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Accounting for the East Asian Crisis: A Quantitative Model of Capital Outflows in Small Open Economies

To what degree can the qualitative and quantitative aspects of the East Asian crisis be accounted for within a dynamic general equilibrium model? This paper investigates that question using a framework in which the crisis itself is modeled as an exogenous shock to the country risk premium. This exercise has empirical discipline because the scale of the shock can be measured by the movement in the reported risk premium. We calibrate a quantitative sticky-price dynamic general equilibrium model of a small open economy to match the features of three East Asian economies: Thailand, Korea, and Malaysia. We identify a shock to the country risk premium using published data from international bond markets, and identify short-run monetary policy using observed domestic interest rates. We find that the modeled response to the observed increase in external interest rates substantially matches macroeconomic data on prices and quantities at the aggregate and sectoral level. However, the model has more difficulty explaining the large exchange rate devaluations that occurred in those economies.

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IN THE MIDDLE of 1997, a number of East Asian economies underwent a common financial crisis. South Korea, Malaysia, and Thailand all

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experienced severe exchange rate devaluations and current account reversals. In each economy, the currency devaluations were followed by large real contractions. Other economies in the region, including Hong Kong, Indonesia, the Philippines, Singapore, and Taiwan, were also affected to varying degrees. This paper examines some of the common features of these economic contractions and assesses the ability of standard, but modern, business cycle theory to quantitatively capture these features. The purpose is to “account” for the East Asian crisis using a quantitative small open economy model whose principles are drawn from the literature on equilibrium sticky-price open economy macroeconomics (S-POEM).

We model the crisis as an exogenous rise in the country risk premium on foreign lending to a small open economy. The data on bond yields show that the premium on the U.S. dollar bonds issued by entities in these countries rose dramatically during the crisis. In our model, we assume a rise in the country risk premium that exactly matches the rise in the country risk premium observed in the data. We compare the dynamic response of the model to the macroeconomic impact of the financial crisis in three East Asian economies (South Korea, Malaysia, and Thailand) that were severely affected by the crisis. In a sticky-price economy, however, the response of the economy to a given shock will depend on the stance of its monetary policy. The East Asian crisis marked a sharp structural break in monetary policy for these three countries, as they had previously been following a U.S. dollar peg. We model post-crisis monetary policy in two ways. First, noting that inter-bank lending rates rose dramatically at the onset of the crisis but then fell within a few quarters, we assume that these countries moved to a monetary policy rule that targeted domestic inflation and output,¹ but that in the immediate post-crisis period they deviated from this rule. We calibrate deviations to exactly match the rise in interest rates in the data. We refer to this as a Transition to Inflation Targeting monetary rule. Second, we assume that the countries immediately switched to a monetary policy rule that targeted domestic inflation and exchange rate changes (as well as domestic output). We refer to this as the Exchange Rate Target rule.

The distinguishing characteristic of the S-POEM literature (see Lane, 2001, for a review) is the notion that equilibrium includes the optimal decision rules of forward-looking agents with rational expectations, but that nominal prices only converge to market-clearing levels over time due to menu costs. A rise in the real interest rate causes households to delay consumption, and firms to delay investment spending. In the absence of a sufficient monetary easing, an external shock to the economy generates a contraction in nominal demand for domestic goods. This contraction in nominal demand translates into a contraction in real demand in the presence of sticky prices.

In East Asia, the U.S. dollar is the currency of denomination of much international trade (see McKinnon and Schnabl 2004). In our model, both import and export prices are set in a foreign currency, while goods produced for the domestic economy are priced in the domestic currency. We refer to this as ‘dollar currency pricing’.

1. South Korea and Thailand explicitly describe their monetary rules as being inflation targeting.

In the model, a rise in external interest rates above domestic interest rates leads to an exchange rate depreciation. A nominal exchange rate depreciation increases the price of imports relative to domestic goods, leading to a switch of expenditure toward domestic goods. Conversely, the exchange rate depreciation does not reduce the real price of exports. This pricing model combines the producer currency-pricing framework of Obstfeld and Rogoff (1995), which emphasizes expenditure switching, and the local currency-pricing framework of Betts and Devereux (1996, 2000), in which exchange rate changes have no immediate expenditure-switching effects. This dollar currency pricing model is effective in matching the immediate response of export and import prices to the currency devaluations observed in East Asia.

Another aspect of the data in which we are interested is the sectoral response of output. The textbook response of a small open economy to an external interest rate shock is a switch from the production of non-traded goods for domestic use to the production of traded goods to repay foreign debts (see Sachs and Larrain 1993). However, this does not match the sectoral response observed in the data for East Asia during the financial crisis, when a sharp drop in the production of both traded and non-traded goods took place. To deal with this, we depart from the textbook model (following McCallum and Nelson, 2000, Christiano, Gust, and Roldos, 2002) by incorporating intermediate imported materials into production. In our model, imported intermediate materials are an important factor in the production of traded goods. These inputs must be purchased in advance, which subjects them to finance costs. The rise in the price of international borrowing during the crisis resulted in higher costs of obtaining the working capital needed to purchase imported materials. This resulted in an equilibrium fall in the output of traded goods. Relative to other papers that have used imported materials, we emphasize sticky prices in general and dollar currency pricing to explain the slow response of exports to an exchange rate devaluation.

We find that when we match the shocks to external interest rates in our model to the data under our two alternative monetary policy rules, the modeled responses of nominal and real macroeconomic aggregates match their counterparts in the data both qualitatively and quantitatively, although the Transition to Inflation Targeting rule performs somewhat better. One controversial aspect of the crisis is whether the monetary response of the central banks contributed to its severity. In light of this, we also examine a counterfactual case in which the monetary policy response to the crisis is purely described by a Taylor (1996) rule. In this case, the contractions in output and investment are substantially smaller and less persistent.

Our paper is related to a large body of literature on the causes of the emerging market crises of the mid- to late-1990s. Explanations for these crises can be divided into two broad categories: internal and external. Internal crisis theories explain the crisis as the result of either policy failings or the limitations of financial markets within the affected economies. External explanations describe the crisis as the result of imperfections within international financial markets themselves. Our paper is essentially agnostic with respect to this distinction. We measure the exogenous shock that drove the crisis using observed country risk spreads on U.S. dollar bonds. These

spreads could be driven by herding behavior among international investors (see Calvo and Mendoza 2000) or by an elimination of loan guarantees by domestic fiscal authorities (see Corsetti, Pesenti, and Roubini 1999). In this sense the shock may be consistent with either an ultimately internal or external source. Thus, our paper does not offer a fundamental explanation of the source of the crisis. Rather, we impose a maintained hypothesis that whatever the underlying source, the scale of the crisis itself can be represented by the movement in observed risk spreads, and that these risk spreads are independent of the subsequent path of the economy and the stance of monetary policy. Under this hypothesis, we ask how well the response to the crisis can be tracked by a sticky-price multi-sector dynamic open economy model.

A number of theories have explained the crises as being outcomes of internal policy errors or market failures internal to the affected countries. Chang and Velasco (2000, 2001) implicate bank runs caused by a maturity mismatch in the domestic banking sector as the source of the crisis. Burnside, Eichenbaum, and Rebelo (2001a) model a currency mismatch that occurs within the banking system due to government loan guarantees. Dooley (2000) argues that implicit loan guarantees of private-sector debt in East Asia would lead to a currency crisis if those guarantees were called and the resulting debts were to be monetized. Burnside, Eichenbaum, and Rebelo (2001b) construct a model that allows for a quantitative study of the size of debts that might be incurred, and the resulting effect on exchange rates. In addition, many papers have stressed the aggregate importance of the balance-sheet aspects of the East Asian crisis. Many private East Asian debtors faced a mismatch in the currency denomination of their assets and liabilities. Aghion, Bacchetta, and Banerjee (2000, 2001) show how balance-sheet constraints may lead to a self-fulfilling exchange rate crisis. Arellano and Mendoza (2002) show that balance-sheet constraints may be important in generating “sudden stops,” defined as a switch toward a binding national constraint on capital inflows for a borrowing country (see Calvo and Reinhart 1999). Since any binding constraint on capital flows can by definition be reinterpreted as a rise in the external borrowing rate, our paper is also consistent with this literature.

A few papers have studied the quantitative impact of interest rate shocks, an exercise very similar to ours. Mendoza (2001) studies the business cycle effects of sudden stops in a quantitative business cycle model. McKibbin (1999) studies the effect of an interest rate shock on a multi-country model at annual frequencies. Neumayer and Perri (2004) examine the business cycle behavior of emerging markets subject to country risk premium shocks calibrated to the time-series behavior of Argentine spreads. Burstein, Eichenbaum, and Rebelo (2002) quantitatively examine the effect of interest rate shocks on exchange rates and nominal prices. However, none of these papers focuses on the quantitative accounting question that is the centerpiece of our analysis. Kim (2002) constructs a dynamic multiple equilibrium model to examine whether “animal spirits” shocks can explain the quantitative features of the Asian crisis. Gertler, Gilchrist, and Natalucci (2000) explore whether balance-sheet effects help in explaining the contraction that occurred following the East Asian currency crisis.

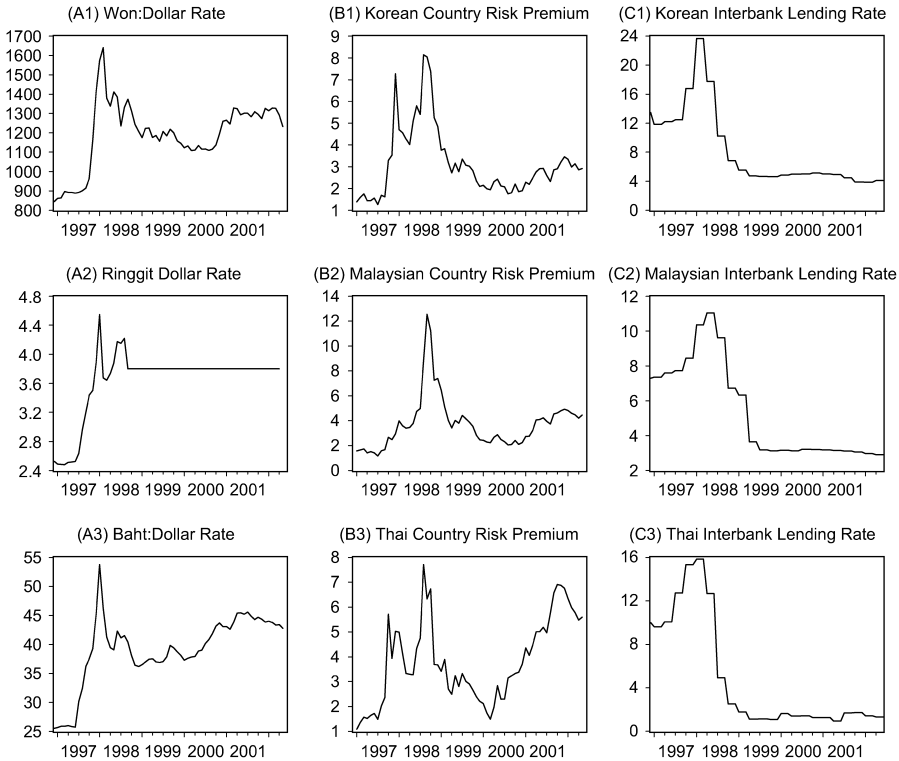


Fig. 1. Financial Market Outcomes. This figure shows monthly time-series data for South Korea [Row 1], Malaysia [Row 2], and Thailand [Row 3]. The series includes the exchange rate with the U.S. dollar [Column A], the spread between the HSBC U.S. dollar bond index and 3-month Treasury yields [Column B], and the inter-bank lending rate [Column C].

