MARK GERTLER
SIMON GILCHRIST
FABIO M. NATALUCCI

External Constraints on Monetary Policy and the Financial Accelerator

We develop a small open economy macroeconomic model where financial conditions influence aggregate behavior. Our goal is to explore the connection between the exchange rate regime and financial distress. We first show that a calibrated version of the model captures well the behavior of the Korean economy during its financial crisis period of 1997–98. In particular, the model accounts for the sharp increase in lending rates and the large drop in output, employment, investment, and measured productivity. The financial market frictions play an important role, further, explaining roughly half the decline in overall economic activity. We then perform some counterfactual exercises to illustrate how the fixed exchange rate regime likely exacerbated the crisis by tying the hands of monetary policy.

JEL codes: E5, F3, F4
Keywords: financial crises, exchange rate policy.

OVER THE PAST 25 YEARS there has been a dramatic rise in the frequency of financial crises that have led to significant contractions in economic activity. One feature of these crises, that pertains in particular to open economies, is the strong connection with a fixed exchange rate regime. In a study covering the 1970s through the 1990s, Kaminsky and Reinhart (1999) document the strong correlation between domestic financial strains and currency crises. Put differently, countries in the

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MARK GERTLER *is at New York University and NBER (E-mail:* mark.gertler@nyu.edu). SIMON GILCHRIST *is at Boston University and NBER (E-mail:* sgilchri@bu.edu). FABIO M. NATALUCCI *in the Board of Governors of the Federal Reserve System (E-mail:* fabio.m.natalucci@frb.gov).

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position of having to defend an exchange rate peg were more likely to have suffered severe financial distress. The likely reason is straightforward: defending an exchange rate peg generally requires the central bank to adjust interest rates in a direction that reinforces the crisis. Moreover, this connection between external constraints on monetary policy and financial crises is not simply a postwar phenomenon: during the Great Depression, as Eichengreen (1992) and others have shown, countries that stayed on the gold standard suffered far more severe financial and economic distress than countries that left early.

In this paper, we develop a small open economy macroeconomic model where financial conditions influence aggregate behavior. Our goal is to explore the connection between the exchange rate regime and financial distress. Specifically, we extend to the open economy the financial accelerator framework developed in Bernanke, Gertler, and Gilchrist (1999) (hereafter BGG), that is in turn based on earlier work by Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Carlstrom and Fuerst (1997), and others. We then consider how the choice of the exchange rate regime influences an economy's response to a financial crisis.

To judge the empirical relevance of our framework, we conduct a quantitative exercise aimed at replicating the key features of the South Korean experience during the Asian financial crisis of 1997–98. We focus on the Korean episode because it is symptomatic of many financial crises that have occurred over time: the country experienced a sharp contraction in both output and measured productivity, along with a sharp deterioration in credit conditions, including falling asset prices and increasing credit spreads. As well, in the process the country's central bank was attempting to defend a fixed exchange rate regime.

Our quantitative model is able to account for the roughly 12% drop in Korean output during the 1997–98 crisis, as well as most of the other salient features of this episode. The financial accelerator mechanism is key: we show that it accounts for roughly half of the decline in economic activity. We also perform some counterfactual exercises to illustrate how being tied to the fixed exchange rate regime may have exacerbated the crisis. Because our model is optimization based, we are able to compute the explicit welfare costs of the crisis and explore the welfare consequences of pursuing alternative policies.

Several papers have recently emphasized that sharp declines in measured productivity are a robust characteristic of financial crises, raising the possibility that productivity shocks (broadly defined) may be the true underlying causal force (e.g., Chari, Kehoe, and McGrattan 2003, Cole, Ohanian, and Leung 2005). We demonstrate, however, that it is possible to explain most of the variation in measured productivity during the Korean crisis by appealing to endogenous utilization of capital, along with fixed overhead costs of producing. Specifically, within our model, the investment and output collapse brought about by the financial crisis induces a drop in capital utilization which in conjunction with overhead costs, leads to a decline in measured productivity. Of course, in this case the drop in productivity reflects mismeasurement of capital input utilization and not a true shift in productivity. To support this modeling approach, we present evidence that electricity utilization (a conventional proxy for capital utilization) fell sharply in tandem with measured productivity.

Finally, we note that there is now a lengthy literature containing theoretical models of financial crises in emerging market economies. Our paper is in the spirit of a large subset of this literature that emphasizes how balance sheets on borrower spending (arising from credit market frictions) give rise to a financial accelerator mechanism that works to propagate financial crises. Some prominent examples include: Aghion, Bacchetta, and Banerjee (2000), Cespedes, Chang, and Velasco (2004) (hereafter CCV), Caballero and Krisnamurthy (1998), Christiano, Gust, and Roldos (2004), Devereux, Lane, and Xu (2004), and Schneider and Tornell (2004). Our paper is probably closest to CCV, who similarly emphasize the role of the exchange rate policy. The analysis in virtually all of this literature, however, is focused on qualitative results. In contrast, we develop a quantitative model and then explore how well the model can account for an actual crisis experience.[1]

The rest of the paper is organized as follows. Section 1 describes the Korean experience and presents evidence on a set of key macroeconomic variables. Section 2 introduces the model. Section 3 first presents some policy experiments to illustrate the interaction between the financial accelerator and the exchange rate regime. In this section, we also illustrate the importance of different features of the model. It then presents an exercise to assess how well the model can capture the Korean experience, along with several counterfactual policy experiments. Section 4 provides concluding remarks.

1. THE KOREAN FINANCIAL CRISIS

The Korean financial crisis began in October of 1997, following crises in Thailand and other Asian countries that had unfolded few months earlier. Even though it was not the first in a chain, the Korean crisis was largely unanticipated, according to Krueger and Yoo (2002). Although Korean banks were heavily exposed to risk in emerging market economies, this was not widely appreciated until October 1997 when Standard & Poor's downgraded the country's sovereign risk status.[2] Massive capital flight along with a sharp rise in the country risk premium followed. Dwindling foreign currency reserves then forced the central bank to raise the overnight call rate over 1,000 basis points. The sharp rise in the country risk premium and short-term interest rates was the prelude to a substantial deterioration of real economic activity.

Figure 1A plots the real-side behavior of the Korean economy during this time period. Real GDP had been consistently above trend for several years before the

1. Christiano, Gust, and Roldos (2004) also perform a quantitative analysis, though they focus on explaining the implications for monetary transmission in a crisis, as opposed to matching model performance against an actual crisis experience.

2. In particular, Korean offshore banks held substantial quantities of dollar-denominated foreign loans from countries such as Indonesia and Russia.

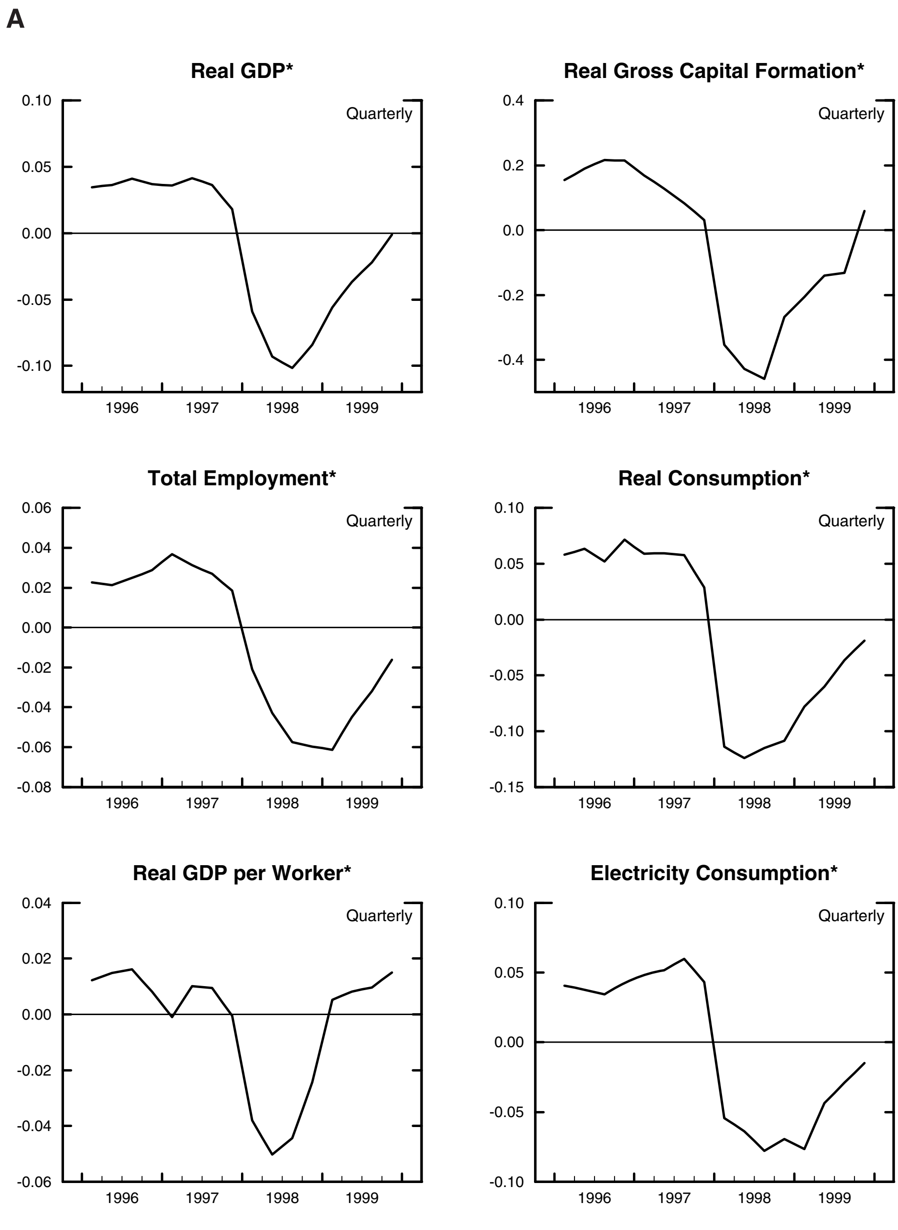


FIG. 1A. Korean Data.

crisis and showed no weakness until the fourth quarter of 1997. During the first quarter of 1998, real GDP fell 8% and subsequently contracted by another 4%. Investment played a key role in the overall decline. Real gross capital formation had been gradually weakening since the beginning of 1997 and then experienced nearly a 40% contraction in the first quarter of 1998, before falling another 10% in the subsequent two quarters. Real consumption spending tracked GDP during the downturn, falling by 14% in the first quarter of 1998 and 15% overall during the crisis period. Employment fell by somewhat less than GDP—8% from peak to trough, implying a 5% reduction in labor productivity, as measured by GDP per worker. The drop in labor productivity is associated with a sharp reduction in capital utilization over this time period, using electricity consumption as a proxy for capital services.[3]

Figure 1B plots the behavior of various financial variables. As we noted earlier, the country borrowing premium, as measured by the EMBI Global spread, rose roughly 500 basis points (from about 100 to about 600 basis points) in a two-month period following the onset of the crisis in October 1997.[4] The central bank's attempt to defend the exchange rate led to an increase in the overnight call rate of about 1,200 basis points between the end of 1997 and the beginning of 1998. Associated with the sharp increase in the country risk premium and the call rate was a substantial rise in credit spreads, together with a substantial decline in asset prices. The corporate–treasury bond spread rose 900 basis points. The stock market, which had been trending downward prior to the crisis, lost 200 points, or a third of its value, in the immediate aftermath of the crisis. Following a brief rally, stock prices lost another 100 points before beginning a recovery in the second quarter of 1998.

