreciation is 143 percent (Philippines) and the largest is 169 percent (Korea). Given the relatively small movements in inflation in these countries, these movements in the nominal exchange correspond closely to the movement in the real exchange rate.

3. Example

A basic result in the dynamic simulations reported in later sections is that a rise in the domestic interest rate in the period of a collateral shock places upward pressure on employment and welfare. At first glance, this result will seem puzzling since the rise in the interest rate effectively raises the tax rate on labor. Partial equilibrium reasoning suggests such a distortion should lead to a decrease in employment and welfare, not an increase. In our model, these partial equilibrium effects are overwhelmed by a general equilibrium effect that relaxes the collateral constraint. In this section we present a simplified version of our dynamic model, which allows us to show how these effects work. In the simplified example, there is no money and there is only one period.

The first subsection below displays the model. The second subsection derives the model's qualitative properties. Here, we state our proposition and provide a heuristic proof (details are provided in Appendix B). The third subsection provides a numerical example.

3.1. Model

A final good sector produces a non-traded consumption good, c , for domestic households, whose utility is as follows:

$$u(c, L) = c - \frac{\psi_0}{1 + \psi} L^{1+\psi}, \quad (3.1)$$

where L denotes is labor. The household's budget constraint is:

$$pc \leq wL + \pi + T, \quad (3.2)$$

where p is the price of consumption, w is the wage rate, π denotes lump-sum profits and T denotes a lump-sum transfer payment from the government. All the quantities in (3.2) are measured in units of the traded good.

The consumption good is produced using intermediate goods, of which there are two types. One is a tradeable good and the other is non-traded. Each of these intermediate goods is essential in the production of the final good. The final good is produced using a Leontieff production function in terms of traded and intermediate goods:

$$c = \min \{ (1 - \gamma)c^T, \gamma c^N \}. \quad (3.3)$$

This is the same production function that we use in the dynamic model economy.

The one period in our example model is the analog of period 0 in our dynamic model. In that model, the economy is in a steady state before period 0, and then in period 0 a collateral constraint suddenly and unexpectedly becomes binding. Since employment in the traded good sector is chosen by firms at the beginning of the period, in period 0 employment is predetermined at the time of the collateral shock. In the example, we capture the predeterminedness of employment by the assumption that labor is not used in the traded good sector at all. The only input in the production of traded goods is an imported intermediate good, z . This good must be financed at the beginning of the period by foreign borrowing, which is subject to a collateral constraint. The imported intermediate good, z , is essential to the overall economy, because of the Leontieff assumption, (3.3). The production function in our traded good sector is the same as in our dynamic economy. That function is a Cobb-Douglas function of capital and labor, and does not involve the use of imported intermediate inputs. The capital in the non-traded sector is the only object in our model economy that can be used to satisfy the collateral constraint. The production functions in the traded and non-traded good sectors are:

$$y^T = Az^\theta, \quad y^N = K^\alpha L^{1-\alpha}, \quad (3.4)$$

respectively. In (3.4), y^T and y^N denote output in the traded and non-traded sectors, respectively. Also, $A > 0$, $\alpha, \theta \in (0, 1)$ are constants and K is the stock of capital used in the non-traded sector.

Production of traded and non-traded intermediate goods is carried out by a single, representative, competitive firm. This assumption allows us to sidestep a potential complication, arising from the fact that the available collateral - the capital in the non-traded sector - is not located in the place where the collateral is needed for borrowing - in the traded good sector. By locating all production in a single firm, we ensure that all the economy's collateral is held in the hands of the agents who need it for borrowing.⁷ To some extent our assumption about firms resembles actual firms in some emerging economies. For example, the Chaebols are an important part of the Korean economy, and they span the tradable and nontradable sectors. Presumably, the assets of a given Chaebol, including capital and land in the non-traded sector, can be used as collateral in all international borrowing by that Chaebol. If there were a mismatch in the allocation of collateral and borrowing needs, there would be a substantial incentive for firms to diversify into different production activities. In effect, our model assumes that diversification has already occurred. An alternative interpretation of our assumption about firms is that it is a stand-in for the existence of financial institutions that efficiently distribute collateral among domestic agents.

As indicated in the previous paragraph, the representative intermediate good firm operates the two technologies, (3.4), and seeks to maximize profits, which we denote by π :

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

Here, p^N denotes the price of non-traded goods, q denotes the price of physical capital and τ denotes the labor tax rate. 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. It is convenient express the firm's profits in non-traded goods units:

$$\frac{\pi}{p^N} = y^N + \frac{1}{p^N} [y^T - R^*z] - \frac{q}{p^N}(K - K_0) - \frac{w}{p^N}(1 + \tau)L. \quad (3.5)$$

Foreign creditors impose a borrowing constraint which stipulates that a fraction, τ^N , of the value of capital, qK , must be no less than the firm's end-of-period international obligations:

$$\tau^N qK \geq R^*z. \quad (3.6)$$

In the dynamic model, there is also capital in the traded good sector and this can also be used as collateral against international borrowing. We leave that out here, because the capital in the non-traded good sector plays a special role in our result that a high interest rate (here captured by the high tax rate) can stimulate the economy in the period of a collateral shock.

The timing of the intermediate good firm's decisions are as follows. First, the tax rate, τ , becomes known. Then, a market opens in which intermediate good firm trades capital among

⁷For an analysis of situations in which collateral is not equally distributed in the economy, see Caballero and Krishnamurthy (1999).

themselves at the price, q . Then z , L , c , y^N and y^T are determined and production occurs. Immediately after paying its wage bill, 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. It is easy to verify that the firm's revenues, after paying the wage bill, are sufficient for this.⁸

The resource constraints in our economy are as follows:

$$y^N = c^N, \quad y^T = c^T + zR^*.$$

The first of these expressions states that all the output of the non-traded good sector, y^N , is used as inputs in the production of non-traded goods. The second says that the gross output of the traded good sector is divided between inputs into the production of final goods, c^T , and gross interest payments abroad for borrowing to finance the imported intermediate good, z .

3.2. Qualitative Analysis

We list the seven equations that characterize seven equilibrium variables - w , p , p^N , q , L , z and the Lagrange multiplier on (3.6) - for our example. Consider the representative final good producer. As long as input prices are strictly positive, the final good producer always sets $c^T = [\gamma/(1 - \gamma)]y^N$. Combining (3.4) and xx(??)xx, this implies:

$$Az^\theta - R^*z = \frac{\gamma}{1 - \gamma}K^\alpha L^{1-\alpha}. \quad (3.7)$$

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 (3.7), or purchasing more. In such a case, we suppose that the producer resolves the indifference by imposing (3.7). Competition in final goods implies that price equals marginal cost:

$$p = \frac{1}{1 - \gamma} + \frac{1}{\gamma}p^N, \quad (3.8)$$

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

$$q = \frac{\alpha p^N K^{\alpha-1} L^{1-\alpha}}{1 - \lambda \tau^N}. \quad (3.9)$$

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 (3.6). The labor demand choice by the intermediate good firm leads it to equate the marginal cost,

⁸Implicitly, 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.

$(1 + \tau)w$, and value marginal product of labor in the production of non-traded goods to obtain (after making use of (3.8)),

$$\frac{1 - \alpha}{\left(\frac{1}{1-\gamma} \frac{1}{p^N} + \frac{1}{\gamma}\right) (1 + \tau)} K^\alpha L^{-\alpha} = \frac{w}{p}. \quad (3.10)$$

Optimization in the choice of z leads to the following first order condition:

$$\frac{1}{p^N} [\theta A z^{\theta-1} - R^*(1 + \lambda)] = 0. \quad (3.11)$$

Evidently, for $p^N < \infty$, (3.11) 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 (3.11) does not require the numerator to be zero. Finally, the complementary slackness condition on λ for intermediate good firm optimization is:

$$\lambda [\tau^N q K - R^* z] = 0, \quad \lambda \geq 0, \quad \tau^N q K - R^* z \geq 0. \quad (3.12)$$

Market clearing requires that prices be strictly positive:

$$q, p^N > 0. \quad (3.13)$$

The latter, in combination with (3.9) impose an upper bound on λ , $\lambda \leq 1/\tau^N$.

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

$$\psi_o L^\psi = \frac{w}{p}. \quad (3.14)$$

The seven equations that characterize equilibrium are (3.7)-(3.12), (3.14), together with the non-negativity constraints, (3.13).

In Appendix B, we establish the following proposition:

Proposition 3.1. *If there is a unique equilibrium in which the collateral constraint binds, then an increase in τ leads to an increase in p^N , q , z , L and welfare.*

This proposition establishes that the real exchange rate, asset prices, intermediate good imports, employment and welfare rise quite generally in our model. This is so, if the equilibrium is unique and the collateral constraint binds in equilibrium. There do exist parameter configurations for which there are multiple equilibria in our model. However, we do not discuss the impact of increases in τ in these cases, since such experiments are hard to interpret when the equilibrium is not unique.⁹ In the following section, we work through a numerical example which illustrates our proposition.

⁹The appendix contains some discussion of the nature of the equilibria when there is more than one.