The rest of the paper is organized as follows. Section 1 describes the response of exchange rates, country risk premiums, and interest rates for South Korea, Malaysia, and Thailand during the East Asian crisis. Section 2 describes a two-sector sticky-price model of a small open economy. Section 3 explains how we calibrate the model. Section 4 presents the results, and section 5 offers some conclusions.

1. FINANCIAL VARIABLES IN SOUTH KOREA, MALAYSIA, AND THAILAND

This section documents the response of some key financial variables in South Korea, Malaysia, and Thailand to the East Asian crisis.^{2,3} Figure 1, Column A,

2. Data on the HSBC indices are from Bloomberg. The remaining East Asian national income accounting, exchange rate, and interest rate data used in this paper are from CEIC/DRI Asia database, which gathers published data from official sources.

3. We defer a full discussion of the response of prices and real aggregates in these countries to Section 4.

graphs the month-by-month movements in the Korean won, the Malaysian ringgit, and the Thai baht relative to the U.S. dollar from 1997 to 2002. Through early 1997, these currencies were stable against the U.S. dollar, but in the third quarter of 1997, each currency experiences a large depreciation. After a large but brief overshooting, the currencies settled at levels that were between 30% and 40% weaker than pre-crisis levels. The timing of the depreciations varied across the countries. The baht began depreciating at the outset of the third quarter, while the ringgit and the won do not depreciate until late in the third quarter.

Figure 1, Column B, shows the response of the country risk premium for each of these economies. Since early 1997, HSBC has calculated yields on an index of U.S. dollar bonds issued in each of a number of Asian emerging markets. We measure the country risk premium for South Korea, Malaysia, and Thailand as the spread between the HSBC yield indices and contemporaneous yields on 3-month U.S. Treasury bills. In early 1997, the observed spreads in each country are between 100 and 200 annualized basis points. During late 1997, spreads rise dramatically in South Korea and Thailand, approaching levels of between 600 and 800 annualized basis points and reaching a peak in late 1998. Malaysia experiences a more moderate rise of 400 basis points in late 1997, before rising to more than 1200 basis points in late 1998. Later, spreads narrow but remain between 300 and 500 basis points even 5 years later.

Figure 1, Column C, reports deviations of the short-term inter-bank lending rate from the mean interest rate in the first half of 1997. In each economy, the inter-bank lending rate rose sharply during the initial periods of the crisis. In Korea, the interest rate at peak was 1200 basis points above the pre-crisis level. In Malaysia and Thailand, the rise in the interest rate was not as sharp, reaching a peak 400 basis points above the previous level. After the fall of 1998, however, interest rates in all countries dropped sharply. In Korea and Thailand, the nominal interest rate was 800 basis points below the pre-crisis level by 1999. In Malaysia, the nominal interest rate was 400 basis points below the pre-crisis level by 1999.

2. THE MODEL

We model a small open economy populated by a representative agent that owns the factors of production and borrows from the world economy at an exogenous interest rate. A range of non-traded and traded goods are produced and sold by a range of monopolistically competitive firms.

2.1 Demand

The representative agent. The infinitely lived representative agent has rational expectations. In any period, the agent derives utility from consumption, C_t , and linear disutility from labor, H_t , as in the indivisible labor model of Hansen (1985) and Rogerson (1988). The agent's subjective discount function is a declining function of the agent's consumption level. Following Mendoza (1991), the subjective discount

rate is a concave function of current consumption to ensure a stationary level of wealth:

$$V_t = \max_{C,H} [\log(C_t) - \Gamma H_t] + \beta(C_t) E_t[V_{t+1}] \beta(C_t) = e^{-\bar{\beta} \ln(\Delta + C_t)}. \tag{1}$$

The agent issues foreign currency debt, D_t , at an exogenous rate $1 + r_t$ and domestic debt, B_t , at a nominal interest rate, $1 + i_t$. Domestic currency debt is in zero net supply. Sector-specific capital K^T and K^N is rented to firms in the traded and non-traded goods industries in competitive markets at rates R^T and R^N , respectively. The agent supplies labor in competitive markets at wage rate W , and receives profits from monopolistically competitive firms that sell traded and non-traded goods domestically as well as to exporters; total profits are $\Pi = \Pi^T + \Pi^N + \Pi^{EX}$. Agents purchase final goods at price P and allocate goods for consumption and for traded and non-traded goods investment, I^T and I^N . Lump-sum taxes finance government spending, G . Define S as the spot exchange rate. The budget constraint is:

$$S_t D_t + B_t = (1 + r_{t-1}) S_t D_{t-1} + (1 + i_{t-1}) B_{t-1} + P_t [C_t + I_t^T + I_t^N + G_t] - (W_t H_t + R_t^T K_t^T + R_t^N K_t^N + \Pi_t). \tag{2}$$

Consumption, investment, and government goods are defined as a nested CES combination of domestically produced non-traded goods, X^N , domestically produced traded goods, X^{Td} , and imported traded goods, X^{Tm} . Domestic and foreign traded goods are combined into a quantity of traded goods absorbed, X^T . The price index is the cost-minimizing marginal cost of acquiring these goods:

$$C_t + I_t^T + I_t^N + G_t = X_t = [a^{\phi-1} \{X_t^T\}^\phi + (1 - a)^{\phi-1} \{X_t^N\}^\phi]^{\frac{1}{\phi}} \tag{3}$$

$$X_t^T = [b^{\mu-1} \{X_t^{Td}\}^\mu + (1 - b)^{\mu-1} \{X_t^{Tm}\}^\mu]^{\frac{1}{\mu}}. \tag{4}$$

The non-traded aggregate is a Dixit-Stiglitz aggregate of a unit range of differentiated goods, x_i^N . The domestic traded aggregate is a combination of differentiated goods, x_i^{Td} . The price indices of domestic traded and non-traded goods are denoted by P^{Td} and P^N :

$$X_t^N = \left[\int_0^1 \{x_{t,i}^N\}^\xi di \right]^{\frac{1}{\xi}} \quad P_t^N = \left[\int_0^1 \{p_{t,i}^N\}^{\frac{1}{1-\xi}} di \right]^{1-\xi} \tag{5}$$

$$X_t^{Td} = \left[\int_0^1 \{x_{t,i}^{Td}\}^\xi di \right]^{\frac{1}{\xi}} \quad P_t^{Td} = \left[\int_0^1 \{p_{t,i}^{Td}\}^{\frac{1}{1-\xi}} di \right]^{1-\xi}. \tag{6}$$

The price index of imported goods is $S \times P^{T*}$. The price of the cost-minimizing

combination of domestic traded goods and imports is then P^T , defined in a straightforward manner from the aggregator X^T .

The representative agent accumulates capital in each sector through investment, subject to adjustment costs:

$$K_{t+1}^T = (1 - \delta)K_t^T + I_t^T - \frac{e}{2} \left(\frac{I_t^T}{K_t^T} - \delta \right)^2 K_t^T \quad (7)$$

$$K_{t+1}^N = (1 - \delta)K_t^N + I_t^N - \frac{e}{2} \left(\frac{I_t^N}{K_t^N} - \delta \right)^2 K_t^N. \quad (8)$$

The home agent maximizes utility subject to the budget constraint and the accumulation equations for sectoral capital. The first-order conditions that characterize the optimal plans are:

$$\frac{1}{C_t} + \beta'(C_t)V_{t+1} \equiv P_t \Omega_t \quad (9)$$

$$\Gamma = W_t \Omega_t \quad (10)$$

$$\Lambda_t^T \equiv \frac{\Omega_t P_t}{1 - e \left(\frac{I_t^T}{K_t^T} - \delta \right)} \quad (11)$$

$$\Lambda_t^N \equiv \frac{\Omega_t P_t}{1 - e \left(\frac{I_t^N}{K_t^N} - \delta \right)} \quad (12)$$

$$P_t a^{\varphi-1} \{X_t^N\}^{\varphi-1} \{X_t\}^{1-\varphi} = P_t^{NT} \quad (13)$$

$$\frac{p_{t,i}^{NT}}{P_t^{NT}} = \left(\frac{x_{t,i}^N}{X_t^N} \right)^{\xi-1} \quad (14)$$

$$P_t (1-a)^{\varphi-1} \{X_t^T\}^{\varphi-1} \{X_t\}^{1-\varphi} = P_t^T \quad (15)$$

$$\frac{p_{t,i}^{Td}}{P_t^T} = \left(\frac{x_{t,i}^{Td}}{X_t^{Td}} \right)^{\xi-1} \quad (16)$$

$$P_t^T b^{\mu-1} \{X_t^{Td}\}^{\mu-1} \{X_t^T\}^{1-\mu} = P_t^{Td} \quad (17)$$

$$P_t^T(1-b)^{\mu-1}\{X_t^T\}^{\mu-1}\{X_t^T\}^{1-\mu} = S_t \times P_t^{*T} \quad (18)$$

$$\Omega_t = \beta(C_t)E_t \left[\Omega_{t+1}(1+r_t) \frac{S_{t+1}}{S_t} \right] \quad (19)$$

$$\Omega_t = \beta(C_t)E_t[\Omega_{t+1}(1+i_t)] \quad (20)$$

$$\Lambda_t^T \equiv \beta(C_t)E_t \left[\Lambda_{t+1}^T \left(1 - \delta + e \frac{I_{t+1}^T}{K_{t+1}^T} \left(\frac{I_{t+1}^T}{K_{t+1}^T} - \delta \right) \right) + \Omega_{t+1} R_{t+1}^T \right] \quad (21)$$

$$\Lambda_t^N \equiv \beta(C_t)E_t \left[\Lambda_{t+1}^N \left(1 - \delta + e \frac{I_{t+1}^N}{K_{t+1}^N} \left(\frac{I_{t+1}^N}{K_{t+1}^N} - \delta \right) \right) + \Omega_{t+1} R_{t+1}^{NT} \right], \quad (22)$$

where Ω_t is the shadow value of domestic currency, and Λ_t^T and Λ_t^N are the shadow values of sector-specific capital. Equations (9) and (10) describe the optimal choice of consumption and labor supply. Equations (11) and (12) characterize the choice of investment in the two sectors. Equations (13)–(14) and (15)–(18), respectively, describe the demand for aggregate non-traded goods and traded goods, and the individual demands for each type of goods. Equations (19) and (20) describe the Euler equations for international borrowing, and Equations (21) and (22) describe the optimal choices for capital accumulation in each sector.