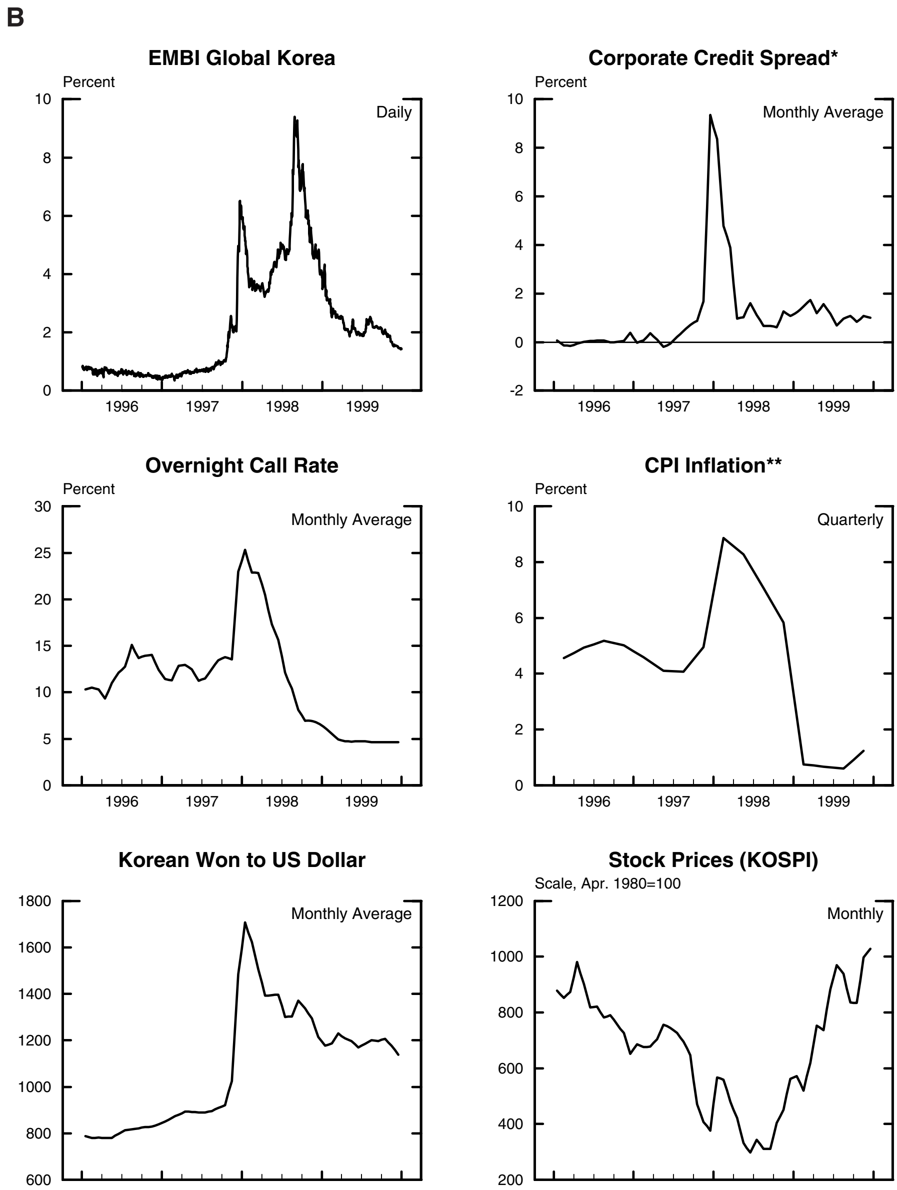
Once the central bank abandoned the peg in favor of a flexible exchange rate, interest rates were gradually reduced during 1998. It is reasonable to believe that prior expectations regarding the probability that Korea would abandon the fixed exchange rate were low.[5] Once it was clear that the Bank of Korea failed in its attempt to defend the won, however, the currency depreciated by almost 50%. Inflation, which was averaging 4% before the crisis, increased five percentage points in the first quarter of 1998 as import prices rose sharply following the devaluation. The overall reduction in economic activity led to a sharp contraction in inflation however. By the first quarter of 1999, inflation had fallen to 0.5%, well below its pre-crisis level.

Figure 1C plots the foreign sector of the Korean economy. The 40% decline in the real exchange rate led to a 15% increase in the ratio of net exports to GDP. Nearly all of this increase in net exports is attributable to the 40% decline in imports rather than

3. If energy and capital services enter the production function as perfect complements owing to a Leontief technology, then electricity is a perfect measure for capital utilization. Econometric estimates imply a very low degree of substitutability between capital and energy especially in the short run, making electricity a very good proxy even in the absence of perfect complementarity.

4. The country risk spread also rose sharply following the Russian crisis. This had very little effect on the Korean economy, however. By this time, the Korean monetary authority had abandoned the fixed exchange rate regime.

5. Even though Thailand, after a strong speculative attack, let the currency float on July 2, 1997, the EMBI Global for Korea climbed above 100 basis points only on October 9, 1997.



* The line depicts the difference in yields between a 3-year corporate bond and the Treasury security of corresponding maturity.
** CPI inflation is year-over-year growth.

FIG. 1B. Korean Data.

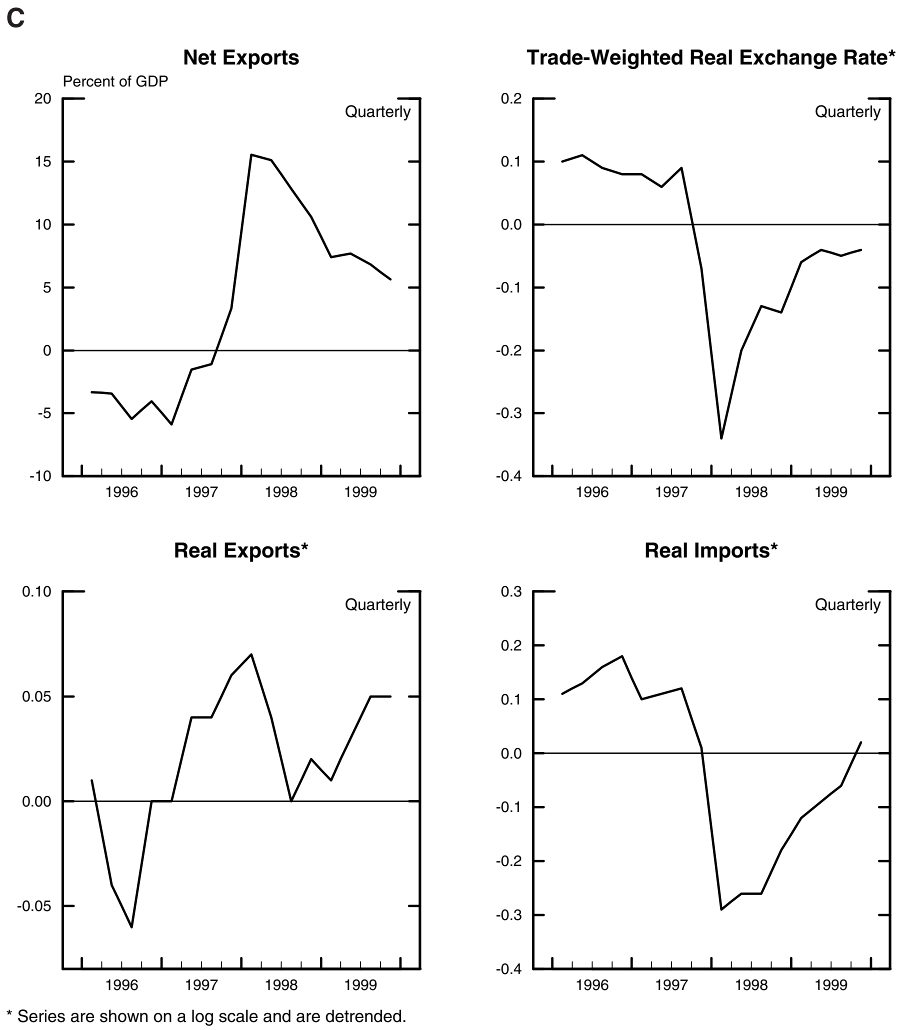


FIG. 1C. Korean Data.

an expansion in exports however. Thus it appears that the competitiveness effect of the devaluation had, at best, only a modest expansionary effect on the economy.[6]

In sum, the initial stages of the Korean crisis were associated with an unanticipated large outflow of capital and a simultaneous increase in the country borrowing premium. Short-term interest rates rose rapidly because the central bank was attempting

6. This reflects, in part, the fact that many of Korea's Asian trading partners were also suffering from the crisis environment. It also reflects the fact that the Korean economy was unable to grow its way out of the recession by exporting more goods to economically stable trading partners such as the U.S and Europe.

to defend a fixed exchange rate. In the months that followed, both financial and real conditions deteriorated sharply. Eventually the economy recovered, though only after the central bank had clearly abandoned the peg. We next proceed to develop a quantitative model designed to capture these phenomena.

2. THE MODEL

The core framework is a small open economy model with money and nominal price rigidities, along the lines of Obstfeld and Rogoff (2000), Svensson (2000), Gali and Monacelli (2002), Chari, Kehoe, and McGrattan (2002), and others. There are two key modifications. First we introduce variable capital utilization in the spirit of Greenwood, Hercowitz, and Huffman (1988) along with fixed operating costs in order to help the model account for movements in measured productivity. Second, we include a financial accelerator mechanism, as developed in BGG. The financial accelerator mechanism links the condition of borrower balance sheets to the terms of credit, and hence to the demand for capital. Via the impact on borrower balance sheets, the financial accelerator magnifies the effects of shocks to the economy. As in Kiyotaki and Moore (1997) and BGG, unanticipated movements in asset prices provide the main source of variation in borrower balance sheets. As in BGG, a countercyclical monetary policy can potentially mitigate a financial crisis: easing of rates during a contraction, for example, helps stabilize asset price movements and hence borrower balance sheets. External constraints on monetary policy, instead, limit this stabilizing option.

Within the model there exist both households and firms. There is also a foreign sector and a government sector. Households work, save, and consume tradable goods that are produced both at home (H) and abroad (F). Domestically and foreign-made goods are imperfect substitutes.

Within the home country, there are three types of producers: (i) entrepreneurs, (ii) capital producers, and (iii) retailers. Entrepreneurs manage the production of wholesale goods. They borrow from households to finance the acquisition of capital used in the production process. Due to imperfections in the capital market, entrepreneurs' demand for capital depends on their respective financial positions—this is the key aspect of the financial accelerator. In turn, in response to entrepreneurial demand, capital producers build new capital. Finally, retailers package together wholesale goods to produce final output. They are monopolistically competitive and set nominal prices on a staggered basis. The role of the retail sector in our model is simply to provide the source of nominal price stickiness.

We now proceed to describe the behavior of the different sectors of the economy, along with the key resource constraints.

2.1 Households

Consumption composites. Let C_t be a composite of tradable consumption goods. Then the following CES index defines household preferences over home consumption, C_t^H, and foreign consumption, C_t^F:

$$C_t = \left[(\gamma)^{\frac{1}{\rho}}\left(C_t^H\right)^{\frac{\rho-1}{\rho}} + (1-\gamma)^{\frac{1}{\rho}}\left(C_t^F\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}. \tag{1}$$

The corresponding consumer price index (CPI), P_t, is given by

$$P_t = \left[(\gamma)\left(P_t^H\right)^{1-\rho} + (1-\gamma)\left(P_t^F\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}. \tag{2}$$

The domestic consumption good, C_t^H, is a composite of differentiated products sold by domestic monopolistically competitive retailers. However, since we can describe household behavior in terms of the composite good, C_t^H, we defer discussion of the retail sector until Section (2.3.3) below.

The household's decision problem. Let H_t denote household labor and (M_t/P_t) denote real money balances. Household preferences are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, H_t, \frac{M_t}{P_t}\right) \tag{3}$$

with

$$U\left(C_t, H_t, \frac{M_t}{P_t}\right) = \frac{\left[(C_t)^{1-\varsigma}(1-H_t)^{\varsigma}\right]^{1-\sigma}}{1-\sigma} + \xi \log\left(\frac{M_t}{P_t}\right) \tag{4}$$

and with $\sigma \geq 0$, $\varsigma \in (0, 1)$, and $\xi > 0$.