The intuition for the proposition was provided in the introduction. The proof is straightforward. For a given value of the multiplier, λ , we are able to compute the remaining equilibrium variables in the model uniquely. We denote the values of q and z computed in this way by $q(\lambda; \tau)$ and $z(\lambda)$, respectively. (The variable, τ , is not included in the argument of $z(\cdot)$ because the equilibrium value of z is not a function of τ .) With this notation, we define the following function:

$$f(\lambda; \tau) \equiv \tau^N q(\lambda; \tau) K - R^* z(\lambda).$$

Suppose there is a unique equilibrium, and that equilibrium has the property that the collateral constraint is binding. We denote the value of λ in this equilibrium by $\lambda(\tau)$. This value of λ is the unique one having the property, $f(\lambda(\tau); \tau) = 0$. A key step in the proof is to show that in the neighborhood of $\lambda = \lambda(\tau)$, $f(\lambda; \tau)$ is increasing in λ . This is shown by establishing that for λ near its upper bound of $1/\tau^N$, $q(\lambda; \tau) \rightarrow \infty$. The economic motivation for this result is simple. The benefit of a marginal unit of capital is its collateral value, $\lambda q \tau^N$, plus its marginal value product in production. When $\lambda q \tau^N = q$, then the collateral value of capital equals its purchase price, and capital is a ‘money-pump’: a \$1 purchase of capital generates \$1 in value as collateral plus the value marginal product of capital in production. In this case, the demand for capital is infinite, and so its market clearing price is infinite. Since z is finite as $\lambda \rightarrow 1/\tau^N$, it follows that $f(\lambda; \tau) \rightarrow \infty$ as $\lambda \rightarrow 1/\tau^N$. By continuity of f , it follows that $f(\lambda; \tau) > 0$ for all $\lambda \in (\lambda^*, 1/\tau^N)$, where $\lambda(\tau) < \lambda^* < 1/\tau^N$. Given continuity it then follows that f must be increasing in λ at $\lambda = \lambda(\tau)$. Suppose, to the contrary, that f had a negative slope at $\lambda(\tau)$. In this case f would have to cross zero for some point, $\lambda(\tau) < \lambda \leq \lambda^*$, contradicting the hypothesis that equilibrium is unique. The rest of the proof follows from the observation that $q(\lambda; \tau)$ is increasing in τ for fixed λ , while $z(\lambda)$ is not a function of τ . We deduce from this observation that $f(\lambda; \tau)$ shifts up with τ . From this (see Figure 4), it follows that the intersection of f with the zero line falls with an increase in τ . That is, $\lambda(\tau)$ falls with an increase τ . The equilibrium values of z , L and c also rise, as can be verified easily from (3.11), (3.7), (3.3) and (3.4). It is also easy to establish that equilibrium utility rises. Details appear in Appendix B.

3.3. Quantitative Analysis

We illustrate the proposition in the previous subsection with a numerical example. We report the equilibrium outcomes for our model economy for a range of values of the labor tax rate. We adopt 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 τ in the range, 0.01 to 1.00. The admissible set of equilibrium values of λ belongs to the compact set, $J = [0, 1/\tau^N]$. By considering

a fine grid of $\lambda \in J$, we found that, for each value of τ considered, the equilibrium is unique. The values of utility, $1/p^N$, q , λ , z , L corresponding to each τ are displayed in Figure 5. Note that for τ in the range of 0 to 0.4, $\dot{\lambda} > 0$. Consistent with the proposition, utility is strictly increasing in this range. The increase in τ also raises p^N , L , z and q . The latter has the effect of relaxing the collateral constraint, which is reflected in the fall in λ . Note that the initial value of λ is extremely high. According to (3.11), λ is equivalent to a tax on the purchase of the foreign intermediate input. When $\tau = 0$ this tax wedge is about 175%. By increasing the labor tax rate, the shadow tax rate on foreign borrowing is completely eliminated.

For τ in the range $0.4 < \tau < 0.72$, utility and employment are invariant to additional increases in τ . 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 (3.11), determines L through (3.7). Eventually, with additional increases in τ , it is employment that becomes the binding constraint in production. At this point, additional increases τ 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 (3.11) and (??), some of this c^T goes unused. On the margin, c^T is literally free and this is reflected in $p^N = \infty$.¹⁰ With additional increases in τ beyond this point, L falls and utility declines.

4. The Dynamic, Monetary Model

This section describes our dynamic, monetary model. The model builds on the structure analyzed in the previous section, and so we limit explanations and motivations to what is new here. In addition, the model is a version of the one in Christiano, Gust and Roldos (2004), and so the presentation is brief. A key difference between the two models is that here, labor in the traded good sector cannot be quickly adjusted in response to a shock.

4.1. Households

Household preferences over consumption and leisure are the dynamic version of the preferences in the previous section:

$$\sum_{t=0}^{\infty} \beta^t u(c_t, L_t), \quad (4.1)$$

where the subscript t denotes the time t realization of the variable. We adopt the following specification of utility:

$$u(c, L) = \frac{\left[c - \frac{\psi_0}{1+\psi} L^{1+\psi} \right]^{1-\sigma}}{1-\sigma}. \quad (4.2)$$

¹⁰Technically, in the range where L is constant, κ in (7.1) in the Appendix is constant. As long as $\kappa/(1+\tau) > 1$, p^N is finite, but $p^N = \infty$ when increases in τ result in $\kappa = 1 + \tau$.

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

$$P_t c_t \leq W_t L_t + \tilde{M}_t - D_t, \quad (4.2)$$

where W_t denotes the wage rate and P_t denotes the price level. These nominal quantities are expressed in domestic currency units.

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

$$\tilde{M}_{t+1} = R_t(D_t + X_t) + P_t^T \pi_t + \left[W_t L_t + \tilde{M}_t - D_t - P_t c_t \right]. \quad (4.3)$$

Here, R_t denotes the gross domestic nominal rate of interest, π_t is profits which derive from household's ownership of firms, and X_t is a liquidity injection from the monetary authority. Profits, π_t , is measured in units of traded goods, and P_t^T is the domestic currency price of traded goods. The term immediately to 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 (4.1) subject to (4.2)-(4.3), and a particular timing constraint. The household's deposit decision is made after the realization of the collateral shock, and before the realization of the current period monetary action. As in the limited participation literature, the fact that the household makes the deposit decision before the monetary policy action is taken, is the reason monetary policy has a non-neutral effect. At the time the household makes its deposit decision, it must have a view about what the relevant price and interest rate variables are. We assume that the household expects the monetary authority to respond to the collateral shock by holding money growth constant, and that the household expects prices and interest rates to be what they would be in a constant money growth equilibrium.¹¹ All other household decisions are taken after the monetary policy action is known. Since the model is deterministic in the periods after the collateral shock, timing is irrelevant then.

4.2. Firms

The basic structure of the firm sector is the same as in the previous section, with some difference. A competitive final good firm produces the consumption good, c_t , and intermediate good firms produce the inputs used to produce c_t . We now discuss the decisions facing these firms.

¹¹Computationally, we determine the household's deposit decision by simulating the economy's response to the collateral shock, when money growth is kept fixed. When compute the optimal sequence of interest rates, we do so subject to the restriction that the household's deposit decision is what it is in the constant money growth simulation.

4.2.1. Final Good Firms

As in the previous section, the production function of the final good firms is given by:

$$c = \min \{ (1 - \gamma) c^T, \gamma c^N \}, \quad (4.4)$$

where c^T and c^N denote quantities of tradeable and non-tradeable intermediate inputs, respectively. As noted above, the domestic currency 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.

As before, zero profits and efficiency imply the following relation between prices:

$$p = \frac{1}{1 - \gamma} + \frac{p^N}{\gamma}, \quad p = \frac{P}{P^T}. \quad (4.5)$$

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.

4.2.2. Intermediate Inputs

As in the previous section, 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:

$$\max \sum_{t=0}^{\infty} \beta^t \Lambda_{t+1} \pi_t, \quad (4.6)$$

where

$$\pi_t = p_t^N y_t^N + y_t^T - w_t^N R_t L_t^N - w_t^T R_t L_t^T - R^* z_t - r^* B_t + (B_{t+1} - B_t), \quad (4.7)$$

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, Λ_{t+1} , is taken parametrically by firms. In equilibrium, it is the

multiplier on π_t in the (Lagrangian representation of the) household problem:¹²

$$\begin{aligned}\Lambda_{t+1} &= \beta \frac{u_{c,t+1} P_t^T}{P_{t+1}} = \\ &= \beta \frac{u_{c,t+1} P_t^T}{p_{t+1} P_{t+1}^T} \frac{1}{(1+x_t)}\end{aligned}\quad (4.8)$$

where

$$p_t^T = \frac{P_t^T}{M_t}.$$

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

$$\frac{M_{t+1}}{M_t} = 1 + x_t. \quad (4.9)$$

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:

$$\begin{aligned}y^T &= \left\{ \theta [\mu_1 V]^{\frac{\xi-1}{\xi}} + (1-\theta) [\mu_2 z]^{\frac{\xi-1}{\xi}} \right\}^{\frac{\xi}{\xi-1}}, \\ V &= A (K^T)^\nu (L^T)^{1-\nu}, \\ y^N &= (K^N)^\alpha (L^N)^{1-\alpha},\end{aligned}\quad (4.10)$$

where ξ 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:

$$L_t = L_t^T + L_t^N.$$

We impose the following restriction on borrowing:

$$\frac{B_{t+1}}{(1+r^*)^t} \rightarrow 0, \text{ as } t \rightarrow \infty. \quad (4.11)$$

¹²The intuition underlying (4.8) is straightforward. The object Λ_{t+1} in (4.8), 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 $\beta u_{c,t+1} P_t^T \pi_t / (p_{t+1} P_{t+1}^T)$, where $u_{c,t}$ is the marginal utility of consumption. This is the first expression in (4.8).