Exports. Some traded goods are sold overseas by exporting retailers. The retailers sell differentiated traded goods at a foreign currency price, p^{ST} . Define aggregate exports, EX , as a Dixit-Stiglitz combination of these differentiated goods and an associated price index, p^{ST} :

$$EX_t^T = \left[\int_0^1 \{ex_{t,i}^T\}^{\xi} di \right]^{\frac{1}{\xi}} \quad P_t^{ST} = \left[\int_0^1 \{p_{t,i}^{ST}\}^{1-\xi} di \right]^{\frac{1}{1-\xi}}, \quad 0 < \xi < 1. \quad (23)$$

The foreign demand for these exports is determined in parallel to the domestic demand for imports.

$$P_t^{*T}(1-b^*)^{\mu-1}\{EX_t^T\}^{\mu-1}\{X_t^{*T}\}^{1-\mu} = P_t^{ST} \quad (24)$$

$$\frac{p_{t,i}^{ST}}{P_t^{ST}} = \left(\frac{ex_{t,i}^T}{EX_t^T} \right)^{\xi-1}, \quad (25)$$

where X^{T*} represents the total foreign demand for traded goods.

2.2 Production

Traded goods. Traded goods are produced with a combination of sector-specific capital, labor H^T , and imported materials M .

$$Y_t^T = A^1 [d^{t-1} \{V_t^T\}^\gamma + (1-d)^{t-1} \{M_t\}^\gamma]^{1/\gamma} \quad V_t^T \equiv A^2 \{K_t^T\}^{\theta_T} \{H_t^T\}^{1-\theta_T}, \quad (26)$$

where V^T is the domestic value added in the traded goods sector. Traded goods manufacturers are price takers in output and input markets. The manufacturers purchase the imported materials one period in advance with foreign currency borrowed at rate r_{t-1} . The first-order conditions of the firms' profit-maximization problem are

$$PPI_t^T (1 - \theta_T) \frac{V_t^T}{H_t^T} d^{t-1} \left\{ \frac{V_t^T}{Y_t^T} \right\}^{\gamma-1} = W_t \quad PPI_t^T \theta_T \frac{V_t^T}{K_t^T} d^{t-1} \left\{ \frac{V_t^T}{Y_t^T} \right\}^{\gamma-1} = R_t^T \quad (27)$$

$$(1-d)^{t-1} E_{t-1} \left[PPI_t^T \left\{ \frac{M_t}{Y_t^T} \right\}^{\gamma-1} \right] = (1+r_{t-1}) P_{t-1}^{T*} E_{t-1} [S_t], \quad (28)$$

where PPI^T is the producer price of traded goods, and P^{T*} is the foreign currency price of imported materials. Conditions (Equations 27) characterize the optimal choice of labor and capital in traded goods production, whereas Equation (28) represents the optimal choice of imported materials. Note that the output of traded goods will be limited within any period by the pre-set quantity of imported materials. In addition, the foreign interest rate will adversely affect the purchases of imported materials.

Non-traded goods. Price-taking non-traded goods manufacturers use labor and capital to produce goods, Y^N , sold at price PPI^N :

$$Y_t^N = \{K_t^N\}^{\theta_N} \{H_t^N\}^{1-\theta_N}. \quad (29)$$

The first-order conditions of the firms' profit-maximization problem, for the choice of labor and capital, are

$$PPI_t^N (1 - \theta_N) \frac{Y_t^N}{H_t^N} = W_t \quad PPI_t^N \theta_N \frac{Y_t^N}{K_t^N} = R_t^N. \quad (30)$$

2.3 Sticky Prices

In this model, there are three types of sticky prices: the retail prices of non-traded goods, domestic retail prices of traded goods, and foreign currency prices of exported goods. The dynamics of each of these prices follow a similar framework. For each, there is a range of monopolistically competitive price setters who purchase an undifferentiated input goods item (i.e. traded or non-traded) from manufacturers at a scale invariant marginal cost, generically referred to as \overline{MC} , and face a constant elasticity demand curve. In each period, a randomly distributed fraction $0 \leq (1 - \kappa) \leq 1$ of price setters get a chance to adjust prices, as described by Calvo (1983) and Yun (1996). The price-setting mechanism can be described as follows.

Define \bar{p} and \bar{q} as the price and quantity of the individual generic price setter, and the generic aggregate output and price indices as \bar{Q} and \bar{P} :

$$\bar{Q}_t = \left[\int_0^1 \bar{q}_{t,i}^\xi di \right]^{\frac{1}{\xi}} \quad \bar{P}_t = \left[\int_0^1 \bar{p}_{t,i}^{1-\xi} di \right]^{1-\xi} \quad \bar{q}_{t,i} = \left(\frac{\bar{p}_{t,i}}{\bar{P}_t} \right)^{-\frac{1}{1-\xi}} \bar{Q}_t. \quad (31)$$

As the model set out above assumes that the elasticity of substitution of the final goods purchaser (whether domestic or foreign) for both traded export goods and non-traded goods are all equal and constant at level ξ , this description of price and quantity aggregators applies to each of the activities equally.

Generic profits are $\bar{\Pi} \equiv (\bar{p} - \widetilde{MC}) \cdot \bar{q}$. Price setters with an opportunity to change their price maximize the sum of expected discounted profits over the expected life of the price. We assume that shocks occur after the price setters have chosen their prices. Thus, the price index is quasi-fixed in any period, as described in Rotemberg and Woodford (1997):

$$\begin{aligned} & \max_p E_{t-1} \left[\sum_{j=t}^{\infty} \left(\prod_{l=t}^j \frac{\kappa}{(1+i_l)} \right) \Pi_j \right] \\ & = \max_p E_{t-1} \left[\sum_{j=t}^{\infty} \left(\prod_{l=t}^j \frac{\kappa}{(1+i_l)} \right) \bar{P}_j^{\frac{1}{1-\xi}} \bar{Q}_j \left\{ \bar{p}_j^{\frac{\xi}{1-\xi}} - \bar{p}_j^{\frac{1}{1-\xi}} MC_j \right\} \right]. \end{aligned} \quad (32)$$

The optimal price \bar{p}_t^* is the choice that maximizes the expected profits as

$$\bar{p}_t^* = \frac{1}{\xi} \frac{E_{t-1} \left[\sum_{j=t}^{\infty} \left(\prod_{l=t}^j \frac{\kappa}{(1+i_l)} \right) \bar{P}_j^{\frac{1}{1-\xi}} \bar{Q}_j MC_j \right]}{E_{t-1} \left[\sum_{j=t}^{\infty} \left(\prod_{l=t}^j \frac{\kappa}{(1+i_l)} \right) \bar{P}_j^{\frac{1}{1-\xi}} \bar{Q}_j \right]}. \quad (33)$$

The price index evolves over time as

$$\bar{P}_t^{\xi-1} = \kappa \bar{P}_{t-1}^{\xi-1} + (1 - \kappa) \bar{p}_t^{*\xi} - 1. \quad (34)$$

Each of the price setters in each of the three areas follows this pattern. A unit measure of non-traded (traded) retailers purchase undifferentiated goods in the non-traded (traded) manufacturing sector, and sell differentiated non-traded (traded) goods to the home country household. Likewise, a unit measure of retailers purchase undifferentiated traded goods, and sell them as differentiated export goods to foreign residents. In the non-traded sector, retailing firms purchase goods at marginal cost, PPI^N , and sell to the household at price p^N . In the traded goods sector, retail firms buy at marginal cost, PPI^T , and sell at price p^T (domestic traded goods retailers) or

Sp^{ST} (export retailers). The variables for the generic price setter are {Price Index, Firm Price, Quantity Index, Firm Quantity, Marginal Cost, Profits}, or in notation $\{\tilde{P}_t, \tilde{p}_t, Q_t, \tilde{q}_t, MC_t, \Pi_t\}$. The corresponding variables for the non-traded industry are, in order, $\{P_t^N, p_{i,t}^{NT}, X_t^N, x_{i,t}^N, PPI_t^N, \Pi_t^N\}$. The corresponding variables for the traded industry are $\{P_t^T, p_{i,t}^T, X_t^{Td}, x_{i,t}^T, PPI_t^T, \Pi_t^T\}$. The corresponding variables for the export firms are $\{P_t^{ST}, p_{i,t}^{ST}, EX_t, ex_{i,t}^T, PPI_t^{ST/ST}, \Pi_t^{EX}\}$.

2.4 Monetary Policy

Before the crisis, the three countries studied were effectively on U.S. dollar exchange rate pegs. Clearly, the crisis represented a structural break in the conduct of monetary policy. During the crisis, there was a sharp rise in interest rates, and at the same time exchange rates depreciated substantially (see Figure 1). In the summer and fall of 1998, South Korea and Thailand adopted domestically oriented monetary policies that their central banks now describe as inflation targets with short-term interest rates as operating targets. At roughly, the same time, Malaysia adopted a currency board to fix the ringgit relative to the U.S. dollar (although at a much weaker rate than the pre-crisis level).