Let W_t denote the nominal wage; Π_t real dividend payments (from ownership of retail firms); T_t lump sum real tax payments; S_t the nominal exchange rate; B_{t+1} and B_{t+1}^* nominal bonds denominated in domestic and foreign currency, respectively; and $(1+i_t)$ and $(1+i_t^*)$ the domestic and foreign gross nominal interest rate, respectively. In addition, Ψ_t represents a gross borrowing premium that domestic residents must pay to obtain funds from abroad. The household's budget constraint is then given by

$$\begin{aligned} C_t = {} & \frac{W_t}{P_t}H_t + \Pi_t - T_t - \frac{M_t - M_{t-1}}{P_t} - \frac{B_{t+1} - (1+i_{t-1})B_t}{P_t} \\ & - \frac{S_t B_{t+1}^* - S_t \Psi_{t-1}\left(1+i_{t-1}^*\right)B_t^*}{P_t}, \end{aligned} \tag{5}$$

where Ψ_t, the country borrowing premium, depends on total net foreign indebtedness, NF_t, and a random shock, Φ_t, as follows: $\Psi_t = f(NF_t)\Phi_t$, with $f'(\cdot) > 0$. We introduce this country borrowing premium partly for technical reasons. Without it, net foreign indebtedness may be non-stationary, complicating the analysis of local dynamics. Thus, following Schmitt-Grohe and Uribe (2001) we introduce a small friction in the world capital market. We set the elasticity of Ψ_t with respect to NF_t very close to zero, so that this distortion does not alter the high-frequency model dynamics but nonetheless makes NF_t revert to trend.[7] A second important reason for introducing

7. Again, we emphasize that the link between the country borrowing premium and the degree of net foreign indebtedness plays no role in the model dynamics. This contrasts with Caballero and Krishnamurthy (1998) where the collateral constraint on foreign borrowing is a key mechanism.

the country borrowing premium Ψ_t is that it is a simple way to model sudden capital outflows of the type that appear to have initiated the Korean crisis, as described in the previous section. In particular, we represent a sudden capital outflow as a positive blip in the random variable Φ_t, which in turn directly raises Ψ_t.

The household maximizes (3) subject to (4) and (5).

Consumption allocation, labor supply, and saving. The optimality conditions for the consumption allocation, labor supply, and the consumption/saving decision are reasonably conventional:

$$\frac{C_t^H}{C_t^F} = \frac{\gamma}{1-\gamma}\left(\frac{P_t^H}{P_t^F}\right)^{-\rho} \tag{6}$$

$$(1-\varsigma)\frac{1}{C_t}\frac{W_t}{P_t} = \varsigma\frac{1}{1-H_t} \tag{7}$$

$$\lambda_t = \beta E_t\left\{\lambda_{t+1}(1+i_t)\frac{P_t}{P_{t+1}}\right\}, \tag{8}$$

where λ_t, the marginal utility of the consumption index, is given by

$$\lambda_t = (1-\varsigma)(C_t)^{(\sigma-1)(\varsigma-1)-1}(1-H_t)^{\varsigma(1-\sigma)} \tag{9}$$

and $(1+i_t)(P_t/P_{t+1})$ denotes the gross real interest rate. In addition, the optimality condition governing the choice of foreign bonds in conjunction with equation (8) yields the following uncovered interest parity condition (UIPC):

$$E_t\left\{\lambda_{t+1}\frac{P_t}{P_{t+1}}\left[(1+i_t)-\Psi_t\left(1+i_t^*\right)\frac{S_{t+1}}{S_t}\right]\right\} = 0. \tag{10}$$

The household also decides money holdings. However, we do not report this relation in the model. Because we restrict attention to monetary regimes where either the nominal exchange rate or the nominal interest rate is the policy instrument, money demand plays no role other than to pin down the nominal money stock (see, e.g., Clarida, Gali, and Gertler 1999).

2.2 Foreign Behavior

In considering arbitrage in goods markets, we distinguish between the wholesale (import) price of foreign goods and the retail price in the domestic market by allowing for imperfect competition and pricing-to-market in the local economy (see Section 2.3.3). At the wholesale level, the law of one price holds. Let $P_{W,t}^F$ denote the wholesale price of foreign goods in domestic currency, and P_t^{F*} the foreign currency price of such goods. The law of one price then implies:

$$P_{W,t}^F = S_t P_t^{F*}. \tag{11}$$

We take as exogenous both the gross foreign nominal interest rate $(1 + i_t^*)$ and the nominal price (in units of foreign currency) of the foreign tradable good, P_t^{F*}. Finally, we assume that foreign demand for the home tradable good, C_t^{H*}, is given by

$$C_t^{H^*} = \left[\left(\frac{P_t^{H*}}{P_t^*} \right)^{-\varkappa} Y_t^* \right]^{\nu} \left(C_{t-1}^{H^*} \right)^{1-\nu}, \quad 0 \leq \nu \leq 1, \tag{12}$$

where Y_t^* is real foreign output, which we take as given. The term $(C_{t-1}^{H*})^{1-\nu}$ represents inertia in foreign demand for domestic products. Because the home economy is small (in the sense that it cannot affect foreign output, the foreign price level, or the foreign interest rate), it is sensible to simply postulate an empirically reasonable export demand curve.

In addition, we assume balanced trade in the steady state and normalize the steady terms of trade at unity.

2.3 Firms

We consider in turn: entrepreneurs, capital producers, and retailers.

Entrepreneurs, finance, and wholesale production. Entrepreneurs manage production and obtain financing for the capital employed in the production process. Entrepreneurs are risk neutral. To ensure that they never accumulate enough funds to fully self-finance their capital acquisitions, we assume they have a finite expected horizon. Each survives until the next period with probability ϕ. Accordingly, the expected horizon is $1/(1 - \phi)$. The entrepreneurs' population is stationary, with new entrepreneurs entering to replace those who exit. To ensure that new entrepreneurs have some funds available when starting out, we follow BGG by endowing each entrepreneur with H_t^e units of labor, which is supplied inelastically as a managerial input to production. Entrepreneurs receive a small wage in compensation.

The entrepreneur starts any period t with capital, K_t, acquired in the previous period (shortly we describe the capital acquisition decision). He then produces domestic output, Y_t, using labor, L_t, and capital services, $u_t K_t$, where u_t is the capital utilization rate. (For notational simplicity, we omit entrepreneur-specific indices.) The labor input L_t is assumed to be a composite of household and managerial labor: $L_t = H_t^{e(\Omega)} H_t^{1-\Omega}$. We normalize H_t^e to unity. The entrepreneur's gross project output, GY_t consists of the sum of his production revenues and the market value of his remaining capital stock. In addition, we assume his project is subject to an idiosyncratic shock, ω_t, that affects both the production of new goods and the effective quantity of his capital. The shock ω_t may be considered a measure of the quality of his overall capital investment.

Let $P_{W,t}$ be the nominal price of wholesale output, Q_t the real market price of capital,[8] $P_{I,t}$ the nominal replacement price of capital (see Section 2.3.2), δ_t the

8. Q_t is in units of the household consumption index (1).

depreciation rate, and A_t a measure of multifactor productivity which is common to all entrepreneurs. Then, by definition, GY_t, equals the sum of output revenues, $(P_{W,t}/P_t)Y_t$, and the market value of the capital stock, $Q_t\omega_t K_t$, net of the cost of repairing the worn out equipment, $(P_{I,t}/P_t)\delta_t\omega_t K_t$:

$$GY_t \equiv \frac{P_{W,t}}{P_t}Y_t + \left(Q_t - \frac{P_{I,t}}{P_t}\delta_t\right)\omega_t K_t, \tag{13}$$

where wholesale good production, Y_t, is given by[9]

$$Y_t = \omega_t A_t (u_t K_t)^\alpha L_t^{1-\alpha}. \tag{14}$$

Note that the entrepreneur has the option of either selling his end-of-period capital on the market or keeping it for use in the subsequent period. We assume that ω_t is an i.i.d. (across firms and time) random variable, distributed continuously with mean equal to one, i.e., $E\{\omega_t\} = 1$.

Following Greenwood, Hercowitz, and Huffman (1988), we endogenize the utilization decision by assuming that the capital depreciation rate is increasing in u_t. As in Baxter and Farr (2005), depreciation is the following convex function $\delta_t(\cdot)$ of the utilization rate:

$$\delta(u_t) = \delta + \frac{b}{1+\xi}(u_t)^{1+\xi} \quad \text{with} \quad \delta, b, \xi > 0. \tag{15}$$

At time t, the entrepreneur chooses labor and the capital utilization rate to maximize profits, conditional on K_t, A_t, and ω_t. Accordingly, labor demand satisfies

$$\begin{aligned}(1-\alpha)(1-\Omega)\tfrac{Y_t}{H_t} &= \frac{W_t}{P_{W,t}} \\ (1-\alpha)\Omega\tfrac{Y_t}{H_t^e} &= \frac{W_t^e}{P_{W,t}},\end{aligned} \tag{16}$$

where W_t^e is the managerial wage. The optimality condition for capital utilization is

$$\alpha\frac{Y_t}{u_t} = \delta'(u_t)K_t\frac{P_{I,t}}{P_{W,t}}. \tag{17}$$

Equation (17) equates the marginal value of the output gain from a higher rate of utilization with its marginal cost owing to a higher rate of capital depreciation.

We now consider the capital acquisition decision. At the end of period t, the entrepreneur purchases capital that can be used in the subsequent period $t+1$ to produce output at that time. The entrepreneur finances the acquisition of capital partly with his

9. For technical convenience, we assume that fixed costs are borne by the retail sector rather than the wholesale sector.

own net worth available at the end of period t, N_{t+1}, and partly by issuing nominal bonds, B_{t+1}. Then capital financing is divided between net worth and debt, as follows:

$$Q_t K_{t+1} = N_{t+1} + \frac{B_{t+1}}{P_t}. \tag{18}$$

The entrepreneur's net worth is essentially the equity of the firm, i.e., the gross value of capital net of debt, $Q_t K_{t+1} - (B_{t+1}/P_t)$. The entrepreneur accumulates net worth through past earnings, including capital gains. We assume that new equity issues are prohibitively expensive, so that all marginal finance is obtained through debt.[10] We also assume that debt is denominated in units of domestic currency. Later, we will consider the case where debt is issued in foreign currency units (see Section 3.3).

The entrepreneur's demand for capital depends on the expected marginal return and the expected marginal financing cost. The marginal return to capital (equal to the expected average return due to constant returns) is next period's *ex post* gross output net of labor costs, normalized by the period t market value of capital:

$$\begin{aligned} 1 + r^k_{t+1} &= \frac{GY_{t+1} - \dfrac{W_{t+1}}{P_{t+1}} L_{t+1}}{Q_t K_{t+1}} \\ &= \frac{\omega_{t+1}\left[\dfrac{P_{W,t+1}}{P_{t+1}}\alpha \dfrac{\bar{Y}_{t+1}}{K_{t+1}} - \dfrac{P_{I,t+1}}{P_{t+1}}\delta(u_{t+1}) + Q_{t+1}\right]}{Q_t}, \end{aligned} \tag{19}$$

where $\bar{Y}_{t+1}$ is the average level of output per entrepreneur (i.e., $Y_{t+1} = \omega_{t+1}\bar{Y}_{t+1}$). Note that the marginal return varies proportionately with the idiosyncractic shock ω_{t+1}. Since $E_t\{\omega_{t+1}\} = 1$, we can express the expected marginal return simply as

$$E_t\left\{1 + r^k_{t+1}\right\} = \frac{E_t\left\{\dfrac{P_{W,t+1}}{P_{t+1}}\alpha \dfrac{\bar{Y}_{t+1}}{K_{t+1}} - \dfrac{P_{I,t+1}}{P_{t+1}}\delta(u_{t+1}) + Q_{t+1}\right\}}{Q_t}. \tag{20}$$

The marginal cost of funds to the entrepreneur depends on financial conditions. We postulate an agency problem that makes uncollateralized external finance more expensive than internal finance. As in BGG, we assume a costly state verification problem. The idiosyncratic shock ω_t is private information for the entrepreneur, implying that the lender cannot freely observe the project's gross output. To observe this return, the lender must pay an auditing cost—interpretable as a bankruptcy cost—that is a fixed proportion μ_b of the project's *ex post* gross payoff, $(1 + r^k{}_{t+1})Q_t K_{t+1}$. The entrepreneur and the lender negotiate a financial contract that: (i) induces the

10. To be clear, being an equity holder in this context means being privy to the firm's private information, as well as having a claim on the earnings stream. Thus, we are assuming that the firm cannot attract new wealthy investors that costlessly absorb all firm-specific information.

entrepreneur not to misrepresent his earnings; and (ii) minimizes the expected deadweight agency costs (in this case the expected auditing costs) associated with this financial transaction.