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 (4.6) by choice of B_{t+j+1} , y_{t+j}^N , y_{t+j}^T , z_{t+j} , L_{t+j}^T , L_{t+j}^M and L_{t+j}^N , $j = 0, 1, 2, \dots$ 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:

$$\tau^N q_t^N K^N + \tau^T q_t^T K^T \geq R^* z_t + (1 + r^*) B_t + \zeta R_t (w_t^T L_t^T + w_t^N L_t^N) \quad (4.12)$$

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, τ^i denotes the fraction of these stocks accepted as collateral by international creditors. The left side of (4.12) is the total value of collateral, and the right side is the payout value of the firm's external debt; ζ 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 (4.12), and assign a zero probability that it will be implemented. With the coming of the crisis, firms believe (correctly) that (4.12) 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

$$q_t^i = \frac{VMP_{k,t}^i + \beta \frac{\Lambda_{t+2}}{\Lambda_{t+1}} q_{t+1}^i}{1 - \lambda_t \tau^i}, \quad i = N, T. \quad (4.13)$$

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

When $\lambda_t \equiv 0$, (4.13) 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 λ_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} :

$$1 = \beta \frac{\Lambda_{t+2}}{\Lambda_{t+1}} (1 + r^*) (1 + \lambda_{t+1}), \quad t = 0, 1, 2, \dots \quad (4.14)$$

Following standard practice in the small open economy literature, we assume $\beta(1 + r^*) = 1$, so that¹³

$$\Lambda_{t+1} = \Lambda_{t+2} (1 + \lambda_{t+1}), \quad t = 0, 1, 2, \dots \quad (4.15)$$

A high value for λ , which occurs when the collateral constraint is binding, raises the effective rate of interest on debt. The interpretation is that when λ 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 λ is high, there is an additional incentive for firms to reduce π 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 $(1 + r^*) (1 + \lambda_{t+1})$.

4.3. Financial Intermediary and Monetary Authority

The financial intermediary takes domestic currency deposits, D_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.¹⁴ 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 $D_t + X_t = W_t L_t$, or, after scaling by the aggregate money stock,

$$d_t + x_t = p_t^T [w_t^N L_t^N + w_t^T L_t^T], \quad (4.16)$$

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 D_t , and before all

¹³See, for example, Obstfeld and Rogoff (1997).

¹⁴In 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.

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 D_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 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 .

4.4. Equilibrium

We consider a perfect foresight, sequence-of-markets 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 (4.16) hold and that actual money balances, M_t , equal desired money balances, \tilde{M}_t . Combining this with the household’s cash constraint, (4.2), we obtain the equilibrium cash constraint:

$$p_t^T p_t c_t = 1 + x_t. \quad (4.17)$$

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:

$$y_t^T - R^* z_t - r^* B_t - c_t^T = -(B_{t+1} - B_t). \quad (4.18)$$

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 (4.18) is the change in net foreign assets. Equation (4.18) 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:

$$y_t^N = c_t^N. \quad (4.19)$$

Our procedure for computing the equilibrium of the model is a generalization on the multiplier-based method used in the Appendix. It corresponds a variation on the procedure applied in Christiano, Gust and Roldos (2004) 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 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 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 that implies an annual nominal domestic interest rate of 11 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 μ_1 and μ_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 τ 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 optimal monetary policy response to the unexpected imposition of the collateral constraint. 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 firm makes its employment decision in the traded good 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 drops in domestic output and consumption are of a similar order of magnitude to corresponding drops in Korea, but substantially less persistent. In the case of employment, the model substantially overstates the initial 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. Conclusion

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 reversal in capital inflows. Using a particular open economy model with collateral constraints, we found that the optimal monetary response to such a crisis involves an initial increase in interest rates, followed by a relatively sharp and rapid reduction in rates in the aftermath of the crisis. Interestingly, this is the policy that was actually followed.

In our model, increasing the interest rate is very much like raising a tax. As a result, our analysis may yield insight into the episodes of “expansionary fiscal consolidations” emphasized by a large literature initiated by Giavazzi and Pagano (1990).

To keep the analysis simple, our model does not include variable investment. In principle, including investment could improve the model’s empirical implications. However, whether it does so remains an important, open question. Because capital appears in the collateral constraint, investment in physical capital represents an alternative strategy - apart from paying off international debt - by which agents can reduce the burden of the collateral constraint. In effect, the imposition of the collateral constraint is equivalent to a subsidy to paying off international debt, as well as to investing in domestic capital.¹⁵ Thus, without additional assumptions, we

¹⁵For a formal statement of this, see Chari, Kehoe and McGrattan (2005).

cannot rule out the possibility that in an environment in which investment is variable, a binding collateral constraint could lead to an increase in investment, and to a *fall* in the current account. Clearly, this would deal a blow to the idea that tightening collateral constraints were the driving force behind the Asian financial crises. We suspect, however, that with reasonable investment adjustment costs and other frictions, paying off the international debt would dominate investment in physical capital as a strategy for reducing the burden of the collateral constraint. If so, then the introduction of variable investment would improve our model's empirical implications, by magnifying the rise in the current account in the wake of a financial crisis.

At a methodological level, this paper adds to the literature that studies the impact of financial frictions on the monetary transmission mechanism. In traditional models, financial frictions have the effect of magnifying - through an 'accelerator effect' - the effects of monetary actions, without changing their sign. In this model we have shown that financial frictions could actually have a 'reverse accelerator effect', in that they reverse the sign of the effect of a monetary action.

References

- [1] Aghion, Philippe, Philippe Bacchetta, Abhijit Banerjee, 2000, "Currency Crises and Monetary Policy in an Economy with Credit Constraints", mimeo.
- [2] Auernheimer, Leonardo and Roberto Garcia-Saltos, 1999, "International Debt and the Price of Domestic Assets", mimeo.
- [3] Black, Jane, David de Meza and David Jeffreys, 1996, "House Prices, the Supply of Collateral and the Enterprise Economy", *The Economic Journal*, 106: 60-75..
- [4] Burnside, Craig, Martin Eichenbaum and Sergio Rebelo, 1999, "Hedging and Financial Fragility in Fixed Exchange Rate Systems", NBER Working Paper No. 7143.
- [5] Caballero, Ricardo and Arvind Krishnamurty, 1999, "Emerging Markets Crises: An Asset Markets Perspective", mimeo.
- [6] Calvo, Guillermo, 1998, "Capital Flows and Capital Market Crises", mimeo, University of Maryland.
- [7] Cespedes, Luis, Roberto Chang and Andres Velasco, 2000, "Balance Sheets and Exchange Rate Policy", mimeo.
- [8] Chari, V.V., Patrick Kehoe and Ellen McGrattan, 2005, 'Sudden Stops and Output Drops,' manuscript.
- [9] Christiano, Lawrence J. and Martin Eichenbaum, "Liquidity Effects and The Monetary Transmission Mechanism", *American Economic Review*, 82: 346-53.
- [10] Christiano, Lawrence J. and Martin Eichenbaum, "Liquidity Effects, Monetary Policy and the Business Cycle", *Journal of Money, Credit and Banking*, 27: 1113-1136.
- [11] Christiano, Lawrence J., Christopher Gust and Jorge Roldos, 2004, "Monetary Policy in a Financial Crisis", *Journal of Economic Theory*, Volume 119, Issue 1, Pages 1-245, November.
- [12] Corsetti, G., C. Pesenti and N. Roubini, 1998, "What Caused the Asian Currency and Financial Crisis? Part I: A Macroeconomic Overview", NBER Working Paper No. 6833.
- [13] Dooley, Michael, 2000, "A Model of Crises in Emerging Markets", *The Economic Journal*, 110: 256-272.