We consider two alternative representations of monetary policy. In each case, the central bank determines a long-term nominal growth rate that implies a long-term nominal interest rate, \bar{i} , and CPI inflation rate, $\bar{\pi}$. The first, referred to as the Transition to Inflation rule, models a break in monetary policy that occurs due to the crisis. During the initial periods of the crisis, the central bank sets domestic interest rates as a direct (though time-varying function) of the interest premium. After some period L , the central bank switches to an inflation targeting interest rate rule.

$$i_t = \omega_t(r_t) \quad t \leq L \quad i_t - \bar{i} = \rho_\pi \left(\frac{P_t}{P_{t-1}} - \bar{\pi} \right) + \rho_Y (GDP_t - \overline{GDP}) \quad t > L. \tag{35}$$

Define real GDP as the sum of the value added in the traded and non-traded sectors divided by the price level and measured as the sales to domestic consumers, plus the sales to foreigners, less the cost of material imports:

$$GDP_t \equiv \frac{P_t^{Td} X_t^{Td} + S_t P_t^{ST} EX_t - (1 + r_{t-1}) S_t P_{t-1}^{*T} M_t + P_t^N Y_t^{NT}}{P_t}. \tag{36}$$

Note that we assume that once the risk premium shock occurs, agents have the full information about the policy pursued in each period after the crisis, including the date of the shift to inflation targeting. Essentially, under the Transition rule, the initial attempts by the central bank to raise interest rates to stabilize exchange rates are viewed as temporary. Note also that the policy targets the absorption deflator, which differs slightly from Taylor (1996) for the U.S., which targets the GDP deflator. This modification is more consistent with the actual, current policies of South Korea and Thailand, which target a basket of goods that includes imports.

Second, we model the rise in interest rates that occurs at the outset of the crisis as the outcome of a credible policy rule that partly targets exchange rates as well as domestic inflation. Under this monetary policy, referred to as the Exchange Rate Target rule, the central bank puts more weight on exchange rate stability than in the pure Taylor rule described above. The Exchange Rate Target rule recognizes the historical importance that these countries placed on exchange rate stability, while at the same time allowing for the fact that post-crisis monetary policy deviated substantially from a fixed exchange rate.⁴ This rule is described by:

$$i_t - \bar{i} = \rho_e \left(\frac{S_t}{S_{t-1}} - \bar{\pi} \right) + \rho_\pi \left(\frac{P_t}{P_{t-1}} - \bar{\pi} \right) + \rho_Y (GDP_t - \overline{GDP}). \tag{37}$$

Unlike the Transition to Inflation Targeting rule, this Exchange Rate Target rule is not designed to match exactly the response of nominal interest rates in the immediate post-crisis period. We discuss the choice of parameters of Equation (37) below. In a steady state with constant inflation and a constant real exchange rate, this rule will exactly equal the Taylor rule in Equation (35).

2.5 The Crisis and Equilibrium

We study the response of the economy to a single shock that occurs at time $t = 1$. The single shock generates a dynamic path for the country risk premium through the finite time period $T, \{r_t\}_{t=1}^T$, after which the external interest rate reverses to its long-term level. Define Ξ_t as the history of the economy up to time t . An equilibrium is a set of policy functions of the representative agents, manufacturers, and price setters: $C(\Xi_t), I^T(\Xi_t), I^N(\Xi_t), X(\Xi_t), X^T(\Xi_t), X^N(\Xi_t), X^{Td}(\Xi_t), EX(\Xi_t), IM(\Xi_t), Y^T(\Xi_t), Y^N(\Xi_t), M(\Xi_t), H(\Xi_t), H^T(\Xi_t), H^N(\Xi_t), D(\Xi_t), K^T(\Xi_t), K^N(\Xi_t), w^T(\Xi_t), w^N(\Xi_t), p^T(\Xi_t), p^N(\Xi_t), p^{ST}(\Xi_t)$; and price functions: $P(\Xi_t), P^T(\Xi_t), W(\Xi_t), R^T(\Xi_t), R^N(\Xi_t), PPI^T(\Xi_t), PPI^N(\Xi_t), S(\Xi_t), i(\Xi_t)$, which solve the first-order conditions of the agents' optimization problems, and labor and goods markets clear:

$$H_t^T + H_t^{NT} = H_t \int_0^1 x_{t,i}^T di + \int_0^1 e x_{t,i}^T di = Y_t^T \int_0^1 x_{t,i}^N di = Y_t^N. \tag{38}$$

3. CALIBRATION

Lacking a closed-form solution, we log-linearize and solve the approximate linear model using the solution algorithm in King and Watson (2002). We examine three separate numerical cases for each of South Korea, Malaysia, and Thailand. We calibrate the long-term macroeconomic ratios of each case to the national income data

4. We find that allowing for alternative monetary rules which place very high weights on exchange rate stability produces far too little movement in real exchange rates, and much too high increases in nominal interest rates and declines in output.

of the corresponding country from the time period 1980–1996 in Korea and Thailand and 1987–1996 for Malaysia. We calibrate a to match non-traded goods as a share of GDP as reported in Table 1, Row [A]. Exports as a share of GDP are reported in Row [B]. Intermediate materials as a share of imports are reported in Row [C]. We calibrate b and d to match Rows [B] and [C]. We calibrate the steady-state government consumption-GDP ratio to the average of this share for each country as reported in Row [D].

Sarel (1997) uses cross-country data to estimate the capital intensity of various one-digit International Standard Industrial Classification (ISIC) code industries. For 1990–1996, we calculate the weighted averages of Sarel’s capital intensity estimates of the traded sectors (Agriculture, Manufacturing, and Mining), where the weights are the share of the one-digit industry in traded value added. We then estimate θ_T , the average traded goods capital intensity across time. We repeat the process for the remaining one-digit sectors that are classified as non-traded to estimate θ_N . The capital intensity parameters are reported in Rows [E] and [F].

Lane and Milesi-Ferretti (2001) construct country-level data on net international investment positions. Row [G] shows the average of net external asset positions as

TABLE 1
PARAMETERS WE CALIBRATE THREE VERSIONS OF THE MODELS, EACH PEGGED TO PARAMETER ESTIMATES FROM SOUTH KOREA, MALAYSIA, AND THAILAND. THIS TABLE REPORTS THE ESTIMATES THAT WERE USED TO CALIBRATE THESE MODELS

	South Korea	Malaysia	Thailand
[A] Non-Traded Goods as a % of GDP [a]	0.597 [0.404]	0.512 [0.486]	0.578 [0.418]
[B] Exports as a % of GDP [b]	0.328 [0.326]	0.728 [0.452]	0.308 [0.510]
[C] Imported Materials as a % of Imports [d]	0.583 [0.311]	0.689 [0.493]	0.273 [0.156]
[D] Government Consumption as a % of GDP (G/GDP)	0.104	0.123	0.112
[E] Traded Capital Intensity (θ_T)	0.307	0.350	0.307
[F] Non-traded Capital Intensity (θ_N)	0.306	0.296	0.234
[G] External Debt as a % of GDP (D/GDP)	0.88	1.78	1.41
[H] Steady-State Interest Rate (r)	0.0138	0.0139	0.0137
Time Discount Factor ($\beta'(C)$)		-0.00001	
Depreciation Rate (δ)		0.025	
Capital Adjustment Elasticity ($e\delta^{-1}$)		0.15	
Price Stickiness (κ)		0.75	
	Elasticity of Substitution Between		
Traded and Non-Traded Goods ($1/(1 - \phi)$)		0.66	
Imported Materials and Domestic Value Added ($1/(1 - \gamma)$)		0.7	
Domestic Goods and Imports ($1/(1 - \mu)$)		0.6	
	Monetary Policy Rule		
Taylor Rule	$\rho_\pi = 1.5$	$\rho_Y = 0.5$	
Exchange Rate Target	$\rho_\pi = 1.2$	$\rho_Y = 0.5$	$\rho_e = 0.3$

a share of GDP. The steady-state interest rate, r , is set as equal to the average of HSBC's country-level U.S. dollar bond yield in the first half of 1997, reported in Row [H]. We calibrate the two parameters of the subjective discount rate function, (\cdot) , so that debt as a share of GDP matches Row [G] at the steady-state interest rate reported in Row [H] and $\beta'(C) = -0.00001$ so as to have little impact on the short-run dynamics of the model.

The remaining parameters are common to all models. We calibrate the dynamics of adjustment at standard values taken from the calibrated business cycle literature. Following Baxter and Crucini (1993), the depreciation rate of capital is set at $\delta = 0.025$ and the capital adjustment cost is set so that the steady-state elasticity of the investment-capital ratio with respect to a marginal Tobin's q , $(e\delta)^{-1} = 15$. Following Galí and Gertler (2000), we set $\kappa = 0.75$, so that prices change on average once per year. Following Galí and Monacelli (2002), we assume a set of tax and transfers such that the steady-state markups are equal to zero (i.e. $\xi \rightarrow 1$).

The elasticity of substitution between domestic production and imports (and the demand elasticity of exports) is set at $1/(1 - \mu) = 0.6$, which is an average of the estimates from Asia that were reported by Reinhart (1995). Kollmann (2001) uses the same elasticity for a model of developed economies. The elasticity of substitution between traded and non-traded goods is $1/(1 - \phi) = 0.66$, based on a GMM estimate using pooled data from five Asian countries as described by Ostry and Reinhart (1992). The elasticity of substitution between materials and value added, $1/(1 - \gamma) = 0.7$, is set at 0.7 following Rotemberg and Woodford (1996). We calibrate the technology parameters, A^1 , A^2 , and A^3 plus the parameters of export demand function so that (1) the steady-state marginal cost of domestic value added in the traded sector is equal to the marginal cost of imported materials, (2) the steady-state marginal cost of domestic final goods is equal to the marginal cost of imported final goods, (3) the steady-state marginal cost of traded goods is equal to the steady-state marginal cost of non-traded goods, and (4) the real exchange rate between the foreign CPI and the domestic traded good price is equal to one.

We calibrate the interest rate shock based on the actual rise in the risk premium that occurred in the data (see Figure 1). For the initial periods, we can calibrate the shock to the actual rise in the average quarterly spreads between HSBC's country-level U.S. dollar bond yield indices (for South Korea, Malaysia, and Thailand) and U.S. Treasury bills. However, the response of the economy to the rise in country risk depends on the complete time path, which is unobservable at the time of writing. We conjecture a very long-lived rise in the country premium, based on the rise in yields of long-term bonds. Before the crisis, very few bonds with maturities greater than 10 years were issued (and only by the most credit-worthy borrowers). However, the yield spread of South Korea, Malaysia, and Thailand⁵ corporate bonds with maturities of between 10 and 30 years over U.S. Treasury bonds were observed

5. Foreign currency bonds with maturities of between 10 and 30 years were issued by Korea Electric Power (KEPCO), Petronas in Malaysia, and the Bangkok Bank. Bloomberg and Reuters report peak yields to maturity on these bonds of approximately 12%–14% which is near the peak yields on the HSBC indices.

to have risen by approximately the same amount as the HSBC indices of bonds of lower maturities. From the expectations theory of the term structure, we therefore take it as reasonable to assume that the markets expected the rise in the risk premium to be very persistent and in a range lying between 10 and 30 years. The modeled shock is a projected path for the country risk premium beginning in period $t = 1$, which we treat as analogous to the fourth quarter of 1997. For periods $t = 1 \dots 19$, the path exactly follows the observed spread between the HSBC index and the 3-month U.S. Treasury rate over the period 1997:4–2002:2 (see Figure 1, Column B). For the periods $t = 20 \dots 80$, the country risk premium follows the average over the initial 19 periods of the shock. Subsequently, we assume that the country risk premium reverts to zero.