We restrict attention to financial contracts that are negotiated one period at a time and offer lenders a payoff that, in nominal terms, is independent of aggregate risk. Under these assumptions, it is straightforward to show that the optimal contract takes a very simple and realistic form: a standard debt with costly bankruptcy. If the entrepreneur does not default, the lender receives a fixed payment independent of ω_t. If the entrepreneur defaults, the lender audits and seizes whatever it finds.[11] It is true that we are arbitrarily ruling out the possibility of either entrepreneurs or households obtaining insurance against aggregate risks to their wealth.[12] We simply appeal to realism and features outside the model (e.g., difficulties in enforcing wealth transfers in bad times) to rule out aggregate state-contingent wealth insurance.[13]

Overall, the agency problem implies that the opportunity cost of external finance is more expensive than that of internal finance. Because the lender must receive a competitive return, it charges the borrower a premium to cover the expected bankruptcy costs. Because the external finance premium affects the overall cost of finance, it therefore influences the entrepreneur's demand for capital.

In general, the external finance premium varies inversely with the entrepreneur's net worth: the greater the share of capital that the entrepreneur can either self-finance or finance with collateralized debt, the smaller the expected bankruptcy costs and, hence, the smaller the external finance premium. Rather than present the details of the agency problem here, we simply observe, following BGG, that the external finance premium, $\chi_t(\cdot)$, may be expressed as an increasing function of the leverage ratio, $(B_{t+1}/P_t)/N_{t+1}$:

$$\chi_t(\cdot) = \chi\left(\frac{\frac{B_{t+1}}{P_t}}{N_{t+1}}\right)$$
$$\chi'(\cdot) > 0, \quad \chi(0) = 0, \quad \chi(\infty) = \infty. \tag{21}$$

The specific form of $\chi_t(\cdot)$ depends on the primitive parameters of the costly state verification problem, including the proportional bankruptcy cost μ_b and the distribution of the idiosyncratic shock ω_t. In addition, note that $\chi_t(\cdot)$ depends only on the

11. Details of the form of the financial contract are provided in the NBER working paper version of the paper. The loan contract guarantees the lender an average return (across contracts) which is nominally riskless. To be consistent with this assumption, the non-default payment to the lender depends on the *ex post* realization of prices.

12. Within our framework both entrepreneurs and households would like to hedge against aggregate shocks to their wealth: entreprenuers because the shadow value of wealth is countercyclical due to the credit market frictions and households because they are risk averse. Some preliminary experiments suggest that under our baseline calibration, insurance would likely flow on net from entrepreneurs to households. This would work to enhance the financial accelerator since it would imply a stronger procyclical movement in entrepreneurial balance sheets.

13. Krishnamurthy (2003), for example, motivates incomplete wealth insurance against aggregate risk by appealing to credibility problems on the part of the supplier.

aggregate leverage ratio and not on any entrepreneur-specific variables. This simplification arises because, in equilibrium, all entrepreneurs choose the same leverage ratio, which owes to having constant returns in both production and bankruptcy costs due to risk neutrality (see, e.g., Carlstrom and Fuerst 1997, BGG.)

By definition, the entrepreneur's overall marginal cost of funds in this environment is the product of the gross premium for external funds and the gross real opportunity cost of funds that would arise in the absence of capital market frictions. Accordingly, the entrepreneur's demand for capital satisfies the optimality condition

$$E_t\{1 + r^k_{t+1}\} = (1 + \chi_t(\cdot))E_t\left\{(1 + i_t)\frac{P_t}{P_{t+1}}\right\}, \tag{22}$$

where $E_t\{(1 + i_t)(P_t/P_{t+1})\}$ is the gross cost of funds absent capital market frictions.

Equation (22) is interpretable as follows: At the margin, the entrepreneur considers acquiring a unit of capital financed by debt. The additional debt, however, raises the leverage ratio, increasing the external finance premium and the overall marginal cost of finance. Relative to perfect capital markets, accordingly, the demand for capital is lower, the exact amount depending on $\chi_t(\cdot)$.[14]

Equation (22) provides the basis for the financial accelerator. It links movements in the borrower financial position to the marginal cost of funds and, hence, to the demand for capital. Note, in particular, that fluctuations in the price of capital, Q_t, may have significant effects on the leverage ratio, $(B_{t+1}/P_t)/N_{t+1} = (B_{t+1}/P_t)/(Q_tK_{t+1} - (B_{t+1}/P_t))$. In this way, the model captures the link between asset price movements and collateral stressed in the Kiyotaki and Moore (1997) theory of credit cycles.

The other key component of the financial accelerator is the relation that describes the evolution of entrepreneurial net worth, N_{t+1}. Let V_t denote the value of entrepreneurial firm capital net of borrowing costs carried over from the previous period. This value is given by

$$V_t = \left(1 + r^k_t\right)Q_{t-1}K_t - \left[(1 + \chi_{t-1}(\cdot))\,(1 + i_{t-1})\,\frac{P_{t-1}}{P_t}\right]\frac{B_t}{P_{t-1}}. \tag{23}$$

In this expression, $(1 + r^k_t)$ is the *ex post* real return on capital, and $(1 + \chi_{t-1}(\cdot))(1 + i_{t-1})(P_{t-1}/P_t)$ is the *ex post* cost of borrowing. Net worth may then be expressed as a function of V_t and the managerial wage, (W^e_t/P_t),

$$N_{t+1} = \phi V_t + W^e_t/P_t, \tag{24}$$

where the weight ϕ reflects the number of entrepreneurs who survive each period.[15]

14. While we use the costly state verification problem to derive a parametric form for $\chi_t(\cdot)$, we note, however, that the general form relating external finance costs to financial positions arises across a broad class of agency problems.

15. In our quantitative exercises, W^e_t is of negligible size, and the dynamics of N_{t+1} are determined by V_t.

As equations (23) and (24) suggest, the main source of movements in net worth stems from unanticipated movements in returns and borrowing costs. In this regard, unforecastable variations in the asset price Q_t likely provide the principle source of fluctuations in $(1 + r_t^k)$. It is for this reason that unpredictable asset price movements play a key role in the financial accelerator. On the liability side, unexpected movements in the price level affect *ex post* borrowing costs. An unexpected deflation, for example, reduces entrepreneurial net worth. If debt were instead denominated in foreign currency, then unexpected movements in the nominal exchange rate would similarly shift net worth (we explore this possibility later).

Entrepreneurs going out of business at time t consume their remaining resources. Let C_t^e denote the amount of the consumption composite consumed by the exiting entrepreneurs.[16] Then

$$C_t^e = (1 - \phi)V_t \tag{25}$$

is the total amount of equity that exiting entrepreneurs remove from the market.

Capital producers. Competitive capital producers engage in two separate activities: the repair of depreciated capital and the construction of new capital goods. Both of these activities take place after production of output at time t. Following Eisner and Strotz (1963) and Lucas (1967), we assume that the construction of new capital goods is subject to adjustment costs whereas the repair of old capital goods is not. We further assume that there is no scope for substitution between repair of old capital and construction of new capital—that is, in order for old capital to be productive it must be repaired.

Both activities, repair and construction, use as input an investment good that is composed of domestic and foreign final goods:

$$I_t = \left[(\gamma_i)^{\frac{1}{\rho_i}}\left(I_t^H\right)^{\frac{\rho_i-1}{\rho_i}} + (1-\gamma_i)^{\frac{1}{\rho_i}}\left(I_t^F\right)^{\frac{\rho_i-1}{\rho_i}}\right]^{\frac{\rho_i}{\rho_i-1}}. \tag{26}$$

The production parameter γ_i measures the relative weight that domestic and foreign inputs receive in the investment composite. Capital producers choose the optimal mix of foreign and domestic inputs according to the intra-temporal first-order condition

$$\frac{I_t^H}{I_t^F} = \frac{\gamma_i}{1-\gamma_i}\left(\frac{P_t^H}{P_t^F}\right)^{-\rho_i} \tag{27}$$

with the investment price index, $P_{I,t}$, given by

$$P_{I,t} = \left[(\gamma_i)\left(P_t^H\right)^{1-\rho_i} + (1-\gamma_i)\left(P_t^F\right)^{1-\rho_i}\right]^{\frac{1}{1-\rho_i}}. \tag{28}$$

16. We assume that entrepreneurs have preferences over domestic and foreign goods that are identical to the households' preferences specified in equation (1). The optimal mix of foreign and domestic tradable goods for entrepreneurial consumption satisfies an equation analogous to (6).

To repair depreciated capital, producers require $\delta(u_t)K_t$ units of the investment good which may be purchased at a cost of $(P_{I,t}/P_t)\delta_t K_t$. Consistent with equation (13), these costs are borne by the entrepreneurs who own the capital stock.

To construct new capital, producers use both investment goods and existing capital, which they lease from entrepreneurs. Let I_t^n denote net investment—the amount of the investment good used for the construction of new capital goods

$$I_t^n = I_t - \delta(u_t)K_t. \tag{29}$$

Each capital producer operates a constant returns to scale technology $\Phi(I_t^n/K_t)K_t$. Consistent with the notion of adjustment costs for net investment, $\Phi\,(\cdot)$ is increasing and concave. Under constant returns to scale, the resulting economy-wide capital accumulation equation is

$$K_{t+1} = K_t + \Phi\left(\frac{I_t^n}{K_t}\right)K_t. \tag{30}$$

Individual capital producers choose inputs I_t^n and K_t to maximize expected profits from the construction of new investment goods. New capital goods are sold at a price Q_t. We assume, following BGG, that capital producers make their plans to produce new capital one period in advance. The idea is to capture the delayed response of investment observed in the data. The optimality condition for net investment satisfies

$$E_{t-1}\left\{Q_t\Phi'\left(\frac{I_t}{K_t} - \delta(u_t)\right) - \frac{P_{I,t}}{P_t}\right\} = 0. \tag{31}$$

Equation (31) is a standard "Q-investment" relation, modified to allow for the investment delay.[17] The variable price of capital, though, plays an additional role in this framework: as we have discussed, variations in asset prices will affect entrepreneurial balance sheets, and hence, the cost of capital.

Retailers, price setting, and inflation. We assume there is a continuum of monopolistically competitive retailers of measure unity. Retailers buy wholesale goods from entrepreneurs/producers in a competitive manner and then differentiate the product slightly (e.g., by painting it or adding a brand name) at a fixed resource cost κ. We assume that the fixed (from the retailers' point of view) resource cost represents distribution and selling costs that are assumed to be proportional to the steady-state value

17. The second input into production, K_t, is required to preserve constant returns to scale. Let r_t^l denote the lease rate for existing capital; then profits equal $Q_t\ \Phi\ (I_t^n/K_t)K_t - (P_{I,t}/P_t)I_t^n - r_t^l K_t$. The optimality condition for the choice of K_t determines the equilibrium lease rate r_t^l:

$$E_{t-1}\left\{Q_t\left(\Phi\left(\frac{I_t^n}{K_t}\right) - \Phi'\left(\frac{I_t^n}{K_t}\right)\frac{I_t^n}{K_t}\right)\right\} = r_t^l.$$

At the steady state, there are no adjustments costs so that $\Phi(0) = \Phi'(0) = 0$. As a result, lease payments $r_t^l K_t$ are second order and are negligible in terms of both steady state and model dynamics.

of wholesale output. We choose the level of the fixed costs so that profits to the retail sector are zero in steady-state.[18]

Let $Y_t^H(z)$ be the good sold by retailer z. Final domestic output is a CES composite of individual retail goods:

$$Y_t^H = \left[\int_0^1 Y_t^H(z)^{\frac{\vartheta-1}{\vartheta}}\, dz\right]^{\frac{\vartheta}{\vartheta-1}} - \kappa. \tag{32}$$

The corresponding price of the composite final domestic good, P_t^H, is given by

$$P_t^H = \left[\int_0^1 P_t^H(z)^{1-\vartheta}\, dz\right]^{\frac{1}{1-\vartheta}}. \tag{33}$$

Domestic households, capital producers, the government, and the foreign country buy final goods from retailers. Cost minimization implies that each retailer faces an isoelastic demand for his product given by $Y_t^H(z) = (P_t^H(z)/P_t^H)^{-\vartheta} Y_t^H$. Since retailers simply repackage wholesale goods, the marginal cost to the retailers of producing a unit of output is simply the relative wholesale price, $(P_{W,t}/P_t^H)$.