- [14] Edison, Hali, Pongsak Luangaram and Marcus Miller, 2000, “Asset Bubbles, Leverage and “Lifeboats”: Elements of the East Asian Crisis”, *The Economic Journal*, 110: 245-255.
- [15] Fuerst, Timothy, 1992, “Liquidity, Loanable Funds, and Real Activity”, *Journal of Monetary Economics*, 29: 3-24.
- [16] Gelos, Gaston and Alejandro Werner, 1999, “Financial Liberalization, Credit Constraints and Collateral: Investment in the Mexican Manufacturing Sector”, IMF Working Paper No.99/25.
- [17] Giavazzi, Francesco, and Marco Pagano, 1990, “Can Severe Fiscal Adjustments Be Expansionary?” in *NBER Macroeconomics Annual 1990*, Olivier Blanchard and Stanley Fischer, eds., (Cambridge, MA: MIT Press, 1990).
- [18] Giavazzi, Francesco, Tullio Jappelli, and Marco Pagano, 1998, ‘Searching for Non-Keynesian Effects of Fiscal Policy,’ manuscript, September.
- [19] Kiyotaki, Nobuhiro, and John Moore, 1997, “Credit Cycles” *Journal of Political Economy*, 105: 211-248.
- [20] Kocherlakota, Narayana, 2002, ‘Money: What’s the Question and Why Should we Care About the Answer?’, *American Economic Review, Papers and Proceedings* 92, 2, pp. 58-61
- [21] Kocherlakota, Narayana, 2003, ‘Societal Benefits of Illiquid Bonds,’ *Journal of Economic Theory*, 108, pp. 179-193.
- [22] Krugman, Paul, 1999, “Balance Sheets, the Transfer Problem, and Financial Crises”, in P.Isard, A. Razin and A.Rose, eds., *International Finance and Financial Crises: Essays in Honor of Robert P. Flood, Jr.*, Kluwer Academic Publishers.
- [23] Krugman, Paul, 1999, *The Return of Depression Economics*, WW Norton & Company, New York.
- [24] Lucas, Robert E., 1990, “Liquidity and Interest Rates”, *Journal of Economic Theory*, 50:273-264.
- [25] Mendoza, Enrique, 2001, “The Benefits of Dollarization when Stabilization Policy Lacks Credibility and Financial Markets are Imperfect”, *Journal of Money, Credit and Banking*.
- [26] Mussa, Michael, 2000, “Using Monetary Policy to Resist Exchange Rate Depreciation”, mimeo, IMF.

- [27] Obstfeld, Maurice, and Kenneth Rogoff, 1997, *Foundations of International Macroeconomics*, MIT Press.
- [28] Perotti, Roberto, 1999, "Fiscal Policy in Good Times and Bad," *The Quarterly Journal of Economics*, November.
- [29] Rebelo, Sergio and Carlos Vegh, 1995, "Real Effects of Exchange-rate-based Stabilization: An Analysis of Competing Theories", *NBER Macroeconomics Annual*, 125-187.
- [30] Uribe, Martin, 1997, "Exchange-rate-based Inflation Stabilization: The Initial Real Effects of Credible Plans", *Journal of Monetary Economics*, 39: 197-221.
- [31] Young, Alwyn, 1995, "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience", *Quarterly Journal of Economics*, 110(3): 641-680.

Table 1: Syndicated Loans to Emerging Markets
(in billions of U.S. dollars)

Year	Total	Secured	Secured as % of Total
1993	47.5	7.9	16.5
1994	64.9	11.5	17.7
1995	93.0	16.1	17.3
1996	104.3	22.0	21.1
1997	143.7	61.4	42.7
1998	77.3	25.9	33.5
1999	73.1	26.3	35.9

Source: Capital Data, Loanware

Table 2: Intermediate Imports and Total Imports

Panel A: **Thailand**

Year	Total	Intermediate	% of Total
1993	45,995	17,184	37%
1994	54,338	19,294	36%
1995	70,718	25,061	35%
1996	72,248	24,874	34%
1997	63,286	21,860	35%
1998	42,403	14,744	35%
1999	49,919	18,205	36%
2000	62,181	23,663	38%
2001	61,847	22,978	37%
2002	64,317	24,461	38%

Panel B: **Korea**

Total	Intemediate	% of Total
83,800	43,987	52%
102,348	50,158	49%
135,119	64,611	48%
150,339	68,556	46%
144,616	69,361	48%
93,282	45,593	49%
119,752	57,253	48%
160,481	78,975	49%
141,098	71,929	51%
152,126	73,891	49%

Panel C: **Malaysia**

Year	Total	Intermediate	% of Total
1993			
1994			
1995	77,601	50,447	65%
1996	78,426	52,201	67%
1997	79,036	51,922	66%
1998	58,293	40,901	70%
1999	65,389	48,321	74%
2000	81,963	61,233	75%
2001	73,856	53,271	72%
2002	79,881	56,939	71%

Panel D: **Indonesia**

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

Panel E: **Philippines**

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

Source: CEIC

Table 3: Parameters Values of the Model

β	0.943	γ	0.27
ψ	3.00	R	1.11
R^*	1.06	r^*	0.06
α	0.36	K^N	10
ν	0.7	K^T	5
μ_1	1	μ_2	3.5
τ	0.08	θ	0.5
ψ_0	0.0036	σ	2
A	1.5	ξ	0.1
		ζ	0.6

Note : Here, β , R and R^* are expressed in annualized terms.

Table 4: Steady State Ignoring Collateral Constraint

L	30	z	2.67
L^T	7.75	L^N	22.25
c^T	6.17	c^N	16.68
w	0.3824	V	9.33
$\frac{p^N c^N}{c^T}$	2.39	y^T	9.34
p^N	0.8861	p^T	0.0515
q^T	22.95	q^N	18.54
B	14.2	$\frac{B}{p^N c^N + y^T - R^* z}$	0.6644

Table 5: Arrival Steady State with Monetary Experiment

L	30.69	z	2.703
L^T	7.911	L^N	22.78
c^T	6.264	c^N	16.94
w	0.4088	V	9.4341
$\frac{p^N c^N}{c^T}$	2.3912	y^T	9.44
p^N	0.8844	p^T	0.047
q^T	23.19	q^N	18.78
B	13.37	$\frac{B}{p^N c^N + y^T - R^* z}$	0.618

7. Appendix A: Strategy for Solving Model in Section 3

For purposes of numerical analysis of the example in section 3, it is convenient to substitute out the real wage rate by combining (3.10) and (3.14), to obtain:

$$\frac{1}{p^N} = \frac{1 - \gamma}{\gamma} \left[\frac{\kappa}{1 + \tau} - 1 \right], \quad \kappa \equiv \frac{\gamma(1 - \alpha)K^\alpha}{\psi_o L^{\psi + \alpha}}. \quad (7.1)$$

In (7.1), κ is of interest because a planner for whom c^T is free would set L so that $\kappa = 1$. We now have five variables, p^N , q , L , z , λ , whose equilibrium values can be determined by the five equations, (3.7), (3.9), (3.11), (3.12), (7.1), as well as the nonnegativity constraints, (3.13).

We find it convenient to divide the collateral constraint, (3.12), by q , so that the complementary slackness condition becomes

$$\lambda \left[\tau^N K - \frac{R^* z}{q} \right] = 0, \quad \lambda \geq 0, \quad \tau^N K - \frac{R^* z}{q} \geq 0. \quad (7.2)$$

These equations suggest a simple strategy for computing an equilibrium. We define a mapping from the space of admissible equilibrium multipliers, $J = [0, 1/\tau^N]$, to candidate equilibrium outcomes that satisfy our five equilibrium conditions, excluding (3.12). We then adjust $\lambda \in J$ until (3.12) is satisfied. When this is so, the candidate equilibrium outcomes constitute an actual equilibrium. The mapping from $\lambda \in J$ 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 (3.11). After this, compute the value of L that satisfies (3.7) and evaluate κ in (7.1). If $\kappa > (1 + \tau)$, then use (7.1) to compute p^N (note that the finiteness assumption on p^N is verified). In this case q can be computed from (3.9). Finally, compute $\tau^N q K - R^* z$, so that (3.12) 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 (larger) value computed above. Solve for the smaller of the two values of z which satisfy (3.7) with the given L (it can be verified that there must be two solutions because the object on the left of the equality in (3.7) forms an inverted ‘U’ shape when graphed as a function of z and because (3.7) was satisfied for the previous, larger, value of L). According to (3.9), $q = \infty$ and therefore $\tau^N q K - R^* z = \infty$ also.

8. Appendix B: Proof of Proposition 1

Following is a proof of the proposition in section 3.2. The proof is accomplished by manipulating the five equilibrium conditions, (3.7), (3.9), (3.11), (3.12) and (7.1). In addition, we impose $\lambda > 0$ and $p^N < \infty$ to capture our assumption that the collateral constraint binds in the equilibrium of the model. The object in square brackets in (3.12) can be viewed as being a function of λ , for each fixed τ . Denote this function by $f(\lambda; \tau)$. The first step in the proof establishes that at

the equilibrium value of λ , which we denote by $\lambda(\tau)$, $f(\lambda; \tau)$ is an increasing function of λ . The second step establishes that $f(\lambda; \tau)$ is increasing in τ for fixed λ , so that $\lambda(\tau)$ is increasing in τ . The third step establishes the result.