The immediate response to the crisis in each of the three countries was a sharp increase in short-term nominal interest rates (see Figure 1, Column C). Beginning in the late summer of 1998, nominal interest rates fell sharply, marking the end of the high interest rate policy in all countries. Moreover, the end of the high interest rate period coincided with structural changes in monetary policy procedures. The Bank of Korea (see Bank of Korea 2002) and the Bank Negara Malaysia (see Bank Negara Malaysia 1998) both adopted new operating targets in the third quarter of 1998, whereas the Bank of Thailand instituted a major restructuring in liquidity management in the summer of 1998 (see Bank of Thailand 1998). By the third quarter of 1998, short-term nominal interest rates had fallen below their pre-crisis levels in Thailand and South Korea, and by the fourth quarter of 1998 interest rates had fallen to below their pre-crisis levels in Malaysia.

For the Transition to Inflation rule, we therefore set $L = 3$ in Thailand and South Korea, and $L = 4$ in Malaysia. Rather than choose a parameterized functional form for the interest rate policy before period L , we set the nominal interest rate equal to the average short-term interest rate observed in each country. In the Transition to Inflation Target model in the short run, we set the monetary policy shock, $\{\omega_t\}_{t=1}^{t=L}$, so that the rise in nominal interest rates exactly matches the rise in interest rates observed in the data. The increase in the nominal interest rate is calibrated as the difference between the observed interest rate and the average interest rate observed in the first half of 1997.

Emerging market countries have increasingly adopted inflation targeting regimes, in part due to the perception of their good performance in developed economies (see Mishkin 2000). In lieu of better parameterizations of the monetary policy rules, we set $\rho_\pi = 1.5$ and $\rho_Y = 0.5$, following Taylor (1996). Our results are not particularly sensitive to reasonable deviations from this calibration.

For the Exchange Rate Target rule, we assume that the monetary authorities rigidly follow the rule, following the crisis, but put more weight on the exchange rate than the simple inflation targeting Taylor rule. We have no clear statistical evidence to calibrate the rule in Equation (37). Rather, we follow a procedure of choosing ρ_e , and ρ_π , so that on average, the right response of interest rates and GDP for the three economies under study is delivered. We find that a value of $\rho_e = .3$ and $\rho_\pi = 1.2$

does the best job of replicating these data. In addition, we set $\rho_Y = .5$, which is the same as for the other rules.

4. IMPULSE RESPONSES

One advantage of examining the East Asian crisis is that the singular, unpredicted nature of the event makes it possible to identify its macroeconomic effects. However, that same singular nature makes it more difficult to use standard statistical analysis to formally test the model. Our main analysis consists of visual and numerical comparison of the impulse responses of an external risk premium shock to the actual paths of output and other variables.

4.1 Qualitative Outcome

Here we briefly summarize the qualitative effects of the crisis. The rise in the country risk premium will raise the cost of repaying the net foreign debt. This will have both substitution and income effects. The substitution effect causes the representative agent to delay consumption and reduce investment in capital goods. As all three economies are net debtors, the interest rate rise has a negative income effect, reducing optimal consumption at all price levels. At given relative prices, the contraction in real demand would reduce the components of domestic absorption: imports, domestic traded goods, and non-traded goods. However, the response to the shock would also involve an adjustment of relative prices.

Given that the shock induces a persistent rise in the external interest rate above the domestic nominal rate, the interest parity condition will imply an immediate depreciation in the nominal exchange rate, followed by a persistent expected appreciation. As there is a full exchange rate pass-through into import prices, the relative price of imports rises sharply. Home agents substitute domestic goods for imports, which bear the brunt of the decline in demand. Domestic goods, however, are relatively imperfect substitutes for foreign goods, and thus changes in the relative price generate only small substitution effects. Hence, in equilibrium, there is a decline in demand for domestic goods. The exchange rate depreciation does not immediately increase the quantity of exports, because exporters practice local currency pricing. Exports increase only over time, as exporters lower their prices to reflect the weakening exchange rate.

The impact of the risk premium shock on production depends on the stance of monetary policy. With a passive or expansionary monetary policy, the authorities can leave domestic nominal interest rates unchanged, or even attempt to reduce interest rates, in response to a risk premium shock. Given the presence of uncovered interest rate parity, this would entail a large and immediate real and nominal exchange rate depreciation. This depreciation would lead to a cushioning of the demand effects of the shock on domestic traded and non-traded goods. However, the contractionary monetary policy, observed in the data and matched by both monetary rules in our model, involves an increase in domestic interest rates. This mitigates the immediate

real exchange rate depreciation, and hence leads to a greater decline in absorption and output in domestic traded and non-traded goods.

The decline in domestic absorption induced by a rise in the external risk premium may have different effects, according to the sector. All output of the non-traded sector is absorbed by the domestic economy, while the output of the traded sector will, over time, face an increasing demand from the export channel. Moreover, because domestically traded goods are better than non-traded goods as substitutes for imported traded goods, the nominal depreciation will elicit a bigger substitution response towards domestic traded goods, whose prices are sticky. Thus, we anticipate a bigger fall in output in the non-traded sector. In contrast, the traded goods sector employs imported intermediate inputs, and the rise in the external real interest rate directly increases the price of these inputs.

The assumption of dollar currency pricing governs the response of nominal prices. The local currency pricing that we assume for exports implies that, in the short run, export prices denominated in the domestic currency will rise along with the exchange rate devaluation. As domestically produced traded goods are a combination of exports and domestically traded goods whose prices are quasi-fixed, the traded goods price will also rise to reflect devaluation. Over time, as exporters and domestic retailers change their prices, the export and traded goods deflator will fall. As importers pass the full effects of changes in the exchange rate through to domestic prices, the exchange rate depreciation leads to a one-for-one rise in the price of these goods, at least in the short run. Total home absorption is a combination of non-traded goods (which have quasi-fixed prices), domestic traded goods, and foreign imports. Consequently, the absorption deflator rises with the exchange rate and import prices in the short run. Over time, contractionary monetary policy will reduce the price of domestically produced goods. This disinflation will initially be muted by sticky nominal prices.

4.2 Quantitative Comparison: Model vs. Data

We examine the cases of South Korea, Malaysia, and Thailand, which differ in terms of the calibration of the parameters and the dynamic shocks to domestic and external interest rates. Figures 2–4 illustrate the theoretical impulse responses for 15 macroeconomic series, as well as the response of corresponding variables observed in the data. We denote the Exchange Rate Targeting regime with a dashed line, the CPI targeting with plus signs, and the Transition to Inflation Target regime with squares.

To identify the macroeconomic effects of the East Asian crisis, we utilize its large size and clear timing, which is reflected in the movements in the country risk premium. We assume that the shock in the risk premium that occurred in the third quarter of 1997 and beyond was responsible for the difference between the actual realizations in an economy and its previous path. A downside of this identification scheme is that it disregards subsequent shocks. However, the unprecedented size of the crisis makes it possible to trace its impact even in the presence of background noise.

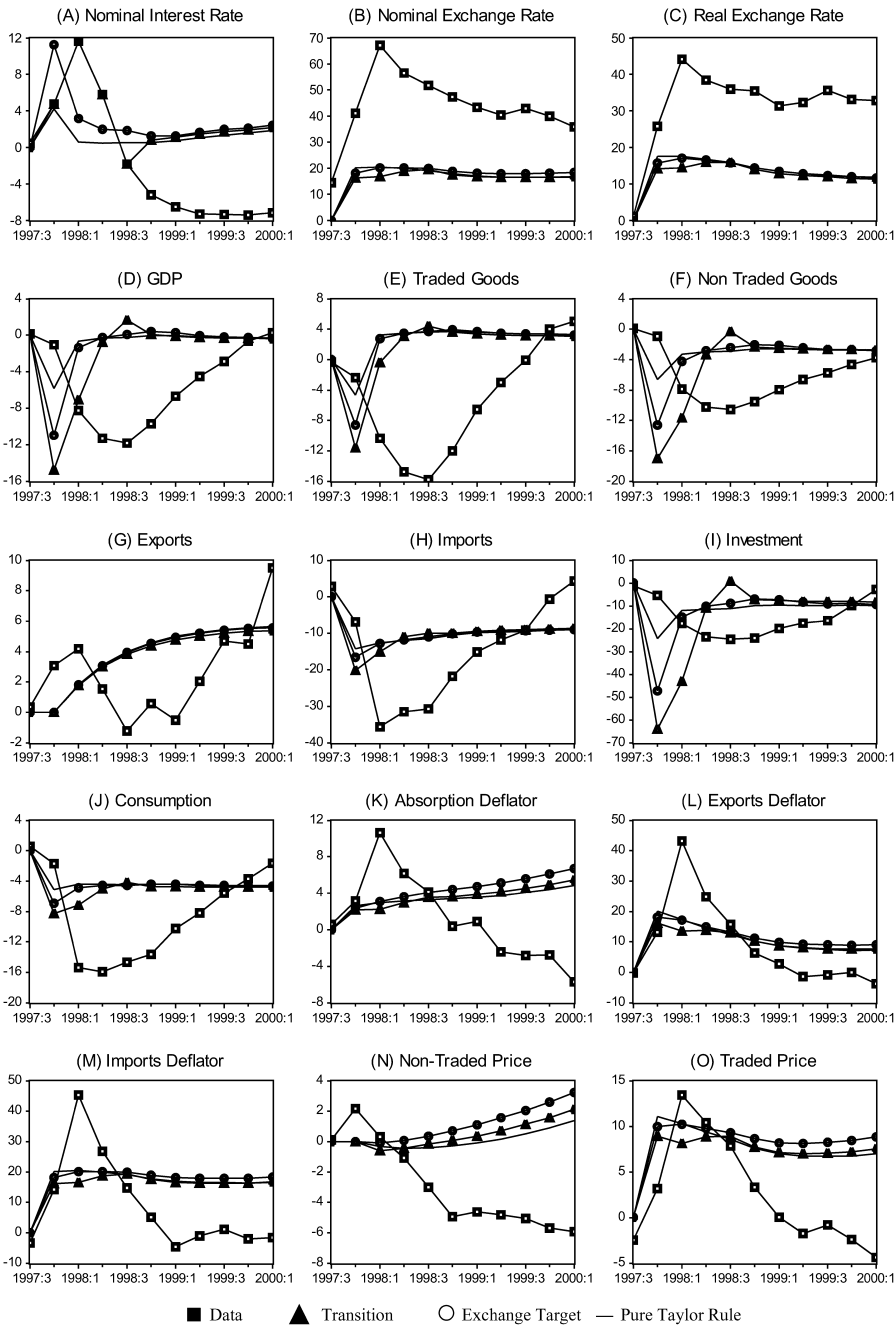


Fig. 2. South Korea. This figure shows the quarterly time-series data for South Korea over the crisis period. Data on real aggregates in Panels A–G and nominal aggregates in Panels H–L are the difference between the log of the actual realization of the de-trended variable and a forecast of the path of the de-trended variable from 1997:2. The variables are de-trended with a log-linear quadratic deterministic trend. The forecast model follows an AR(1). The nominal and real exchange rate and the nominal interest rate are differences between the actual variables and the mean in the first half of 1997. The figure shows the dynamic response to the shock in a model based on parameters and shock dynamics from South Korea that occurs in period 1.