As we have noted, the retail sector provides the source of nominal stickiness in the economy. We assume retailers set nominal prices on a staggered basis, following the approach in Calvo (1983): each retailer resets his price with probability $(1 - \theta)$ independently of the time elapsed since the last adjustment. Thus, each period a measure $(1 - \theta)$ of producers reset their prices, while a fraction θ keeps their prices unchanged. Accordingly, the expected time a price remains fixed is $1/(1 - \theta)$. Thus, for example, if $\theta = 0.75$ per quarter, prices are fixed on average for a year.

Since there are no firm-specific state variables, all retailers setting price at t will choose the same optimal value, $\bar{P}_t^H$. It can be shown that, in the neighborhood of the steady state, the domestic price index evolves according to

$$P_t^H = \left(P_{t-1}^H\right)^{\theta} \left(\bar{P}_t^H\right)^{1-\theta}. \tag{34}$$

Retailers free to reset choose prices to maximize expected discounted profits, subject to the constraint on the frequency of price adjustments.[19] Here we simply observe that, within a local neighborhood of the steady state, the optimal price is

$$\bar{P}_t^H = \mu \prod_{i=0}^{\infty} (P_{W,t+i})^{(1-\beta\theta)(\beta\theta)^i}, \tag{35}$$

where $\mu = 1/(1 - (1/\vartheta))$ is the retailers' desired gross mark-up over wholesale prices. Note that if retail prices were perfectly flexible, equation (35) would simply imply $\bar{P}_t^H = \mu P_{W,t}$; i.e., the retail price would simply be a proportional mark-up over the wholesale price. However, because their prices may be fixed for some time, retailers set prices based on the expected future path of marginal cost, and not simply on current marginal cost.

18. In addition to justifying zero profits for the retail sector, the presence of fixed costs in the production chain increases the economy-wide benefit to varying capital utilization at the margin.

19. Since it is standard in the literature, we do not report the maximization problem here.

Combining equations (34) and (35) yields an expression for the gross inflation rate for domestically produced goods (within the neighborhood of a zero-inflation steady state):

$$\frac{P_t^H}{P_{t-1}^H} = \left(\mu \frac{P_{W,t}}{P_t^H}\right)^{\lambda} E_t \left\{\frac{P_{t+1}^H}{P_t^H}\right\}^{\beta}, \tag{36}$$

where the parameter $\lambda = (1-\theta)(1-\beta\theta)/\theta$ is decreasing in θ, the measure of price rigidity. Equation (36) is the canonical form of the new optimization-based Phillips curve that arises from an environment of time-dependent staggered price setting (see, e.g., Gali and Gertler 1999). The curve relates inflation to movements in real marginal cost and expected inflation.

Owing to imperfect competition, foreign goods sold in the local economy are subject to an analogous mark-up over the wholesale price. We assume that retailers of foreign goods face the marginal cost $P_{W,t}^F$—see equation (11)—and set prices according to a Calvo-style price setting equation. Let $(1-\theta^f)$ denote the probability that a retailer of foreign goods resets its price in any given period. The inflation rate for foreign goods then satisfies

$$\frac{P_t^F}{P_{t-1}^F} = \left(\mu^f \frac{S_t P_t^{F*}}{P_t^F}\right)^{\lambda_f} E_t \left\{\frac{P_{t+1}^F}{P_t^F}\right\}^{\beta}, \tag{37}$$

where $\lambda_f = (1-\theta^f)(1-\beta\theta^f)/\theta^f$. This specification of the pricing process for domestically sold foreign goods implies temporary deviations from the law of one price owing to delay in the exchange rate pass-through mechanism.[20] The coefficient θ^f captures the degree of this delay. When calibrating the model, we assume that retailers of domestic and foreign goods face the same degree of price rigidity, so that $\theta^f = \theta$.[21]

CPI inflation is a composite of domestic and foreign good price inflation. Within a local region of the steady state, CPI inflation may be expressed as

$$\frac{P_t}{P_{t-1}} = \left(\frac{P_t^H}{P_{t-1}^H}\right)^{\gamma} \left(\frac{P_t^F}{P_{t-1}^F}\right)^{1-\gamma}. \tag{38}$$

2.4 Resource Constraint

The resource constraint for the domestic tradable good sector is

$$Y_t^H = C_t^H + C_t^{eH} + C_t^{H*} + I_t^H + G_t^H, \tag{39}$$

where Y_t^H is final domestic output net of fixed costs (equation (32)), G_t^H is government consumption and C_t^{eH} is entrepreneurial consumption of the domestic good.

20. Chari, Kehoe, and McGrattan (2002) also consider pricing-to-market specifications to explore the role of nominal rigidities in explaining exchange rate dynamics.

21. Since foreign prices are exogenous, we can assume, without loss of generality, that the steady-state markup $\mu^f = \mu$.

2.5 *Government Budget Constraint*

We assume that government expenditures are financed by lump-sum taxes and money creation as follows:

$$\frac{P_t^H}{P_t} G_t^H = \frac{M_t - M_{t-1}}{P_t} + T_t. \tag{40}$$

Government expenditures are exogenous. Lump-sum taxes adjust to satisfy the government budget constraint. Finally, the money stock depends on monetary policy, which we will specify in the next section.

Except for the description of monetary policy, we have completed the specification of the model. The distinctive aspect is the financial accelerator, characterized by just two equations: (22) and (24). The former describes how net worth influences capital demand. The latter characterizes the evolution of net worth. If we restrict the external finance premium $\chi(\cdot)$ to zero in equation (22), we effectively shut off the financial accelerator, and the model reverts to a reasonably conventional new open economy macroeconomic framework. In what follows, we will explore the performance of the model under alternative exchange rate regimes, with and without an operative financial accelerator.

2.6 *Exchange Rate Regimes*

In the quantitative analysis discussed in the next section, we consider shocks to the economy under three different scenarios: (i) a pure fixed exchange rate regime; (ii) a floating exchange rate regime, where the central bank manages the nominal interest rate according to a Taylor rule; and (iii) a hybrid case, where the central bank initially fixes the exchange rate but then eventually abandons the peg in favor of the floating exchange rate regime. The latter regime is meant to approximate the monetary policy response over the crisis episode in Korea.

Under the fixed exchange rate regime, the central bank keeps the nominal exchange rate pegged at a predetermined level, i.e.,

$$S_t = \bar{S}, \quad \forall t. \tag{41}$$

In doing so, the central bank sets the nominal interest rate to satisfy the uncovered interest parity condition given by equation (10).

Under the flexible exchange rate regime, the policy instrument becomes the nominal interest rate. The central bank adopts a feedback rule that has the nominal interest rate adjust to deviations of CPI inflation and domestic output from their respective target values.[22] Let Y_t^0 denote the output target level, which we take to be domestic output relative to its steady state. The feedback rule, accordingly, is given by

22. CPI inflation targeting is a realistic description of the conduct of Korean monetary policy following the abandonment of the fixed exchange rate (see Bank of Korea 2003 for details). Moreover, as shown by Devereux, Lane, and Xu (2004), CPI inflation targeting is the best monetary policy rule in an environment of low exchange rate pass-through.

$$(1 + i_t) = (1 + rr^{ss}) \left(\frac{P_t}{P_{t-1}} \right)^{\gamma_\pi} \left(\frac{Y_t^H}{Y_t^0} \right)^{\gamma_y} \tag{42}$$

with $\gamma_\pi > 1$ and $\gamma_y > 0$, and where rr^{ss} is the steady state real interest rate. For simplicity, we take the target gross inflation rate to be unity.[23] We interpret this rule as being a form of flexible inflation targeting, in the sense of Bernanke et al. (1999). The central bank adjusts the interest rate to ensure that over time the economy meets the inflation target, but with flexibility in the short term so as to meet stabilization objectives. Importantly, we assume that the central bank is able to credibly commit to the Taylor rule.

In the hybrid regime, as a shock hits the economy, the central bank initially maintains the exchange rate peg. Conditional on being on the peg in the current period, it abandons the peg with probability Π in the subsequent period, where Π is independent of time. Once off the peg, the central bank reverts to the interest rate feedback rule given by equation (42).

2.7 Model Parametrization

Our quantitative analysis is meant to capture the broad features of an emerging market economy such as South Korea for which financial frictions seem particularly relevant. We first discuss the choice of the parameters governing preferences and technology, and then describe the choice of the parameters pertinent to the financial structure. A detailed list of the parameter values is presented in Table 1.

Preferences. We fix the quarterly discount factor, β, at 0.99. We set the elasticity of inter-temporal substitution, $1/\sigma$, equal to 0.2, consistent with the evidence of low sensitivity of expected consumption growth to real interest rates. Since consumption goods are thought to have a higher degree of substitution than intermediate or investment goods,[24] we set the intra-temporal elasticity of substitution for the consumption composite, ρ, at unity and the intra-temporal elasticity of substitution for the investment composite, ρ_i, at 0.25. To match the average ratio of consumption to GDP in Korea over the period 1990–2002—approximately 0.5—we set the share of domestic goods in the consumption composite, γ, equal to 0.5. Finally, we assume that the elasticity of labor supply is equal to 2 and that average hours worked relative to total hours available are equal to $1/3$.

With regard to the parameters of the export demand, equation (12), we set the elasticity $\varkappa$ equal to 1 and the share parameter, ν, equal to 0.25. This implies a relatively high degree of inertia in export demand, in line with the response of Korean exports during the 1997–98 crisis.

23. Our results are robust to allowing for a managed float, where the Tayor rule is appended with a term that allows for a modest adjustment of the nominal interest rate to deviations of the nominal exchange rate from target.

24. Around 50% of Korean imports are intermediate goods.

TABLE 1

CALIBRATION

Symbol	Value	Description
β	0.99	discount factor (equation (3))
$\frac{1}{\sigma}$	0.2	elasticity of inter-temporal substitution (equation (4))
ρ	1	consumption intra-temporal elasticity of substitution (equation (1))
ρ_i	0.25	investment intra-temporal elasticity of substitution (equation (26))
γ	0.5	share of domestic goods in consumption (equation (1))
H	0.33	hours worked relative to total hours available (equation (3))
$\varkappa$	1	elasticity of export demand (equation (12))
$1-\nu$	0.75	weight of inertia in export demand (equation (12))
α	0.5	share of capital in production function (equation (14))
γ_i	0.5	share of domestic goods in investment (equation (26))
$\frac{C^{H*}}{Y^H}$	0.4	steady-state ratio of exports to output
Ω	0.01	share of entrepreneurial labor (equation (16))
u	1	steady-state capital utilization rate (equation (14))
$\delta(u)$	0.025	capital depreciation rate (equation (13))
ξ	1	elasticity of marginal depreciation with respect to utilization rate (equation (15))
μ	1.2	steady-state mark-up (equation (35))
κ	0.2	fixed resource cost (equation (32))
$\eta_{\frac{i}{k}}$	2	elasticity of price of capital with respect to investment-capital ratio
θ	0.75	probability of not adjusting prices (equation (34))
$1-\phi$	0.0272	entrepreneurs' death rate (equation (25))
σ	0.28	variance of the log-normally distributed productivity variable ω
μ_b	0.12	fraction of realized payoffs lost in bankruptcy
γ_π	2	Taylor rule coefficient on inflation (equation (42))
γ_y	0.75	Taylor rule coefficient on output (equation (42))
$\frac{G^H}{Y^H}$	0.2	steady-state government expenditure ratio
η_Ψ	10^{-5}	elasticity of country risk premium with respect to net foreign debt

Technology. Over the period 1990–2002, the average gross capital formation-to-GDP and exports-to-GDP ratios in Korea were approximately 0.3 and 0.4, respectively. To match these characteristics, we set the capital share, α, equal to 0.5; the share of domestic goods in the investment composite, γ_i, equal to 0.5; and the steady-state ratio of exports to domestic output equal to 0.4. We set $\Omega = 0.01$, implying that entrepreneurial labor accounts for 1% of the total wage bill. The steady-state utilization rate is normalized at 1 and the steady-state quarterly depreciation, $\delta(u_{ss})$, is assigned the conventional value of 0.025, consistent with the evidence. The parameter ξ, which represents the elasticity of marginal depreciation with respect to the utilization rate, $u\delta''(u)/\delta'(u)$, is set equal to 1, consistent with Baxter and Farr (2005), who rely on estimates provided by Basu and Kimball (1997). The steady state mark-up value, μ, is set at 1.2. Consistent with the retail sector earning zero profits in steady state, the fixed resource cost κ is assumed to be 20% of wholesale output. The elasticity of the price of capital with respect to the investment-capital ratio is taken to be 2. As is common in the literature on the Calvo (1983) pricing technology, we assume the probability of the price not adjusting, θ, to be 0.75.