The function, f , is constructed as follows. The variable, z , is a function of λ by equation (3.11). Denote this function by $z(\lambda)$. The variable, L , is a decreasing function of λ , $L(\lambda)$, by combining (3.11) and (3.7). The variable, p^N , is a function of λ for each τ , $p^N(\lambda; \tau)$, by (7.1). It is easy to verify that $z(\lambda)$, $L(\lambda)$, $p^N(\lambda; \tau)$, converge to well defined limits as $\lambda \rightarrow 1/\tau^N$. We construct the function $q(\lambda; \tau)$ using the functions, $z(\lambda)$, $L(\lambda)$, $p^N(\lambda; \tau)$, and (3.9). The given properties of $z(\lambda)$, $L(\lambda)$, $p^N(\lambda; \tau)$ imply that $q(\lambda; \tau) \rightarrow \infty$ as $\lambda \rightarrow 1/\tau^N$. Finally,

$$f(\lambda; \tau) \equiv \tau^N q(\lambda; \tau) K - R^* z(\lambda).$$

We conclude that $f(\lambda; \tau) > 0$ for λ sufficiently large. In an equilibrium with $\lambda > 0$,

$$f(\lambda(\tau); \tau) = 0.$$

By the fact that f is continuous and by our assumption that the equilibrium is unique, it follows that $f(\lambda; \tau)$ cuts the zero line from below at $\lambda(\tau)$, as in Figure 4. The second step in the proof follows from the fact that $p^N(\lambda; \tau)$ is increasing in λ for each τ . This implies that $f(\lambda; \tau)$ shifts up with an increase in τ , for each fixed λ . Thus, (see Figure 4), $\lambda(\tau)$ is decreasing in τ . We now turn to the third step in the proof. We established above that $z(\lambda)$ is decreasing in λ , so that $z(\tau) \equiv z(\lambda(\tau))$ is increasing in τ . The fact that $L(\lambda)$ is decreasing in λ , implies that $L(\tau) \equiv L(\lambda(\tau))$ is increasing in τ . The rise in τ and resulting rise in L drives up p^N according to (7.1). By the collateral constraint, the rise in z must be associated with a rise in q after the rise in τ . Finally, consider utility. From (3.1):

$$c - \frac{\psi_0}{1 + \psi} L^{1+\psi} = \gamma K^\alpha L^{1-\alpha} - \frac{\psi_0}{1 + \psi} L^{1+\psi},$$

using (3.3) and (3.4). Differentiating this function, it is easy to verify that it is strictly increasing in L up to the point,

$$L = \left(\frac{(1 - \alpha) \gamma K^\alpha}{\psi_0} \right)^{\frac{1}{\psi + \alpha}}.$$

Thus, for values of $\kappa \geq 1$ in (7.1), utility is strictly increasing in L . But, the fact that $p^N < \infty$ implies $\kappa > 1 + \tau$. The result for utility follows. Q.E.D.

It is straightforward to see what happens when the collateral function, $f(\lambda; \tau)$, crosses the zero line twice in Figure 4, in which case there are two equilibria. When τ is increased there exists an equilibrium in the neighborhood of the high λ equilibrium, which satisfies our proposition. However, there exists an equilibrium in the neighborhood of the low λ equilibrium, in which the results of the proposition are reversed. These observations about comparative statistics when there are multiple equilibria but no credible equilibrium selection mechanism is available are of little practical interest.

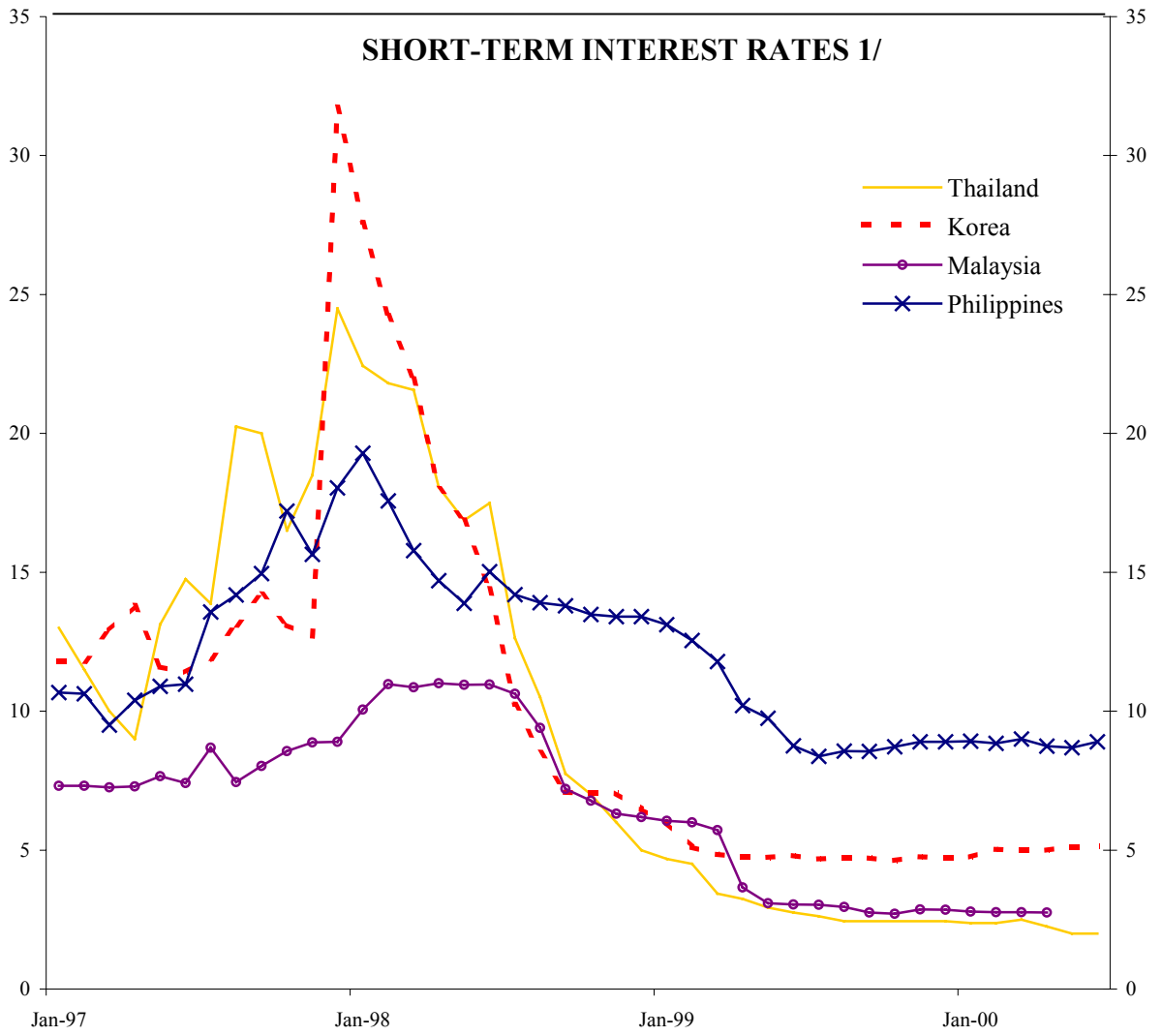
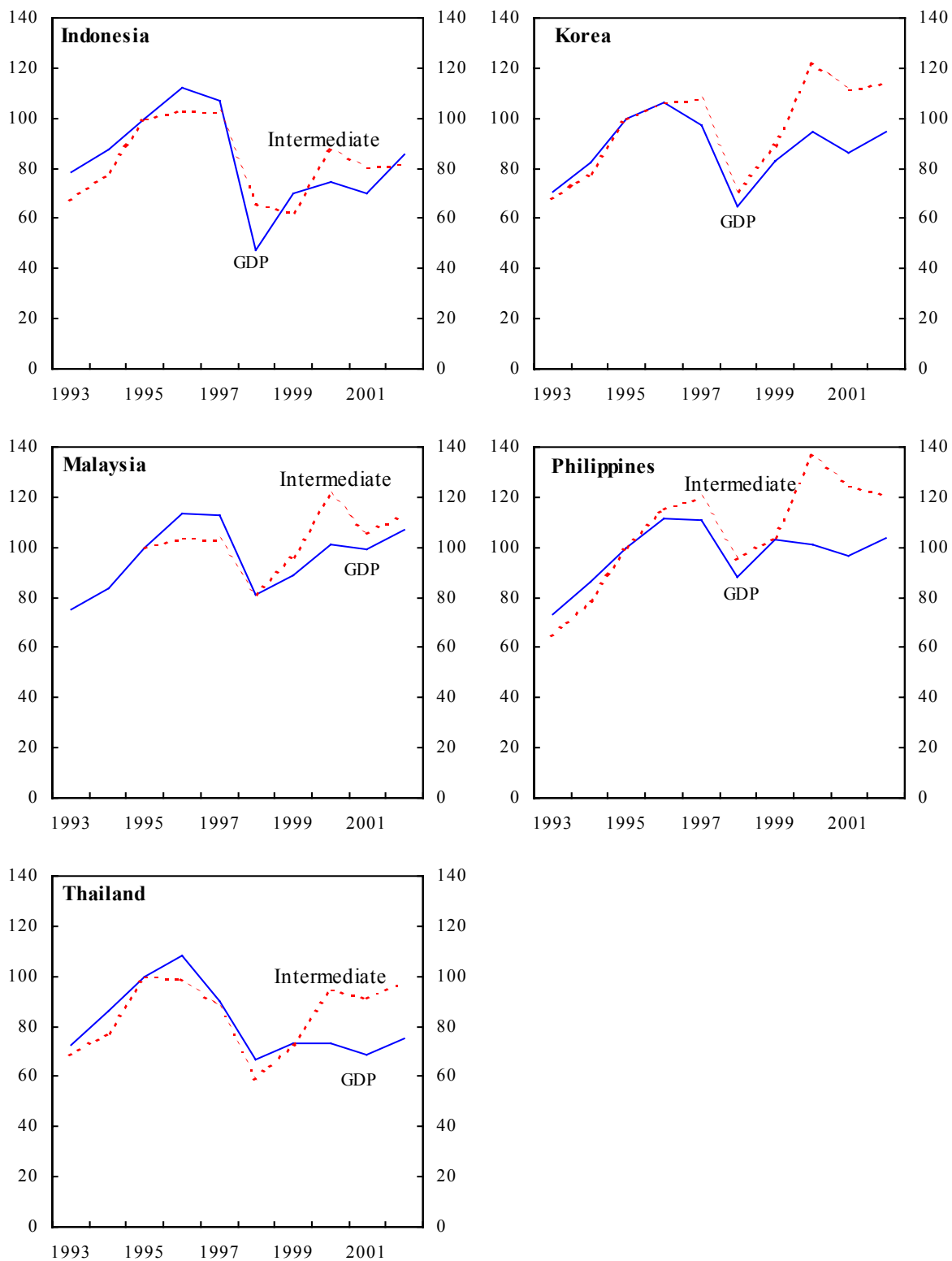