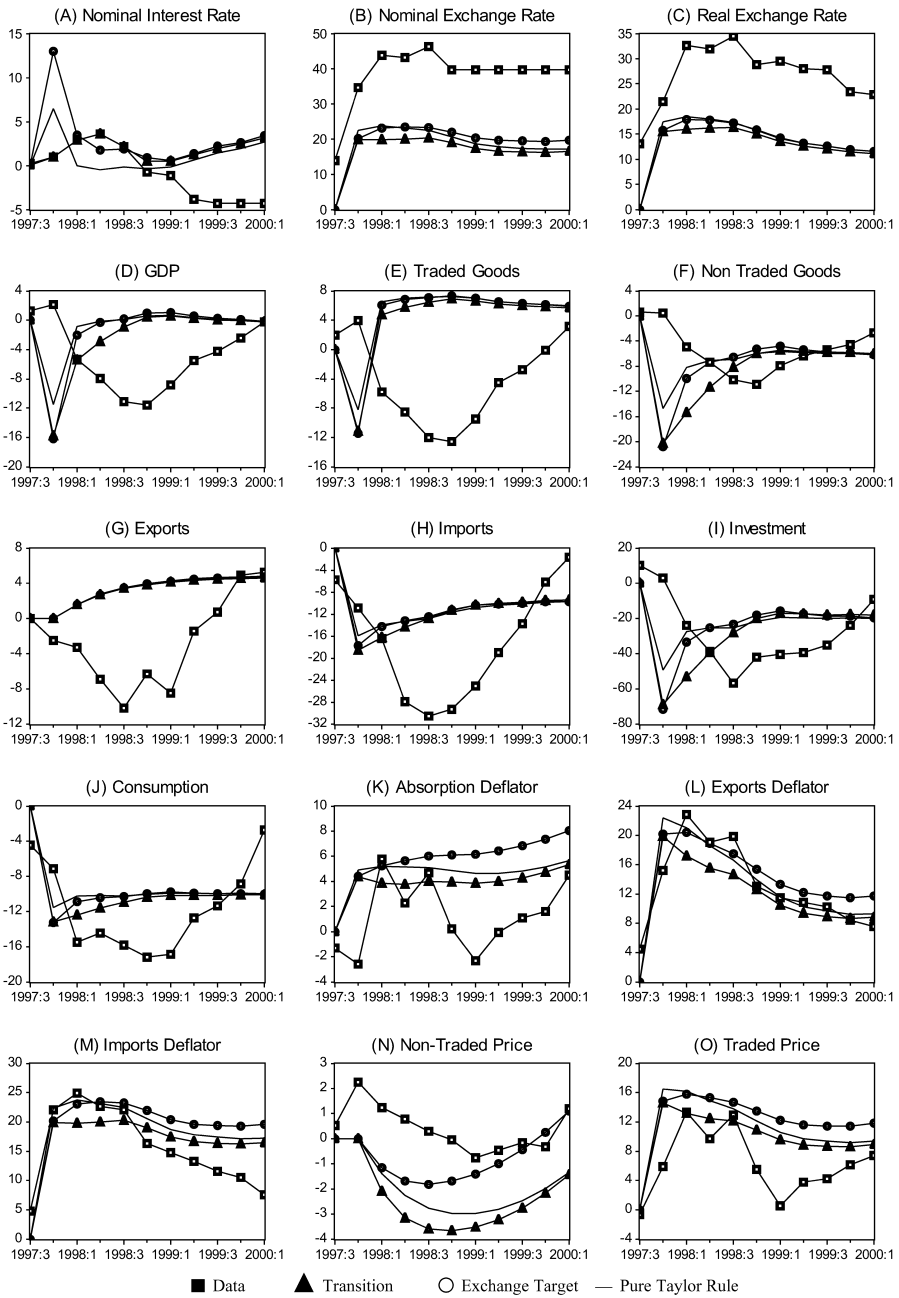


FIG. 3. Malaysia. This figure shows the quarterly time-series data for Malaysia over the crisis period. Data on real aggregates in Panels A–G and nominal aggregates in Panels H–L are the difference between the log of the actual realization of the de-trended variable and a forecast of the path of the de-trended variable from 1997:2. The variables are de-trended with a log-linear quadratic deterministic trend. The forecast model follows an AR (1). The nominal and real exchange rate and the nominal interest rate are differences between the actual variables and the mean in the first half of 1997. The figure shows the dynamic response to the shock in a model based on parameters and shock dynamics from Malaysia that occurs in period 1.

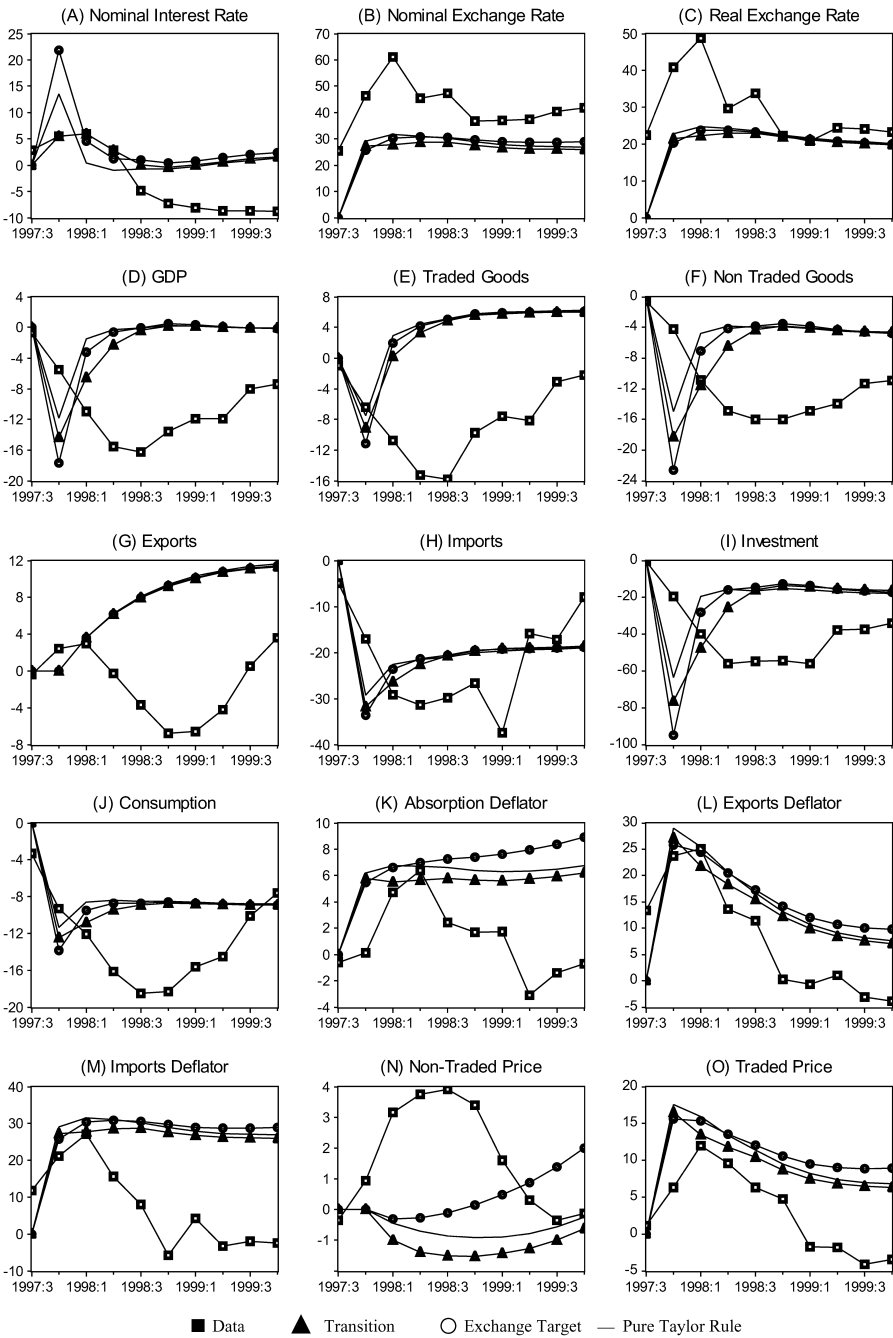


Fig. 4. Thailand. This figure shows the quarterly time-series data for Thailand over the crisis period. Data on real aggregates in Panels A–G and nominal aggregates in Panels H–L are the difference between the log of the actual realization of the de-trended variable and a forecast of the path of the de-trended variable from 1997:2. The variables are de-trended with a log-linear quadratic deterministic trend. The forecast model follows an AR (1). The nominal and real exchange rate and the nominal interest rate are differences between the actual variables and the mean in the first half of 1997. The figure shows the dynamic response to the shock in a model based on parameters and shock dynamics from Thailand that occurs in period 1.

In Panels (A)–(C) of each figure, we report the response of nominal interest rates, nominal exchange rates, and real exchange rates. The series for nominal interest and exchange rates are quarterly averages of those in Figure 1. The series for the real exchange rate is constructed using the U.S. dollar spot rate and the U.S. and domestic absorption deflators. We estimate the response to the crisis as the difference between realizations of these series and their mean in the first half of 1997.