External finance premium. The data suggest that capital markets in Korea are somewhat less developed relative to the United States. Debt-equity ratios were particularly high at the onset of the financial crisis.[25] Early in 1998, the Korean authorities urged the 30 largest chaebols to reduce their debt-equity ratios to "below 2" by the end of 1999. Conservatively, we set the steady-state leverage ratio equal to 1.1, more than twice the historical U.S. average.

The spread between corporate and government bond yields appears to be consistently zero prior to 1997 (see Figure 1B). We interpret this as evidence of some sort of explicit/implicit government guarantees to the Korean corporate sector. After reaching about 900 basis points in December 1997 to January 1998, the spread dropped and stabilized at around 100–200 basis points in the late spring of 1998. Since there is still some evidence of government meddling in capital markets in Korea, we set the steady-state external finance premium at 3.5%, roughly 150 basis points higher than U.S. historical data.

To obtain these steady-state values, we need to set the non-standard parameters of the model that affect the relation between real and financial variables. In particular, we set the entrepreneurs' death rate, $(1 - \phi)$, equal to 0.0272. We assume that the idiosyncratic productivity variable ω_t is log-normally distributed with variance equal to 0.28. Finally, we fix the fraction of realized payoffs lost in bankruptcy, μ_b, to 0.12.

Government policy. We set the Taylor rule coefficients on CPI inflation and output relative to steady state, γ_π and γ_y, equal to 2 and 0.75, respectively. These coefficients provide a reasonable approximation of the response of the real interest rate in Korea after the abandonment of the fixed exchange rate regime. Finally, we take the steady state government expenditure ratio, (G^H/Y^H), to be 0.2.

3. EXTERNAL SHOCKS AND FINANCIAL CRISES: A QUANTITATIVE ASSESSMENT

In this section, we evaluate how well the model is able to replicate a financial crisis, such as the one that occurred in Korea in 1997–98. In particular, we consider the response of the model economy to an exogenous rise in the country risk premium, meant to reflect the sudden and unanticipated capital outflows that appear to have triggered the events that followed the Korean crisis, as we discussed in Section 1. As in the actual crisis episode, we have the economy begin in a fixed exchange rate regime but then abandon the peg as the crisis unfolds. To illustrate the impact of the exchange rate policy, we also simulate two alternative cases: one where the economy remains under the pure fixed exchange rate regime; the other where the economy begins in a flexible exchange rate/inflation targeting regime (as described by equation (42)) and sticks with this policy throughout. In addition, we show what role each of the key features of our model plays, including the financial market frictions, variable

25. According to Krueger and Yoo (2002), in 1997 the debt-equity ratio was 5.2 for the 30 largest chaebols, 4.8 for the 5 largest chaebols, 4.6 for the 5 largest manufacturing firms, and 3.9 for all firms in the manufacturing sector.

capital utilization, and the various international trade frictions. Finally, for Korea, only about 25% of debt was in units of foreign currency.[26] For this reason, in our baseline exercises we have assumed that debt was in domestic currency units. We conclude this section by considering the implications of having debt denominated entirely in units of foreign currency.

3.1 Accounting for Korean Experience

We capture the notion that Korea began the episode under a fixed exchange rate regime and then subsequently abandoned the peg as follows: we assume that the exchange rate is initially fixed when the shock hits, but that the central bank may either abandon the regime in any subsequent period with a fixed probability Π or maintain the peg with fixed probability $(1 - \Pi)$. Because the Korean devaluation was largely unanticipated, we set the abandonment probability at a relatively low value, 0.1. Accordingly, conditional on being on the peg, the expected duration is $1/\Pi = 1/0.1 = 10$ quarters. To roughly match the Korean experience, we set the actual abandonment at two quarters after the shock (thus, the abandonment occurs sooner than the market would have guessed *ex ante*).[27]

We analyze an unanticipated increase in the country borrowing premium.[28] In particular, we consider a 500 basis point increase in Ψ_t, which is in line with the rise in the EMBI Global that occurred in Korea during the financial crisis. We assume that the shock persists as a first-order autoregressive process with a 0.95 coefficient, which is also in line with the evidence.[29] The solid line in Figures 2A and 2B denote the response of 12 key variables under the policy of probabilistic abandonment. For comparison, the dashed line reports the response under a pure fixed exchange rate regime, while the dotted line reports the response under a pure flexible exchange rate regime.

Because the economy is initially on fixed rates, in the wake of the shock, the domestic nominal interest rate rises sharply following the increase in the country borrowing premium.[30] Due to nominal price rigidities, there is also a significant increase in the real interest rate which, in turn, induces a contraction in output. The financial accelerator magnifies the output drop—the rise in the real interest rate causes

26. This refers to the share of liabilities denominated in foreign currency for commercial banks in Korea in January/February 1998. See Krueger and Yoo (2002) for details.

27. The reason why we set two quarters before the regime switch in our Korean experiment is the following. Even though the IMF stand-by credit for Korea, approved on December 4, 1997, included a flexible exchange rate policy, monetary policy was tightened to restore and sustain calm in the markets, and to contain the inflationary impact of the won depreciation. This implied a reversal of liquidity injected prior to the IMF program and a sharp increase in money market rates—see Figure 1B—to stabilize the markets. Since rates were reduced only gradually in 1998, we do not characterize the end-1997/beginning-1998 period as a switch to flexible inflation targeting yet.

28. Note that, within the context of our model, an exogenous rise in the country borrowing premium introduces a wedge between domestic and foreign interest rates in the uncovered interest parity condition (see equation (10)). Formally, it is equivalent to a shock to the foreign interest rate.

29. Even after controlling for the sharp spike in the EMBI Global following the Russian crisis in 1998, it appears that the increase in the Korean spread was persistently high after the 1997 Asian crisis.

30. Because agents expect the monetary authority to abandon eventually, expected future inflation is higher and, consequently, so is current inflation. As a result, both nominal and real interest rates rise by more under the model with probabilistic abandonment than in the case of a pure fixed exchange rate.

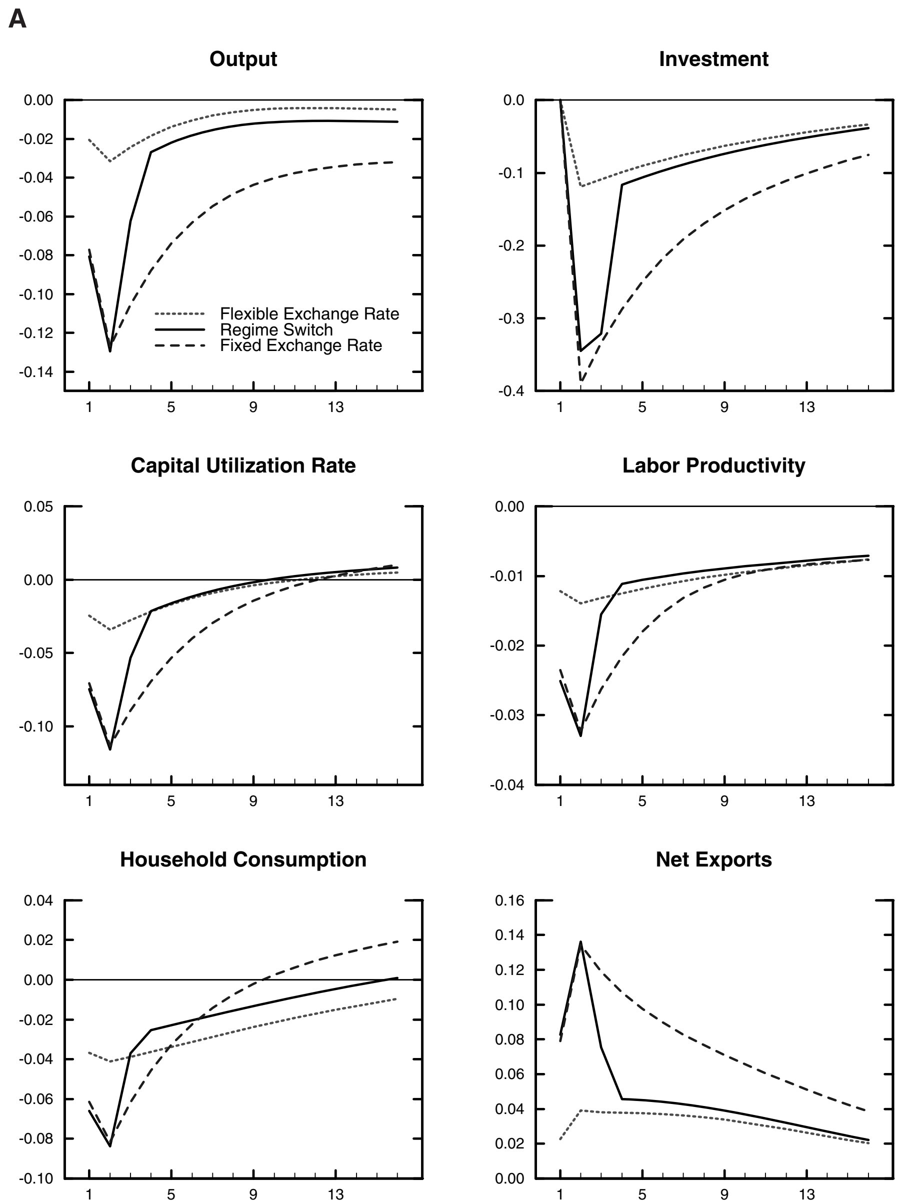


FIG. 2A. Korean Crisis Experiment.

NOTE: Model's response to a country risk premium shock.

a contraction in asset prices, which raises the leverage ratio and thus the external finance premium. The increase in the latter further dampens investment and output.