Figure 1

Intermediate Goods Import vs. GDP (Index 1995 = 100)



Sources: CEIC; and WEO.

Figure 2

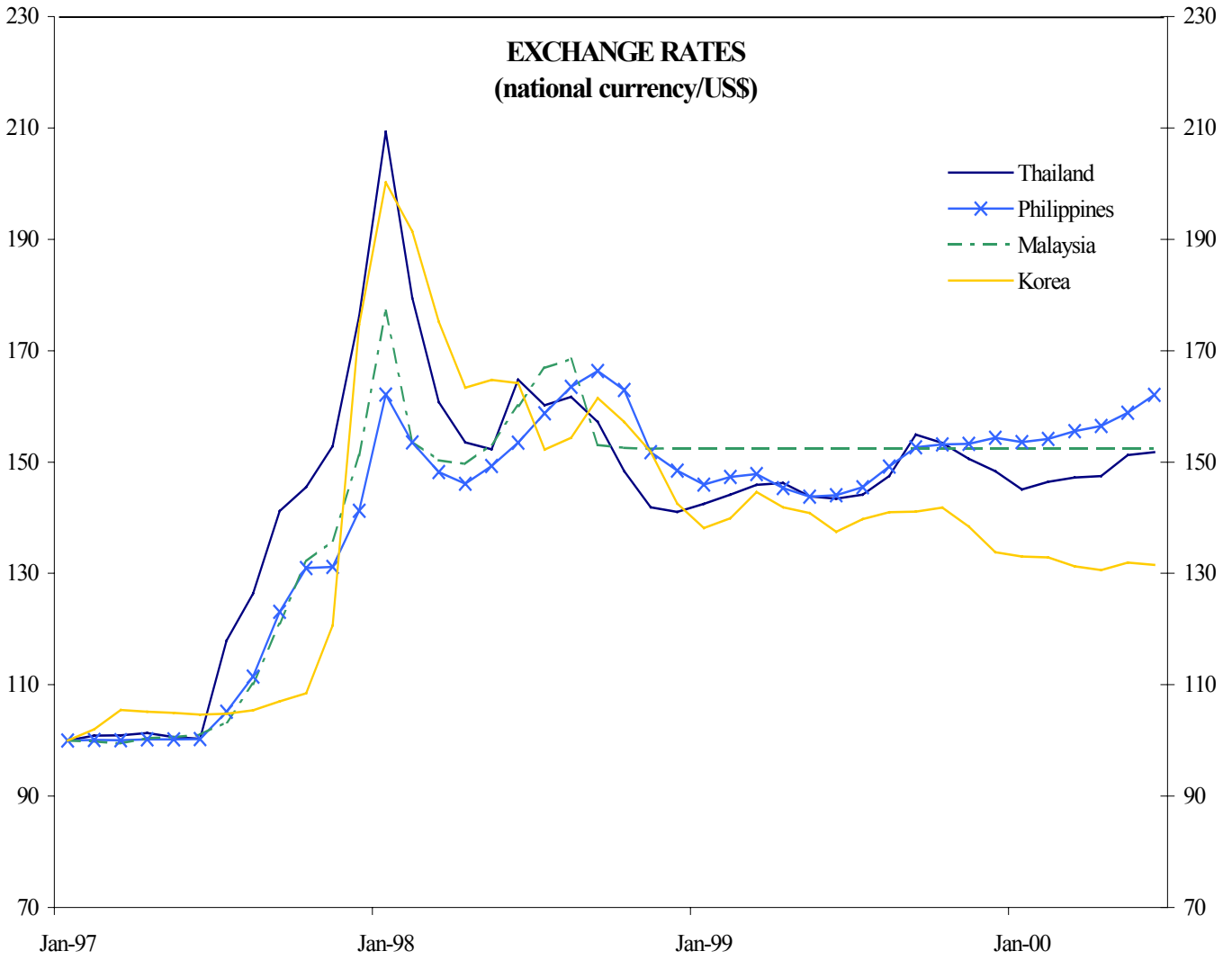


Figure 3

Figure 4: Labor Market Equilibrium

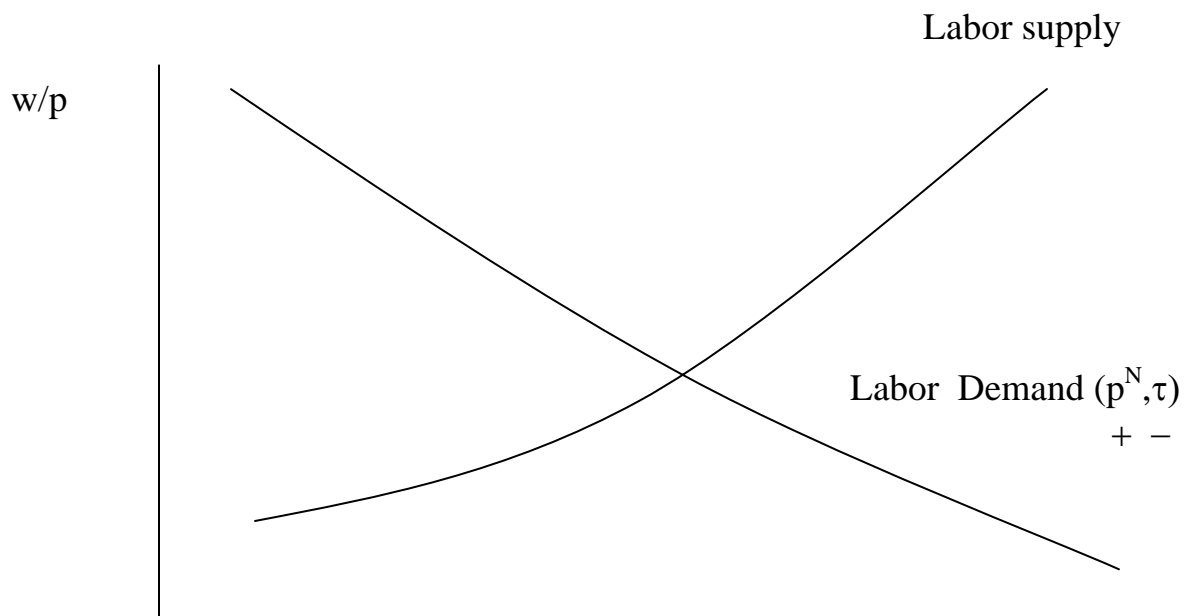


Figure 5: Equilibrium Associated With Various Tax Rates

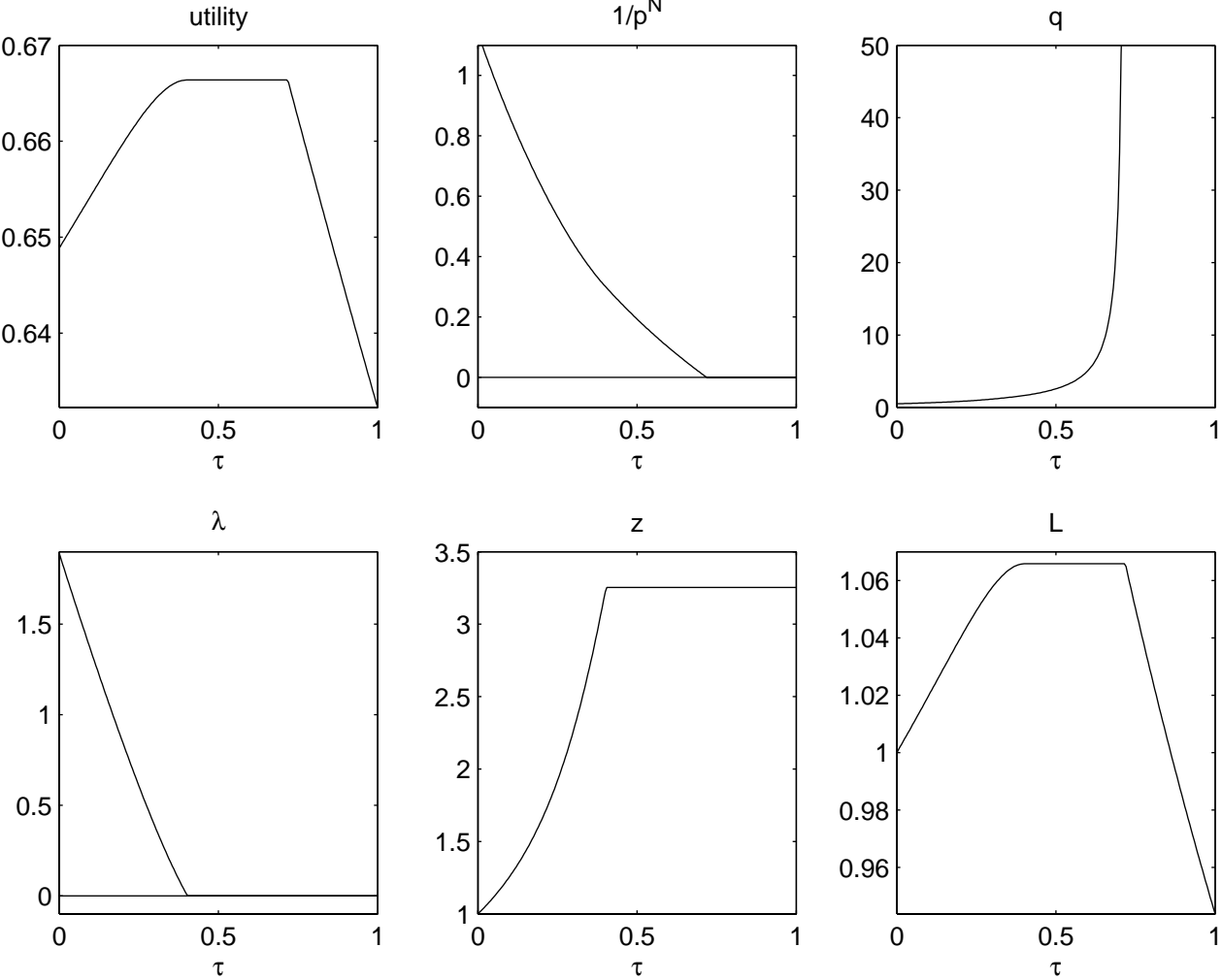


Figure 6: Timing

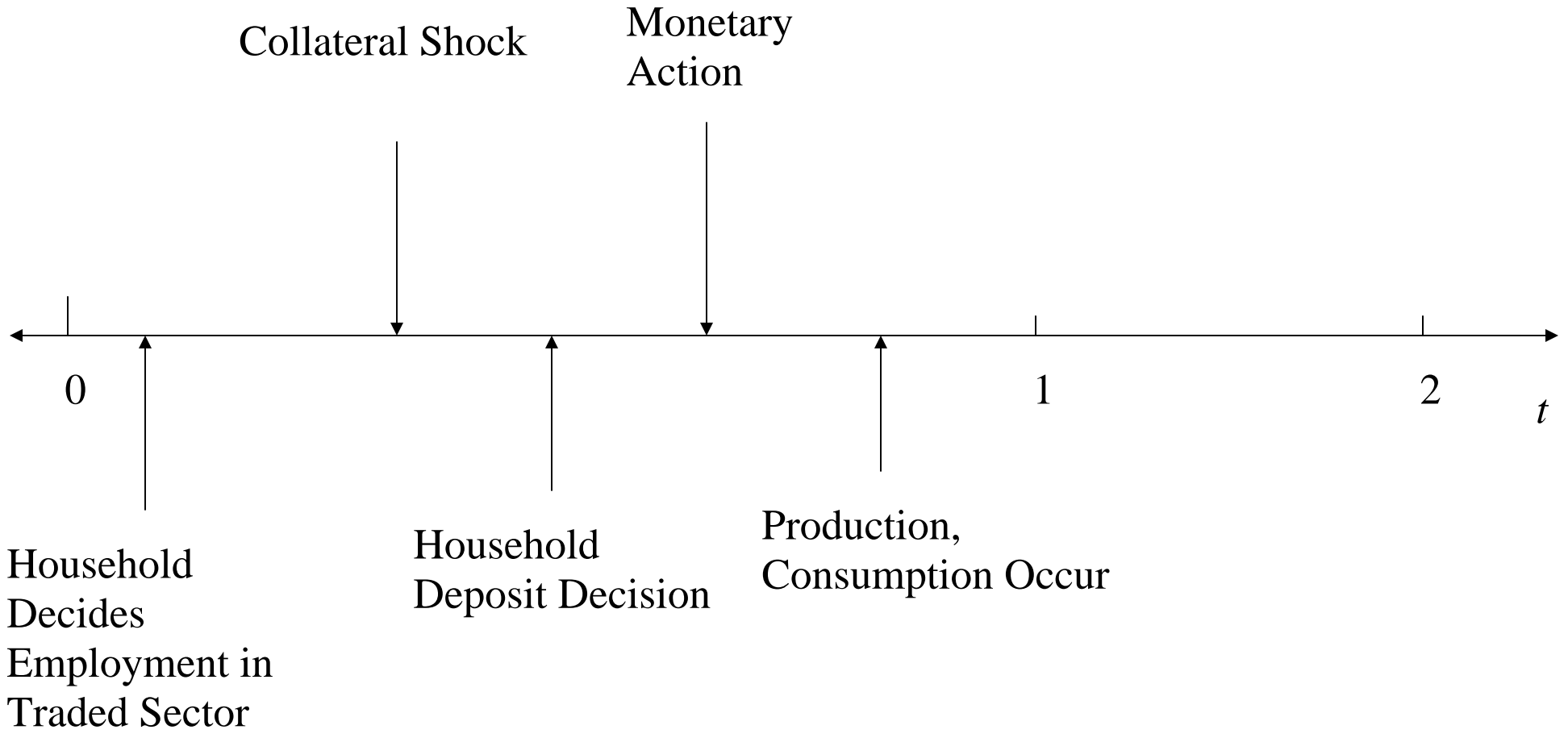
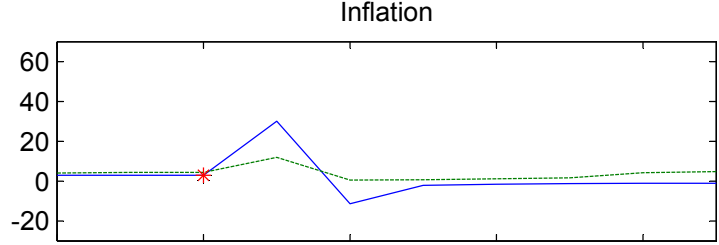