We report the responses of real and nominal variables from seasonally adjusted quarterly national income accounts in Panels (D)–(O). The real variables we examine are GDP, Personal Consumption Expenditure, Gross Fixed Capital Formation, Exports, Imports, Traded Goods Value Added (the traded goods sector being the sum of manufacturing, mining, and agriculture), and Non-Traded Goods Value Added (GDP minus traded goods). The nominal variables are the deflators of domestic absorption, exports, imports, traded goods, and non-traded goods. We must first estimate the pre-crisis paths of each economy's macroeconomic aggregates. We detrend all variables, except the exchange and interest rates, with a log-linear quadratic trend. In many cases, the real variables are substantially above the trend of mid-1997. We estimate AR (1) processes for each of the de-trended variables. Figures 2, 3, and 4, Panels (D)–(O), show the difference between each series and their outcomes if they had reverted geometrically back to trend after the third quarter of 1997 for South Korea, Malaysia, and Thailand, respectively.

South Korea. In Korea, nominal interest rates rise by an annualized rate of 12% in the crisis period. This is matched, by construction, by the Transition rule (see Panel A). Under the Exchange Rate Target rule, interest rates rise by about the same as in the data, but one period early, and then fall quickly. In subsequent periods, interest rates are similar under the two policy rules. Nominal exchange rates depreciate by approximately 15%–20% under both policies in the period of the shock; nominal rates depreciate slowly thereafter. This is far less than the 70% depreciation observed in South Korea in early 1998. In the data, the Korean won strengthens through 1998 and 1999, but even in 2000 it is still 30% below pre-crisis levels. In the short run, real exchange rate depreciations are similar to nominal depreciations under each policy. In the model, there is a persistent real depreciation of approximately 10% regardless of monetary policy. This is milder than the persistent 30% real depreciation seen in the data.

Panels (D)–(F) show that the country premium shocks induce similar responses in terms of aggregate and sectoral production under each policy. The Transition rule produces a greater fall in production than the Exchange Rate Target rule, as under the former rule, interest rates stay high for a greater number of periods. GDP declines by slightly less than 15% and 12%, respectively, under the two rules. The decline observed in the data bottoms out at approximately 12% below the trend. The model under both monetary rules predicts a decline in non-traded production which is sharper than that which appears in the data (13%–18% in the model vs. approximately 12% in the data (see panel F), whereas the trough in traded production is higher in the data (8% and 12% in the models vs. 16% in the data, see panel E). The decline in aggregate production is persistent in the model under both rules. However, this

persistence is far less than that observed in the data, and is lowest for the Exchange Rate Target rule. In the model, GDP reverts to a steady state after four periods, but output is significantly below trend in the data after ten periods. The modeled lack of persistence is most stark in the traded sector, which reverts to a steady state after two periods under each monetary policy. In the data, the decline in the traded sector was less persistent than in the non-traded sector, but substantially more persistent than in the model. This reflects the fact that while dollar currency pricing and the rise in the cost of raw materials goes some way to producing a fall in traded goods output, there is still a significant force causing factors to reallocate to traded production following the real exchange rate depreciation.

The comparison between the Transition rule and the Exchange Rate Target rule indicates that for real variables, the Transition rule is more contractionary, and closer to the data in some dimensions while further away in others. In addition, the Transition rule has a more persistent effect. The Exchange Rate Target rule has only a very transitory negative effect, as interest rates come down very sharply after one period under this rule.

In the model, there is a slow, steady increase in exports to approximately 4% above the previous steady state under both policies, due to dollar currency pricing. In South Korea, exports rise briefly to about 4% above the trend before mildly declining to below the trend for most of the crisis and then sharply rising to 8% above trend in later periods. Imports decline sharply in the model under both monetary policies (hitting a trough at 20% below steady state) and in the data (hitting a trough at 35% below the trend). In both the model and the data, investment and consumption decline sharply and persistently, with the decline in investment being greater. Quantitatively, the trough of investment is much sharper in the model (45% below steady state under the Exchange Rate Target and 65% below steady state under the Transition rule) than in the data (about 30% below the trend). The decline in consumption is greater in the data (about 16% below the trend) than in the model (about 8% below steady state), and is significantly more persistent. However, the consumption data includes consumer durables, which are likely to be more volatile than non-durables. Both the import and export deflators rise sharply with the nominal exchange rate in the period of the shock in both the model and the data. The rise in these deflators is quantitatively similar to the size of the nominal exchange rate depreciation, and thus the rise observed in the model is substantially milder than the data. There is a rise in the absorption deflator of about 2% in the models, and a large but brief rise in the Korean data to about 10% above the trend. In the initial periods of the shock, non-traded deflators remain steady in the model and the data. Traded prices initially rise, then decline in the data and the model under the Transition rule. The Exchange Target rule displays a slightly greater rise in the nominal level of the economy that contrasts with the disinflation observed in the data in later periods.

Malaysia. Figure 3 shows the results for the model calibrated for Malaysia, as well as the response of the data in Malaysia. The rise in the nominal interest rate under the Exchange Rate Target is about 13%, which is substantially greater than

the approximately 4% rise observed in the data and under the Transition rule. The nominal exchange rate depreciates sharply by 40% in the data and by 20% under the Transition rule, before leveling off. The behavior of the nominal exchange rate under the Exchange Rate Target is quite similar. In the initial periods, the real exchange rate depreciation is similar to the nominal depreciation in the model and the data. Malaysia experiences a persistent real depreciation of 25%, while in the model, regardless of monetary policy, there is a persistent real depreciation of about 12%.

There is a sharp decline in aggregate and sectoral output in the data and the model under both rules. The trough response of GDP under both monetary rules is approximately 16%, close to the trough in the data of approximately 13%. Under the Transition rule, the trough in Traded GDP (12% below steady state) is similar to the trough in the data (14% below the trend), while the trough in non-traded GDP is deeper (at about 20% below steady state) than the trough in the data (about 12% below steady state). The Exchange Rate Targeting rule produces a response of aggregate and sectoral GDP, which is very similar to the Transition rule. As is the case for South Korea, the decline in aggregate and sectoral GDP is not nearly as persistent in the model as in the data and, as before, the model produces the least persistence in traded goods. Again, the Exchange Rate Target rule displays less persistence than the Transition rule.

Exports rise smoothly by 4% under all monetary policies, and imports decline sharply to a 20% trough. In the data, exports decline by about 8% below trend, and imports decline by about 30%. Modeled investment declines by just over 60% in the data and by somewhat more in the model under both rules. The decline in consumption (approximately 16%) is slightly larger in the data than in the model under both monetary rules (approximately 13%).

The modeled response of price deflators is similar to the response of the data. The exports deflator, the imports deflator, and the traded price initially rise (by approximately 30%, 24%, and 16%) before declining back toward a steady state or trend. The model under both monetary policy rules does a good job of tracking these deflators. The absorption deflator rises by about 4% before leveling off, whereas the model predicts a more persistent increase. The non-traded price shows little initial movement, but eventually slightly contracts below steady state.

Thailand. In Thailand, the nominal interest rates rise by 4%–5% in the initial periods of the crisis in the data and by construction under the Transition rule; the Exchange Rate Target rule suggests a rise in interest rates which is much sharper than that suggested by the data. Soon after the initial crisis, the baht had depreciated by nearly 60%. Under both monetary rules, the model suggests an exchange rate depreciation of 30%. The long run real exchange rate depreciation is approximately 20% under all policies, which is very near to that observed in the data.

As in Malaysia, the trough response of aggregate GDP is similar in the data (about 14%) as in the model under the two monetary rules (about 17%), although GDP falls by more under the Exchange Rate Target rule given the sharp rise in interest rates produced. Traded goods production declines by about 15% in the data,

and by closer to 10% in the model. Non-traded production declines by about 16% in the data, by about 18% in the Transition model, and by 20% under the Exchange Rate Target rule. Again, the real response is not as persistent in the model under either monetary policy as it is in the data, with the least persistence occurring under the Exchange Rate Target rule. The model under both monetary policies produces a decline in imports that is similar to the decline in the data (about 30%), and a smooth increase in exports (to about 8% above steady state) that does not match the substantial but temporary decline in exports observed in the data. There is a sharp decline in investment in the data (approximately 60% below trend), but the decline in the model is greater (and greatest for the Exchange Rate Target rule, due to the behavior of interest rates under this rule), but as before, it is substantially less persistent. The decline in consumption in the data (about 18%) is larger than that observed in the model for both monetary rules (about 13%).

The initial response of the price deflators in the data is close to that in the model under both monetary rules. The export and import deflator each rise very quickly by 25%–30% in both the data and the model. The absorption deflator initially rises by about 5% in the data and in each model. In the data, the non-traded deflator rises by about 3%, and slowly declines in each of the models. The traded deflator rises more quickly in the model than in the data.

Pure Inflation Target. Additionally, we examine dynamics of each model under a pure inflation target, as described by the solid line in the figures. Under the Pure Inflation Target rule, the central bank switches to the inflation target contemporaneously with the shocks (i.e. $L = 0$). The Pure Inflation Target is more of interest as a counterfactual policy experiment than as an attempt to model the monetary rule empirically. We find that the inflation target produces a much briefer rise in interest rates in all three modeled countries than the Exchange Rate Target rule, the Transition rule, or the data. The exchange rate depreciates more under the Pure Inflation Target rule than under either the Exchange Rate Target or the Transition rule. However, this depreciation is still small, relative to the data. The real contraction in GDP and investment is much milder and more transitory under the Pure Inflation Target rule than under the Exchange Rate Target rule, under the Transition rule, or in the data. With respect to differences across countries, the results show that because Korea's risk premium shock was less severe than that of the other two countries, the Pure Inflation Target rule implies a substantially less severe decline in output in Korea than in the other countries. Overall, these results suggest that a good part of the decline in output in these countries might be attributed to the attempt on the part of the monetary authorities to defend the exchange rate during the crisis.

Comparisons. Overall, the model under the Transition rule, and to a slightly lesser degree the Exchange Rate Target rule, is able to match many patterns observed in the East Asian national income data. A rise in the real interest rate combined with an empirically reasonable rise in nominal interest rates leads to declines in output, consumption, investment, and imports of a size that is generally in line with the data. Due to a rise in the cost of financing the intermediate inputs used in the savings

sector, there are large modeled declines in the traded sector and the non-traded sector. In most cases, the model does a good job of matching the initial behavior of various price deflators. Dollar currency pricing implies that export and import deflators will rise immediately with the exchange rate depreciation, whereas sticky prices (combined with the fact that a large share of imports are used as materials in production) imply that domestic absorption and production price levels will rise more slowly.