Overall, the model does well at capturing the key outcomes of the Korean experience displayed in Figures 1A–1C. In the Korean data, the drop in real GDP is 12% whereas

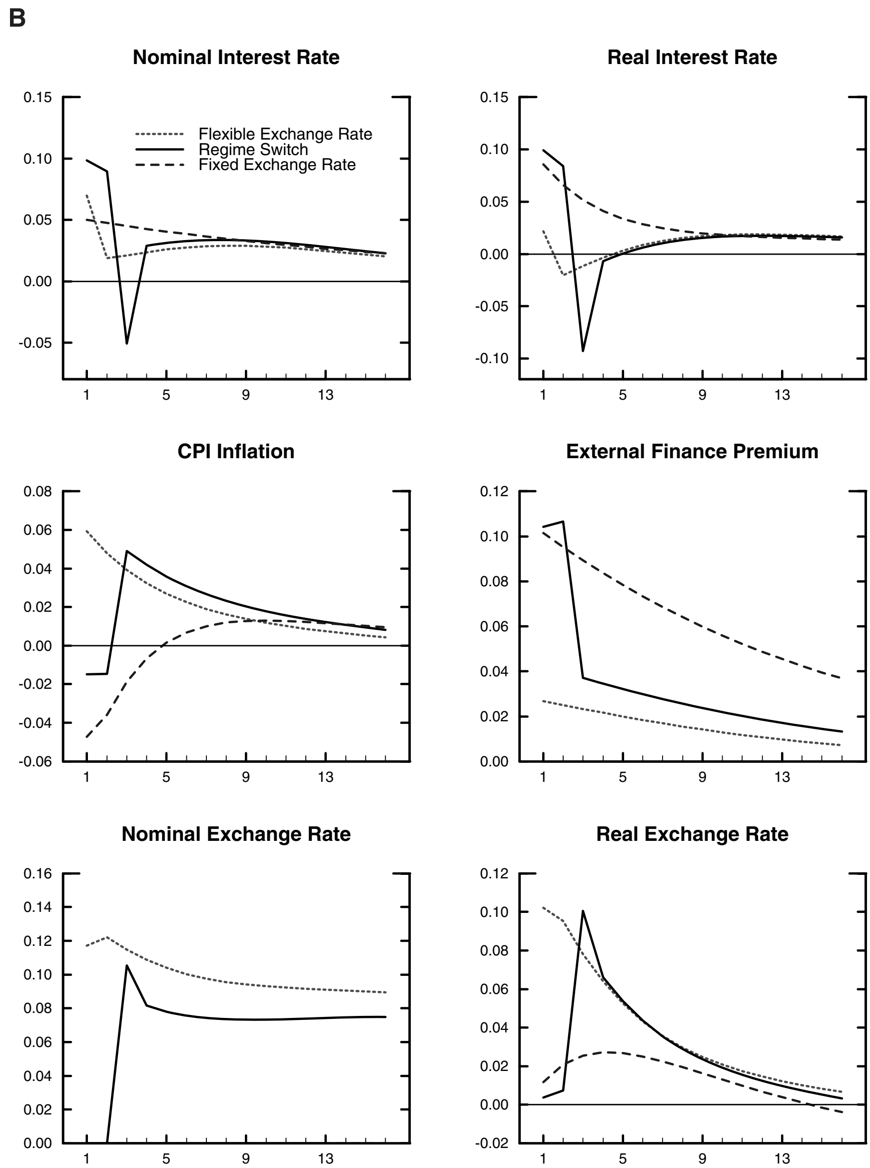


FIG. 2B. Korean Crisis Experiment.

NOTE: Model's response to a country risk premium shock.

the model produces roughly a 13% drop. The reduction in gross capital formation for Korea is on the order of 45%, again in line with, albeit somewhat larger than, the model's 35% response. Net exports (as a percentage of GDP) increase by about 15% in the data, compared with nearly 14% in the model. Notably, both the data and the model imply a large reduction in imports, especially capital goods, which drives the expansion in net exports. In the data, consumption falls by roughly 15%, which is almost double the nearly 9% drop implied by the model. A good chunk of this discrepancy, though, might be explained by the fact that data include durables as well as non-durables, while consumption in the model includes only non-durables.

The model also does well at capturing the productivity and utilization variables observed in Korea over this time period. The Korean data imply a 5% drop in labor productivity over the period December 1997 through September 1998 while the model implies roughly a 3% drop. The magnitude of the decline in labor productivity observed in the data is probably exaggerated, however, since it is based on output per worker and not on output per hour.[31] As shown in Figure 1A, electricity consumption for the Korean economy falls almost 14% during the crisis period. In the model, capital utilization drops about 12%, in the same ballpark as the decline in electricity utilization.[32] Overall, these results imply that variable capital utilization (along with fixed overhead costs) provides a reasonable explanation for the contraction in productivity that emerging market economies such as Korea experience in the wake of a financial crisis.

Importantly, the model's ability to match observed movements in employment and capacity utilization as measured by electricity usage implies that we can explain the movement in measured total factor productivity that occurred during the financial crisis. According to Meza and Quintin (2005), measured total factor productivity falls 7% during the crisis period. In our model, measured total factor productivity, defined as $\ln(Y_t^H) - \alpha \ln K_t - (1-\alpha)\ln L_t$, falls 8% in response to the contraction in output. In our model, the drop in measured total factor productivity again reflects the fall in utilization, weighted by capital share, combined with the effect of fixed costs of production, which provide some degree of short-run increasing returns to scale.[33]

The model also does well at capturing various financial features of the Korean experience. The 900-basis-point increase in the corporate–treasury bond spread observed in the data is very close in magnitude to the response obtained by the model's external finance premium. In addition, the model does a good job of capturing the sudden reduction in the corporate–treasury bond spread following the abandonment

31. A stylized fact for U.S. data is that, of the total drop in hours during a typical recession, roughly one-third reflects a drop in hours per worker. Not taking into account the hours per worker change, accordingly, suggests a significant exageration of the movement in labor productivity (based on measures that use employment as opposed to hours). Furthermore, Meza and Quintin (2005) report that Korean hours fell 8.6% during the crisis period. Although this is below the 10.4% drop in hours implied by our model, this gap partly reflects the fact that our model slightly overstates the true output drop.

32. Given that oil is an imported good, we would expect some substitution away from energy toward other capital goods and inputs in the case where energy and capital show some degree of substitutability. Hence the 14% drop in energy is likely to overstate the decline in capital services owing to a drop in utilization rates.

33. Measuring capacity utilization through electricity usage is conventional in the literature (see, e.g., Burnside, Eichenbaum, and Rebelo 1995) and is also consistent with the approach taken by Brandt, Dressler, and Quintin (2004). In contrast, Meza and Quintin (2005) model electricity usage as entering the production function with unit elasticity (i.e., production is Cobb–Douglas in capital services, labor, and energy). We do not follow this latter approach because we believe that it suggests an implausibly high short-run elasticity of electricty with respect to other inputs.

of the peg. It also does well at mimicking both the nominal and real interest rate movements observed in the data. In particular, in the data, the (*ex post*) real interest rate initially rises by 8 percentage points prior to the abandonment and then falls by 16 percentage points following the abandonment—a result that is similar to the real rate path generated by the model.[34] Consistent with this path, both the data and the model exhibit a surge in inflation—on the order of 5 percentage points—following the abandonment.

The financial variable that is difficult to match is the actual exchange rate movement when the monetary authority abandons the fixed exchange rate regime probabilistically. The fact that quantitative macroeconomic models have difficulty in matching exchange rate movements comes as no surprise however. Our model nonetheless produces a sizable depreciation in the real exchange rate—on the order of 10%. As it is well known, movements in the nominal exchange rate dramatically over-state movements in the real exchange rate and the terms of trade.[35] To the extent that our model does well at capturing the dynamic response of net exports, we are less concerned that it does not fully account for the volatility of the exchange rate during this time period.

Up to the point where the peg is abandoned, the contraction is as severe as if the economy had been on a lasting peg (the dashed line). The abandonment, of course, frees the hand of monetary policy and allows the economy to recover much faster than otherwise, as Figures 2A and 2B show.

3.2 Alternative Monetary Policies and Welfare

As Figures 2A and 2B indicate, the crisis would have been much less severe had the economy been operating in a credible floating exchange rate regime all along. Under the flexible exchange rate, the domestic nominal interest rate is no longer tied to the foreign interest rate and is instead governed by the feedback rule, equation (42). In this case, the rise in the country risk premium produces an immediate depreciation of the domestic currency, which in turn prompts an increase in exports and a sharp rise in CPI inflation. The central bank raises the nominal interest rate to fight inflation, according to the feedback rule. This monetary policy implies only a modest increase in the real interest rate however, and a relatively moderate drop in investment. Because the rise in CPI inflation is due to the currency depreciation, it is somewhat short lived. Nominal rates fall back to trend one period after the shock while real rates fall slightly

34. Although we do not have data on *ex ante* real interest rates, it is useful to look at the *ex post* real interest rate as a guide. The nominal interest rate rises from 13% to 25% on an annual basis in January 1998, before falling to 8% by September 1998. The inflation rate rises from 5% in the fourth quarter of 1997 to 9% in the first quarter of 1998 before falling to 7% by September of 1998. Thus, the *ex post* real rate is approximately 8% in October 1997, 16% in January 1998, and about zero in September 1998, indicating an initial 8 percentage point rise followed by a 16 percentage point fall in the real interest rate.

35. As emphasized by Burstein, Eichenbaum, and Rebelo (2002), in the absence of a substantial non-tradable good sector, it is extremely difficult to match movements in the nominal exchange rate. Barth and Dinmore (1999) provide further discussion of the response of the real exchange rate and the terms of trade for various Asian countries during the financial crisis.

TABLE 2

WELFARE LOSS AS A PERCENT OF STEADY-STATE CONSUMPTION

Model with financial accelerator	
Exchange rate regime	Loss
Flexible rates	12.1%
Switching regime	16.4%
Fixed rates	20.5%

below trend. Output falls on net, due to offsetting effects of a reduction in investment demand and increasing exports. Overall, output is significantly more stable under the flexible exchange rate regime than under either the probabilistic regime or the pure fixed exchange rate regime.

To get a sense of the payoff from having pursued a different exchange rate policy, we now consider the welfare loss associated with the financial crisis and then compare it with the loss that might have occurred under alternative policy scenarios. In particular, we compute the drop in household and entrepreneurial utility suffered during the crisis and then convert this drop into consumption equivalents. In doing so, we measure the crisis period to be six quarters, approximately the amount of time it took for Korea's detrended GDP to recover to its pre-crisis level. We then calculate the amount of steady-state consumption that an appropriately weighted average of households and entrepreneurs would be willing to forgo as a one-time payment to avoid the present-discounted loss in utility associated with the crisis.[36] We express the amount that individuals are willing to forgo as a fraction of one year's steady-state consumption.[37]

The results are reported in Table 2. In the case meant to capture the Korean crisis, the "switching regime," the welfare loss of the crisis is quite substantial, roughly 16% of one year's consumption. Had the economy stayed on fixed rates throughout, the loss would have been worse, about 20% of steady-state annual consumption. Had the economy been on flexible rates, however, the welfare loss would have still been considerable—12% of one year's consumption—but, nonetheless, significantly lower than under the other policy regimes, especially the pure fixed exchange rate regime.

3.3 Effects of: (i) the Financial Accelerator, (ii) Variable Capital Utilization, and (iii) International Trade Frictions

We now explore the role of different key features of the model. To evaluate the impact of a particular feature, we perform a simple counterfactual, where we re-create the crisis experiment but with the feature under consideration "turned off."

36. The loss incorporates the current and future foregone consumption of households and entrepreneurs as well as the gain in current and future household leisure that accompanies the crisis.

37. Details of the welfare calculations are available in the NBER working paper version of the paper.

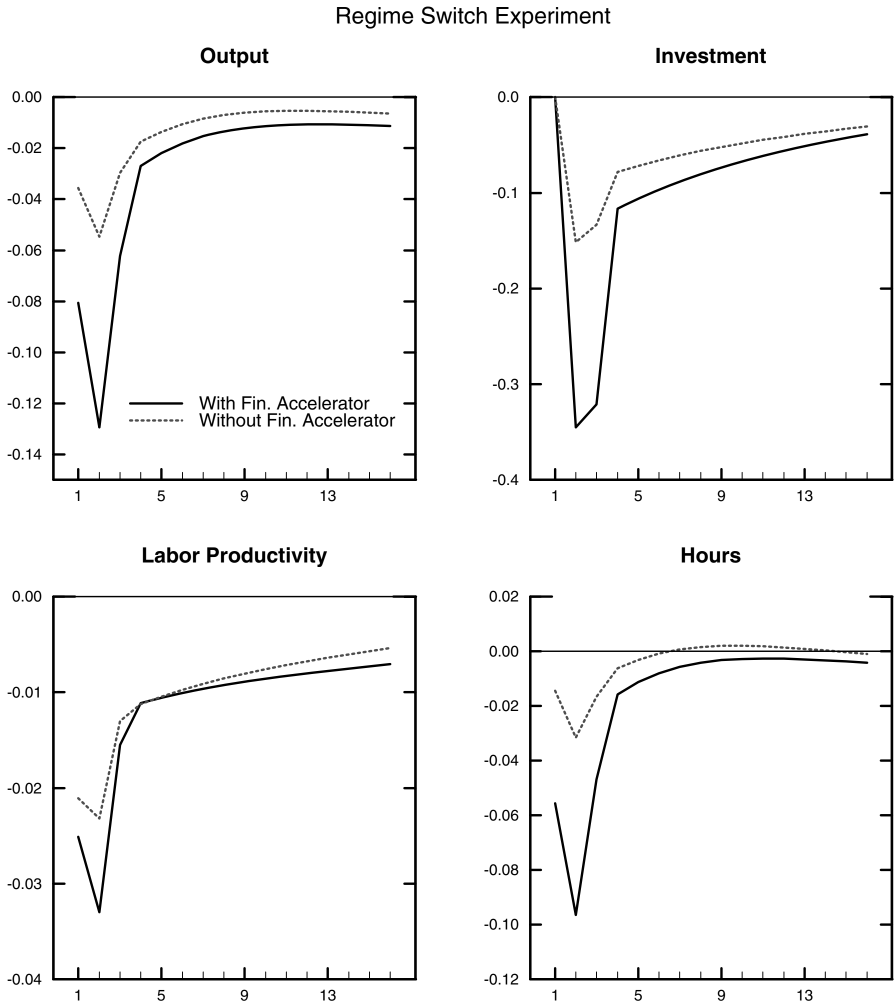


FIG. 3. The Amplification Effect of the Financial Accelerator.