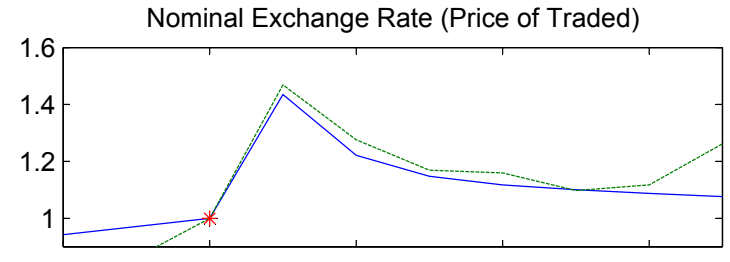
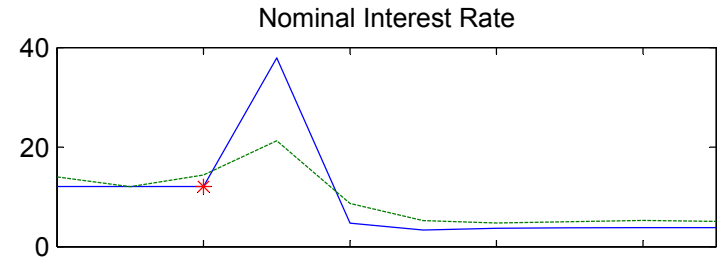
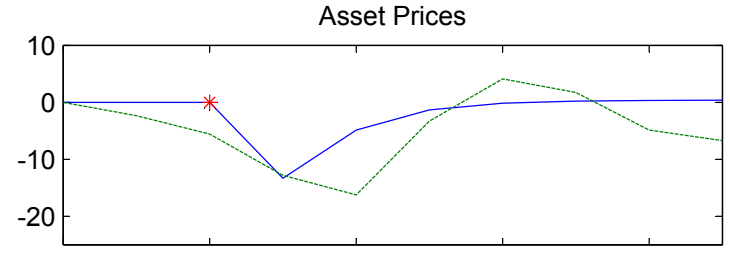
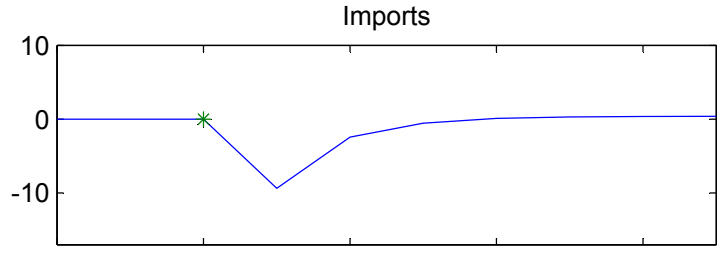
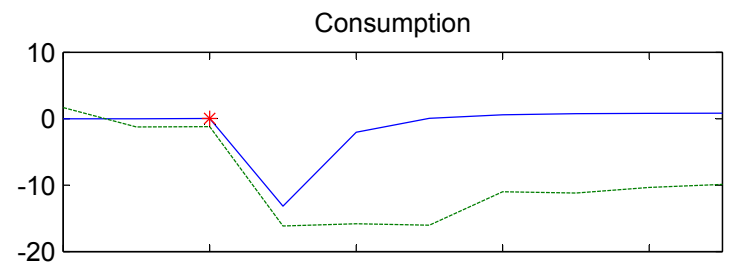
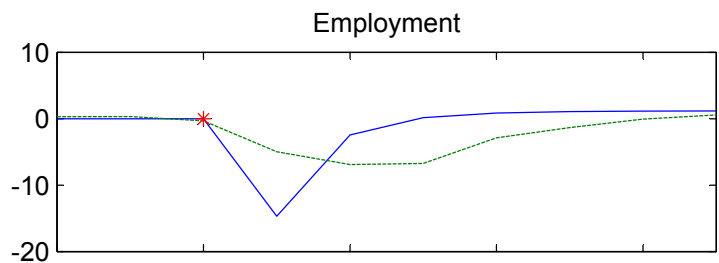
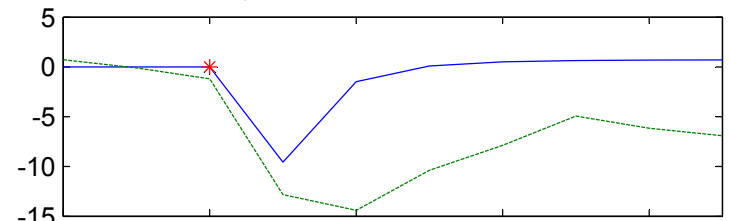
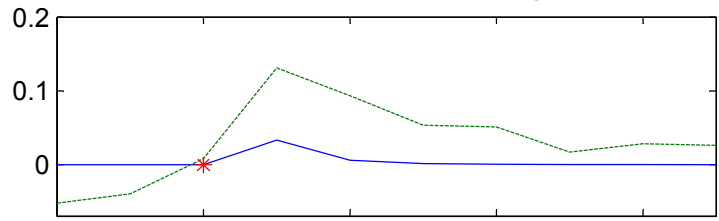
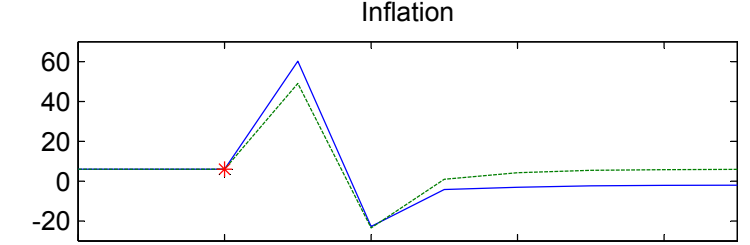
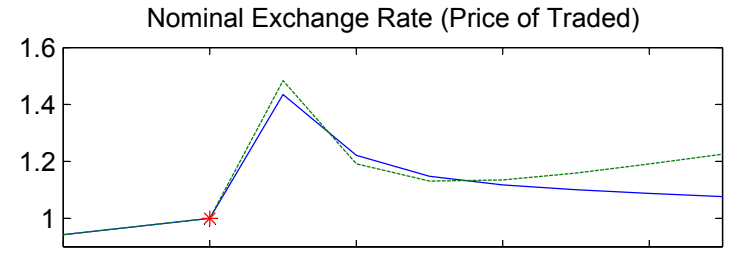
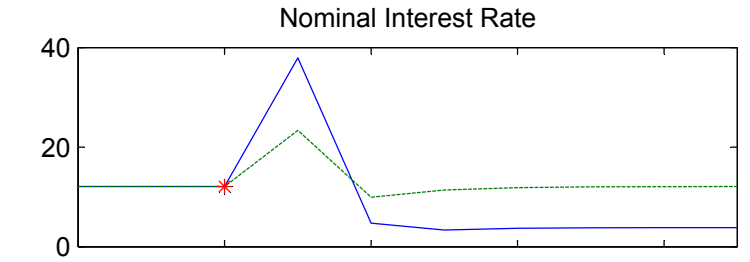