The model clearly has a number of shortcomings. Most obviously, the exchange rate depreciations in the model are small compared to those observed in the data. This shortcoming manifests itself in two ways. First, we are unable to capture the large overshooting of exchange rates that occurred in each model. The failure to match the dynamic behavior of exchange rates is especially striking for the Transition rule which is calibrated using the exact paths of domestic and foreign interest rates. The model economy incorporates uncovered interest parity, and thus the inability of uncovered interest parity to explain nominal exchange rate dynamics is a persistent puzzle. Second, in the case of South Korea and Malaysia, we are unable to match the persistent real exchange rate depreciations observed in the data. Persistent movements in real exchange rates are another puzzle in international macroeconomics. The relatively large and persistent size of the country risk premium in Thailand implies a sharper real exchange rate depreciation, which is consistent with the data.

The model generates contractions in output that at the trough level are comparable in size with the data. However, the contraction is less persistent in the model than in the data along two dimensions. First, the trough of the contraction occurs in the period of the shock in the model but occurs several periods later in the data. Second, production converges back to a steady state faster in the model than in the data. In constructing a relatively parsimonious model using the standard features of the S-POEM literature in matching models and data for all three economies, we have not attempted to add additional dynamic mechanisms that have been shown in the real business cycle literature to be important for propagation (see Cogley and Nason 1995).

Finally, the model does not fully capture the contraction in international trade that occurred within East Asia during the crisis. In the data, each of the three countries encountered a persistent decline in real exports, but the models suggest a slow but steady expansion. We have modeled exports as flowing entirely to the developed world, but large shares of exports from Korea, Malaysia, and Thailand go to other developing Asian countries that were similarly affected by the crisis. The degree to which the decline in inter-regional trade can explain the reductions in exports is left for further research.

5. CONCLUSION

Our interpretation of these results is that there is a sufficient match between models and data to build confidence in the sticky-price open macroeconomic framework. In this sense, our model does an adequate job of accounting for the experiences

of these three countries following the East Asia crisis, when we measure the shocks using the observed rise in the foreign currency risk premium, calibrate the structural models of these economies to reflect observed features of these economies during the crisis, and specify a monetary reaction rule that mirrors the behavior of domestic interest rates in the aftermath. In terms of matching the response of most quantities—including output, consumption, investment, imports, and exports, as well as the sectoral composition of output—our model seems quite successful. The “dollar currency pricing” mechanism in our model allows us to understand the observed simultaneously weak export response and a large fall in imports purely through substitution and income responses to the crisis, without recourse to exogenous credit or financial constraints.

LITERATURE CITED

- Aghion, Philippe, Philippe Bacchetta, and Abhijit Banerjee (2000). “A Simple Model of Monetary Policy and Currency Crises.” *European Economic Review* 44, 728–738.
- Aghion, Philippe, Philippe Bacchetta, and Abhijit Banerjee (2001). “Currency Crises and Monetary Policy in an Economy with Credit Constraints.” *European Economic Review* 45, 1121–1150.
- Arellano, Christina, and Enrique G. Mendoza (2002). “Credit Frictions and ‘Sudden Stops’ in Small Open Economies: An Equilibrium Business Cycle Framework for Emerging Markets Crises.” NBER Working Paper No. 8880.
- Bank Negara Malaysia (1998). *Annual Report*. Kuala Lumpur.
- Bank of Korea (2002). *Monetary Policy in Korea*. Seoul.
- Bank of Thailand (1998). *Annual Report*. Bangkok.
- Bank of Thailand (2002). *Annual Report*. Bangkok.
- Baxter, Marianne, and Mario Crucini (1993). “Explaining Saving-Investment Correlations.” *American Economic Review* 83, 416–436.
- Betts, Caroline, and Michael B. Devereux (1996). “The Exchange Rate in a Model of Pricing-to-Market.” *European Economic Review* 40, 1007–1021.
- Betts, Caroline, and Michael B. Devereux (2000). “Exchange Rate Dynamics in a Model of Pricing-to-Market.” *Journal of International Economics* 50, 215–244.
- Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo (2001a). “Hedging and Financial Fragility in Fixed Exchange Rate Regimes.” *European Economic Review* 45, 1151–1193.
- Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo (2001b). “Prospective Deficits and the Asian Currency Crisis.” *Journal of Political Economy* 109, 1155–1097.
- Burstein, Ariel Martin Eichenbaum, and Sergio Rebelo (2002). “Why are Rates of Inflation so Low after Large Devaluations?” NBER Working Paper No. w8748.
- Calvo, Guillermo A. (1983). “Staggered Prices in a Utility-Maximizing Framework.” *Journal of Monetary Economics* 12, 383–398.
- Calvo, Guillermo A., and Enrique G. Mendoza (2000). “Rational Contagion and the Globalization of Securities Markets.” *Journal of International Economics* 51, 79–113.
- Calvo, Guillermo A., and Carmen Reinhart (1999). “Capital Flow Reversals, the Exchange Rate Debate, and Dollarization.” *Finance and Development* 36, 13–15.

- Chang, Roberto, and Andres Velasco (2000). "Liquidity Crises in Emerging Markets: Theory and Policy." In *NBER Macroeconomics Annual 1999*, edited by Ben S. Bernanke and J.J. Rotemberg, pp. 11–78. Cambridge and London: MIT Press.
- Chang, Roberto, and Andres Velasco (2001). "A Model of Financial Crises in Emerging Markets." *Quarterly Journal of Economics* 116, 489–518.
- Christiano, Lawrence J., Christopher Gust, and Jorge Roldos (2002). "Monetary Policy in a Financial Crisis." NBER Working Paper No. w9005.
- Cogley, Timothy, and James M. Nason (1995). "Output Dynamics in Real-Business-Cycle Models." *American Economic Review* 85, 492–509.
- Corsetti, Giancarlo, Paulo Pesenti, and Nouriel Roubini (1999). "Paper Tigers? A Model of the Asian Crisis." *European Economic Review* 43, 1211–1236.
- Dooley, Michael P. (2000). "A Model of Crises in Emerging Markets." *Economic Journal* 110, 256–272.
- Galí, Jordi, and Mark Gertler (2000). "Inflation Dynamics: A Structural Econometric Analysis." NBER Working Paper No. 7551. Cambridge, MA: National Bureau of Economic Research.
- Galí, Jordi, and Tommaso Monacelli (2002). "Monetary Policy and Exchange Rate Volatility in a Small Open Economy." NBER Working Paper No. 8905.
- Gertler, Mark, Simon Gilchrist, Fabio Natalucci (2000). "External Constraints on Monetary Policy and the Financial Accelerator." Mimeo, Boston University.
- Hansen, Gary (1985). "Indivisible Labor and the Business Cycle." *Journal of Monetary Economics* 16, 309–327.
- Kim, David K. (2002). "Can 'Sunsspots' Explain the Asian Financial Crisis." Mimeo, University of Sydney.
- King, Robert G., and Mark Watson (2002). "Systems Reduction and Solution Algorithm for Singular Linear Difference Systems Under Rational Expectations." *Computational Economics* 20, 57–86.
- Kollmann, Robert (2001). "The Exchange Rate in a Dynamic-Optimizing Business Cycle Model with Nominal Rigidities: A Quantitative Investigation." *Journal of International Economics* 55, 243–262.
- Lane, Phillip R. (2001). "The New Open Economy Macroeconomics: A Survey." *Journal of International Economics* 54, 235–266.
- Lane, Phillip R., and G. Milesi-Ferretti (2001). "The External Wealth of Nations: Measures of Foreign Assets and Liabilities for Industrial and Developing Countries." *Journal of International Economics* 55, 263–294.
- Mendoza, Enrique G. (1991). "Real Business Cycles in a Small Open Economy." *American Economic Review* 81, 797–818.
- Mendoza, Enrique G. (2001). "Credit, Prices and Crashes: Business Cycles with a Sudden Stop." NBER Working Paper No. w8338.
- Mishkin, Frederic S. (2000). "Inflation Targeting in Emerging Market Economies." *American Economic Review* 9, 105–109.
- McCallum, Bennett T., and Edward Nelson (2000). "Monetary Policy for an Open Economy: An Alternative Framework with Optimizing Agents and Sticky Prices." *Oxford Review of Economic Policy* 16, 74–91.
- McKibbin, Warrick J. (1999). "Modeling the Crisis in Asia." In *Southeast Asia's Economic Crisis: Origins, Lessons, and the Way Forward*, edited by Hal Hill and H.W. Arndt, pp. 119–127. Singapore: Institute of Southeast Asian Studies.
- McKinnon, Ronald, and Gunther Schnabl (2004). "The East Asian Dollar Standard, Fear of Floating and Original Sin." Mimeo, Stanford University.

- Neumayer, Pablo A., and Fabrizio Perri (2004). "Business Cycles in Emerging Economies: The Role of Interest Rates." NBER Working Paper No. 10387.
- Obstfeld, Maurice, and Kenneth Rogoff (1995). "The Intertemporal Approach to the Current Account." In *Handbook of International Economics*, Vol. 3, edited by Gene M. Grossman, and K. Rogoff, pp. 1731–1799. Amsterdam: Elsevier.
- Ostry, Jonathan D., and Carmen M. Reinhart (1992). "Private Saving and Terms of Trade Shocks." *IMF Staff Papers* 39, 495–517.
- Reinhart, Carmen M. (1995). "Devaluation, Relative Prices, and International Trade: Evidence from Developing Countries." *International Monetary Fund Staff Papers* 42, 290–312.
- Rogerson, Richard (1988). "Indivisible Labor, Lotteries and Equilibrium." *Journal of Monetary Economics* 21, 3–16.
- Rotemberg, Julio J., and Mark Woodford (1996). "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity." *Journal of Money, Credit, and Banking* 28, 550–577.
- Rotemberg, Julio J., and Mark Woodford (1997). "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy." In *NBER Macroeconomics Annual 1997*, edited by Ben S. Bernanke and J.J. Rotemberg, pp. 297–344. Cambridge and London: MIT Press.
- Sachs, Jeffrey D., and Felipe Larrain (1993). *Macroeconomics in the Global Economy*. New Jersey: Prentice Hall.
- Sarel, Michael (1997). "Growth and Productivity in Asean Countries." IMF Working Paper No. 97/97.
- Taylor, John B. (1996). "Discretion vs. Policy Rules in Practice." *Carnegie-Rochester Series on Public Policy* 39, 195–214.
- Yun, Tak (1996). "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles." *Journal of Monetary Economics* 37, 345–370.

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