NOTE: Model's response to a country risk premium shock. The case without the financial accelerator mechanism corresponds to $\chi_t = 0$ for all t.

We begin with the financial accelerator. In the case without an operative financial accelerator mechanism, we set the external finance premium $\chi_t(\cdot)$ equal to zero for all t. Figure 3 shows the response of output, investment, labor productivity, and employment to the country risk premium shock in this instance. In each panel, the dotted line reflects the model economy with the financial accelerator shut off, while the solid line is our baseline case with an operative financial accelerator.

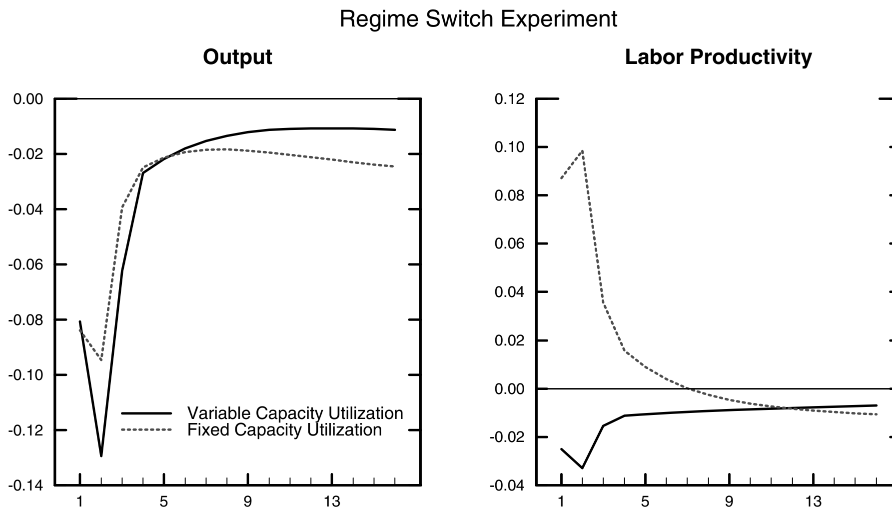


FIG. 4. The Role of Utilization Margins.

NOTE: Model's response to a country risk premium shock. In the case without variable capacity utilization, $\mu_t = 1$ for all t and k is equal to zero.

The figure shows that the financial accelerator more than doubles the contraction in output, investment, and employment. The decline in labor productivity is roughly 15% larger when the financial accelerator is operative, reflecting the enhanced contraction in capital utilization. The combination of variable utilization and sticky prices, of course, explains why the direct impact of the financial accelerator on investment translates into an enhanced impact on labor productivity and employment. Without the financial accelerator, however, the contraction is much less severe, as the figure clearly illustrates.

We next explore the role of variable capital utilization and fixed costs. The dotted line in Figure 4 is the response the response of output and labor productivity to the country risk premium shock when these factors are absent. As with Figure 3, the solid line is our baseline model economy. As the figure illustrates, the presence of variable utilization enhances the output contraction by about 25%. The most dramatic effect is on labor productivity, however. Absent variable utilization and overhead costs, measured labor productivity would actually rise significantly during the crisis, reflecting diminishing marginal product of labor. With these factors present, however, labor productivity declines. The contraction in capital utilization reduces the marginal product of labor. The fixed costs work to enhance the contraction of measured output per worker.

Finally, we consider the role of the two key friction in the international sector: the inertia in foreign demand and the nominal rigidities in the retail sector for foreign goods. Though we do not report the results here, these international frictions do not

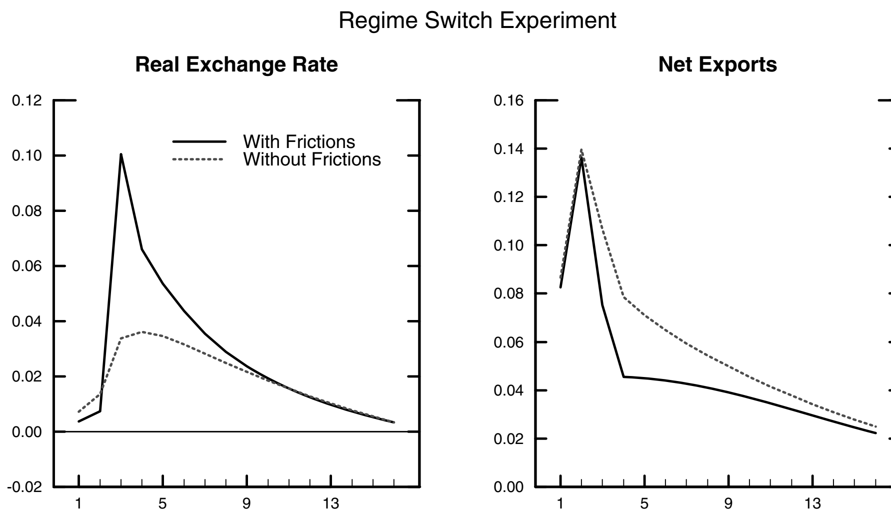


FIG. 5. The Role of Frictions in the International Sector.

NOTE: Model's response to a country risk premium shock. In the case without frictions, we eliminated trading frictions owing to inertia in foreign demand (i.e., $\nu = 1$) and nominal rigidities for foreign goods at the retail level.

affect substantially the response of the key aggregate quantity variables, including output, investment, and employment, etc. They do matter for the dynamics of the real exchange rate and net exports, however, as Figure 5 indicates. Note that as the left panel indicates, the real exchange rate depreciates sharply once the central bank abandons the exchange rate peg. The international frictions enhance the depreciation by a factor of about three (though, as we noted earlier, this contraction is still well below what occurred in practice.) Finally, with these frictions, the increase in net exports shrinks helping the model capture the relatively modest movements in net exports during the crisis.

3.4 Foreign-Denominated Debt

A number of authors have recently stressed that if debt is denominated in foreign currency units—as was recently the case for many emerging market economies—a fixed exchange rate regime may in fact be more desirable than a flexible exchange rate regime, since a devaluation weakens borrowers' balance sheets.[38] As we have discussed, in the Korean case only about a quarter of debt was denominated in foreign currency, which led us to consider debt in domestic currency as the baseline case. Nonetheless, it is useful to explore the extent to which our conclusions are robust to having foreign-indexed debt. Accordingly, we briefly consider the effect of

38. See, for example, Aghion, Bacchetta, and Banerjee (2000).

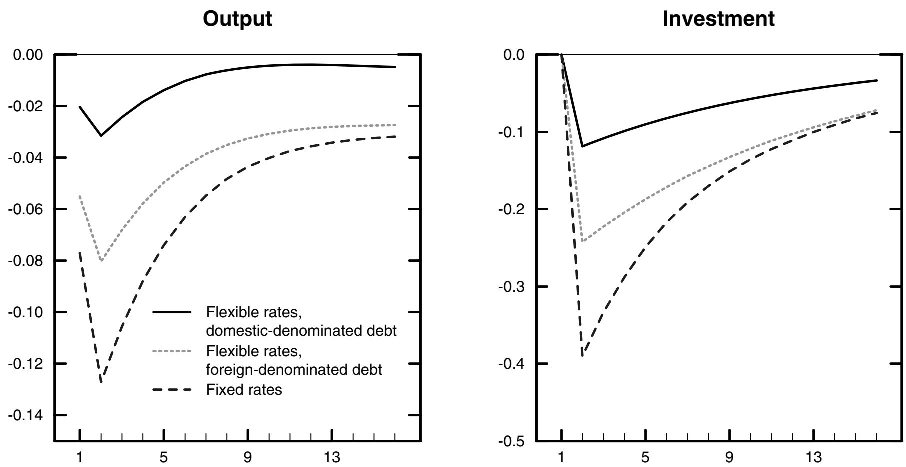


FIG. 6. Foreign-Denominated Debt.

NOTE: Model's response to a country risk premium shock.

foreign-indexed debt for the response of the model to an unanticipated increase in the country borrowing premium.[39]

Figure 6 plots the response of output and investment under three different scenarios: flexible exchange rate with debt denominated entirely in foreign currency, flexible exchange rate with domestic-denominated debt, and fixed exchange rate. As one would expect, foreign currency debt makes the flexible exchange rate regime considerably less attractive. Allowing for foreign currency debt implies a contraction in investment that is about twice as large as the contraction obtained in the case of domestic currency debt. With foreign currency debt, the depreciation of the exchange rate reduces entrepreneurial net worth, thus enhancing the financial accelerator mechanism. Nonetheless, even in this instance, the output drop remains smaller under flexible rates than under fixed rates. Put differently, the impact of the exchange rate on the balance sheets under flexible rates is less damaging than the contraction in asset prices under fixed rates. Our conclusion that a flexible rate regime remains dominant, even with foreign-indexed debt, is consistent with the conclusions of Cespedes, Chang, and Velasco (2004), though the details of the transmission mechanisms under fixed versus flexible rates differ significantly.

39. In the presence of debt denominated in foreign currency, the entrepreneurial net wealth and the external finance premium equations are modified as follows:

$$V_t = \left(1 + r_t^k\right) Q_{t-1} K_t - \left[(1 + \chi_{t-1}(\cdot))\, \Psi_{t-1} \left(1 + i_{t-1}^*\right) \frac{S_t}{S_{t-1}} \frac{P_{t-1}}{P_t}\right] \frac{S_{t-1} B_t^*}{P_{t-1}}$$

and

$$E_t \left\{1 + r_{t+1}^k\right\} = (1 + \chi_t(\cdot)) E_t \left\{\Psi_t \left(1 + i_t^*\right) \frac{S_{t+1}}{S_t} \frac{P_t}{P_{t+1}}\right\}.$$

4. CONCLUDING REMARKS

We developed a small open economy general equilibrium framework that featured money, nominal price rigidities, variable factor utilization, and a financial accelerator mechanism. The goal was to explore the interaction between the exchange rate regime and financial crises. As a way to judge the framework, we explored how well it was able to explain the behavior of the Korean economy over the 1997–98 period of financial crisis. We found that overall the model does well. It is able to match the observed drop in Korean output, employment, investment, and productivity during this time period. The financial accelerator mechanism turns out be quantitatively significant—accounting for about 50% of the total reduction in economic activity. In particular, the credit market frictions magnify the drop in investment demand during the crisis. Because prices are sticky and there is variable capital utilization, the enhanced decline in investment demand translates into an enhanced contraction in output, employment and labor productivity.

Our counterfactual exercises suggested that a policy of fixed exchange rates would have led to substantially higher welfare losses following a financial crisis than would have been obtained under a policy of flexible inflation targeting. The flexible inflation targeting policy was characterized by floating exchange rates and a well-formulated Taylor rule that had the nominal interest rate adjust to stabilize CPI inflation and deviations of output from steady state. Of course, our counterfactual experiment assumed that the Taylor rule was fully credible. In practice, however, successful implementation of a "good" Taylor rule requires that the overall economic infrastructure must be sound; e.g., the domestic budget cannot be out of control. This kind of consideration, however, poses a dilemma for the successful working of any kind of monetary regime. Indeed, as Obstfeld and Rogoff (1995) note, given that fixed exchange rate regimes never seem to last, it is not clear that this kind of policy can solve the credibility problem. Nonetheless, we concede that a better understanding of how credibility considerations factor into the choice of exchange regimes is an important topic for future research.

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