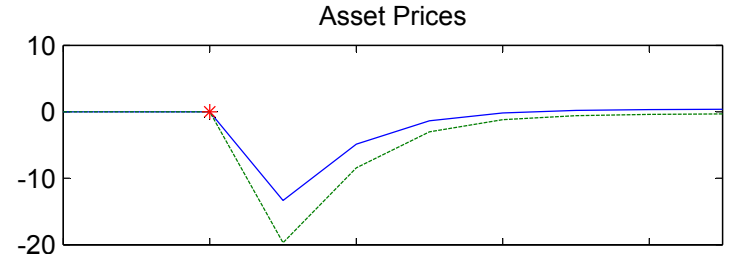
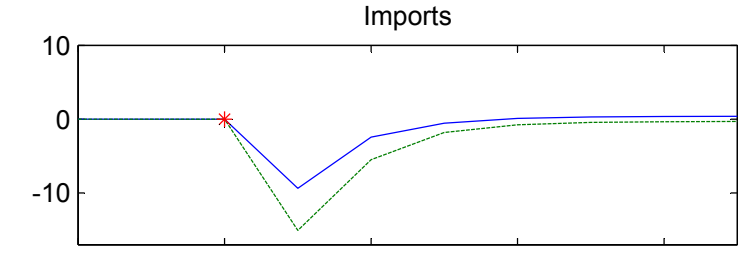
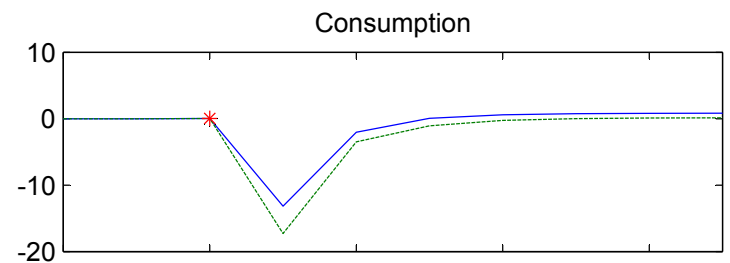
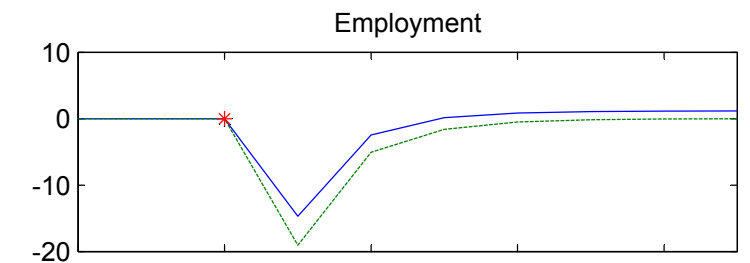
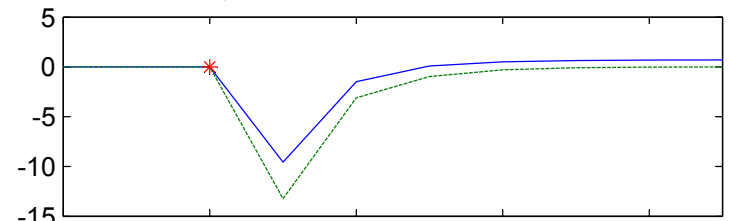
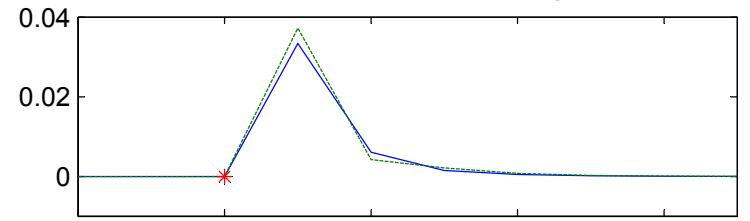


Figure 7: Optimal and Constant Money Growth



— Simulation
 - - - Actual Korean Data

Figure 8: Optimal and Constant Money Growth



— Optimal Money Growth
 - - - Constant Money Growth